Elsevier Editorial System(tm) for Behaviour Research and Therapy
Manuscript Draft

Manuscript Number: BRAT-D-09-00303R2

Title: Visuospatial tasks suppress craving for cigarettes

Article Type: Full Length Article

Keywords: Cigarette craving; imagery; brief intervention; cognition; working memory

Corresponding Author: Professor Jon May,

Corresponding Author's Institution: University of Plymouth

First Author: Jon May

Order of Authors: Jon May; Jackie Andrade; Nathalie Panabokke; David Kavanagh

Abstract: The Elaborated Intrusion (EI) theory of desire posits that visual imagery plays a key role in craving. We report a series of experiments testing this hypothesis in a drug addiction context. Experiment 1 showed that a mental visual imagery task with neutral content reduced cigarette craving in abstaining smokers, but that an equivalent auditory task did not. The effect of visual imagery was replicated in Experiment 2, which also showed comparable effects of non-imagery visual working memory interference. Experiment 3 showed that the benefit of visual over auditory interference was not dependent upon imagery being used to induce craving. Experiment 4 compared a visuomotor task, making shapes from modelling clay, with a verbal task (counting back from 100), and again showed a benefit of the visual over the non-visual task.
We conclude that visual imagery supports craving for cigarettes. Competing imagery or visual working memory tasks may help tackle craving in smokers trying to quit.

This is the Authors' Copy of the original manuscript, following referees' comments. It was published as:

May, J., Andrade, J., Panabokke, N. & Kavanagh, D. (2010) Visuospatial tasks suppress craving for cigarettes. Behaviour Research and Therapy, 48, 476-485.
http://dx.doi.org/10.1016/j.brat.2010.02.001

Please find attached the second revision of our paper in light of the comments of 19/1/2010.

In this revision we have made two changes to the text, as requested in the decision letter of 19/1/2010.

1) We have added a sentence and two citations in the introduction, to further situate our EI Theory in relation to existing work on craving:

page 4:
The distinction between background or tonic craving and episodic or phasic craving (e.g., Ferguson & Shiffman, 2009; Sayette, Shiffman, Tiffany et al., 2000) is captured in EI theory by the precursors of craving episodes (such as physiological deficit states or negative affect) that increase the likelihood of intrusions, and the elaboration that follows these intrusions.

2) We have added subsection headings within the General Discussion, 'Limitations' and 'Implications', and under Limitations we have added two paragraphs:

pages 20-21:
We have noted a number of limitations and problems with each of the experiments reported, and summarise them here. Our samples are mainly of young, moderate smokers, who were not actively trying to quit, and we do not yet know if similar results would be found with more heavily addicted smokers under more severe abstention. However, young, moderate smokers are precisely the group upon whom prevention efforts are being targeted, and so the results are informative. In the first two studies we did not measure breath CO to ensure compliance with our request to abstain, nor could we tell if non-abstainers had actually smoked recently, although any non-compliance would have worked against our hypotheses.

In Experiment 1, the imagery task was very obvious and so a demand effect might have arisen. We tried to deal with this in Experiment 2 by using the DVN task, but the crossed nature of the design was problematic, and the fact that this experiment was conducted in Sri Lanka whereas the others were based in the U.K. could also make it difficult to determine why some findings did not replicate across experiments. The first two studies relied upon induction scripts which, despite being widely used, might have confounded our experiments through artificially emphasising imagery or distracting participants from smoking, and so in Experiments 3 and 4 we used a more naturalistic cue-based induction procedure, which we found to be just as effective in inducing cravings. Any induced craving might differ in processes and nature from a naturally occurring craving, of course, which is a problem for all laboratory studies of craving.

*Manuscript

Visuospatial tasks suppress craving for cigarettes

Jon May[1], Jackie Andrade[1] ,
Nathalie Panabokke[2] and
David Kavanagh[3]

[1] *School of Psychology*
University of Plymouth
Drake Circus
Plymouth
UK – PL4 8AA

[2] *Department of Psychology*
University of Sheffield
Western Bank
Sheffield
UK – S10 2TP

[3] *School of Psychology and Counselling*
Queensland University of Technology
GPO Box 2434
Brisbane Qld 4001
Australia

Corresponding Author:
Prof Jon May, jon.may@plymouth.ac.uk
tel +44 1752 584839

Running Head: Visuospatial suppression of cigarette craving

Conflict of Interest Statement: No conflict of interest.

Ethical Conduct: All data collection was conducted in accordance with ethical guidelines of the BPS and APA.

Abstract

The Elaborated Intrusion (EI) theory of desire posits that visual imagery plays a key role in craving. We report a series of experiments testing this hypothesis in a drug addiction context. Experiment 1 showed that a mental visual imagery task with neutral content reduced cigarette craving in abstaining smokers, but that an equivalent auditory task did not. The effect of visual imagery was replicated in Experiment 2, which also showed comparable effects of non-imagery visual working memory interference. Experiment 3 showed that the benefit of visual over auditory interference was not dependent upon imagery being used to induce craving. Experiment 4 compared a visuomotor task, making shapes from modelling clay, with a verbal task (counting back from 100), and again showed a benefit of the visual over the non-visual task.

We conclude that visual imagery supports craving for cigarettes. Competing imagery or visual working memory tasks may help tackle craving in smokers trying to quit.

(156 words)

Keywords: Cigarette craving, imagery, brief intervention, cognition, working memory.

Elaborated Intrusion theory and smoking

This paper applies a cognitive theory of desire, the Elaborated Intrusion theory (EI theory; Kavanagh, Andrade & May, 2005) to the field of addiction. Specifically, it tests a key prediction of EI theory – that competing imagery or visual working memory loads will reduce desire – in the context of cigarette craving in smokers. Despite concerted government efforts to reduce tobacco use, in the United States around a fifth of women and high school students and one quarter of men still smoke, and the proportion who smoke has not changed significantly since 2004 (National Center for Health Statistics, 2009). In the UK, the proportion of adult smokers has also stabilized, with 21% of adults being smokers in 2007, and is highest in the 20-24 year old age group, at 31% (Robinson & Lader, 2009). Seven out of 10 smokers in the U.K. want to quit (Department of Health, 2008) and each year, approximately half of all smokers in England try to quit smoking. However, only around 2% succeed in doing so permanently (West, 2006).

One of the main reasons why people fail to abstain is the continued occurrence of cravings for cigarettes. Craving is an emotionally charged mental state where an urge or desire to engage in a particular behaviour is maintained in focal attention. It helps sustain nicotine habits (Carter, Lam, Robinson, et al., 2008) and persists long after physiological dependence has ceased. It is an important trigger of relapse in people who have quit smoking (Killen & Fortmann, 1997; Shiffman, Engberg, Paty *et al*., 1997; Zhou, Nonnemaker, Sherrill *et al*., 2009). Even if craving is resisted, it induces discomfort and distress (Kavanagh et al, 2005), and diverts attention from other tasks (e.g., Cepeda-Benito & Tiffany, 1996). A better understanding of craving would help develop better support for people trying to quit smoking permanently (Kavanagh, Andrade & May, 2004).

In terms of theory development, there has been a focus on the triggers of craving (e.g., cue-exposure theory, Drummond 2000) and on specific neural changes that occur as addiction develops (e.g., incentive-sensitization theory, Robinson & Berridge, 2000). The influential approach of Tiffany (e.g., Tiffany, 1990) sees craving as resulting from the blocking of automatic substance related action schemata. This approach is extended by recent work by Baker and colleagues, who argue that preconscious negative affect resulting from withdrawal forms the primary motivational basis for drug cravings and use (Baker, Piper, McCarthy *et al.,* 2004), with craving being the experience associated with conscious cognitive control over automatic drug use responses (Curtin, McCarthy, Piper, & Baker, 2006). This conscious experience is the focus of EI theory (May, Panabokke, Andrade, & Kavanagh, 2004; Kavanagh, Andrade & May, 2004, 2005) which gives conscious cognitive processes a key role in *driving* consumption, rather than just being a behaviour inhibitor or passive concomitant. EI theory defines craving as a cycle of cognitive elaboration and associated emotions, which follows an initial intrusive thought about a substance. It attributes the emotional and motivational power of craving to mental images, constructed as part of the elaboration, which simulate the desired substance or behavior. In the case of nicotine addiction, an intrusive thought about smoking may be triggered by a range of environmental, emotional, physiological or cognitive cues. Depending on the salience of the thought and the demands of concurrent cognitive activity, the intrusive thought may be elaborated, and it is this elaboration and associated emotional states that constitute craving. The distinction between background or tonic craving and episodic or phasic craving (e.g., Ferguson & Shiffman, 2009; Sayette, Shiffman, Tiffany *et al.,* 2000) is captured in EI theory by the precursors of craving episodes (such as physiological deficit states or negative affect) that increase the likelihood of intrusions, and the elaboration that follows these intrusions.

Cognitive elaboration involves the search, retention and manipulation of craving relevant information in working memory, and in particular the generation and maintenance of target-related imagery. EI theory argues that the search for information may increase the salience of target-related information in the environment and activate information held in long-term memory such as sensory information (the smell of a cigarette), generic information (the shape of a cigarette), specific personal experiences (how well a cigarette calmed a stressful situation) and relevant schemata (lighting a cigarette). When this information is combined in working memory to form sensory images of the target, e.g. cigarettes and smoking, EI theory claims that the images are immediately rewarding, as substitutes for smoking, but eventually become distressing as they increase awareness of the discrepancy between the actual and desired state. The theory predicts that the increased distress leads to a vicious circle of greater cognitive effort being directed to imagery that gives immediate pleasure or relief but worsens mood in the longer term, leading to more imagery to compensate, and so on.

Although the specific sensory make-up of the images varies from one type of desire to another, visual imagery is consistently important as it plays a role in planning to acquire or use substances as well as simulating the substance and its use. Olfactory imagery may also play a role in desires for food, drink and other substances that can be tasted or smelt, and auditory imagery might be involved in desires for activities in which sound is an important cue, such as playing slot machines. One area of support for EI theory comes from self-reports of imagery, and particularly visual imagery, as a key feature of craving episodes (Salkovskis & Reynolds, 1994). May *et al.,* (2004) found that 62% of people describing an episode of craving agreed that they were 'visualizing it', and 65% were 'imagining the taste of it', but only 9% could 'hear myself having it'.

Another form of support comes from evidence that interfering with imagery reduces craving. Vivid visual imagery loads limited-capacity visual working memory resources (Baddeley & Andrade, 2000), thus competing visual working memory loads are predicted to reduce craving by reducing vividness of craving-related imagery. Reduced image vividness is associated with reduced emotionality of images (Andrade, Kavanagh & Baddeley, 1997; Kavanagh, Freese, Andrade & May, 2001; Kemps & Tiggemann, 2007a; Van den Hout, Muris, Salemink, & Kindt, 2001). This is consistent with EI theory, since weaker target-related images should have less emotional impact and drive the cycle of craving more weakly, allowing other task demands or goals to end the craving episode, even if physiological withdrawal remained high. Because it is difficult to imagine two different scenes simultaneously, competing visual imagery tasks are predicted to reduce craving not merely by reducing vividness of craving imagery, but also by reducing the opportunity for craving imagery. In line with these predictions from EI theory, visual imagery and visual working memory loads have been shown to reduce craving for chocolate (Kemps & Tiggemann, 2007b; Kemps, Tiggemann & Hart, 2005) and craving for food in general (Harvey, Kemps & Tiggemann, 2005; Kemps & Tiggemann, 2007b; Kemps, Tiggemann & Christianson, 2008; Kemps, Tiggemann, Woods & Soekov, 2004; McClelland, Kemps, & Tiggemann, 2006; Steel, Kemps & Tiggemann, 2006).

Only one study to date has extended these findings to the field of addiction, specifically to nicotine. Versland and Rosenberg (2007) assessed cigarette craving in a sample of university students who had been smoking 20 cigarettes a day for at least 3 months. Participants were asked to abstain from smoking for at least 6 hours before coming to the laboratory. In the laboratory, they underwent a cue-exposure craving induction in which they were asked to focus on the sight and smell of a lit cigarette, and to imagine the taste of the cigarette. They rated their current craving and then spent 2 minutes counting backwards by sevens or following an audiotaped, guided imagery script that asked them to focus on the sights, or smells, or both associated with being on a beach. All three guided imagery conditions reduced craving relative to the serial sevens task.

The present series of studies extended Versland and Rosenberg's study in three ways: choice of tasks and controls, inclusion of a non-craving sample, and use of a non-imaginal craving induction. In Experiments 1 and 3 we used an auditory imagery task, rather than serial sevens, to control for the general resource demands of neutral imagery; in Experiment 2 we used a non-imagery visual working memory task, known to disrupt visual imagery, to avoid demand characteristics of an imagery intervention; in Experiment 4 we chose a novel visuospatial task with potential use as a take-home tool (Experiment 4; see Stuart, Holmes & Brewin, 2006), as a step towards extending this laboratory research to a real-world context. We used a non-deprived group of smokers to provide a baseline measure of craving against which to compare the effects of the visual imagery intervention (Experiments 1 and 2). We used a non-imaginal craving induction, to show that the benefits of imagery interference are not an artefact of the induction process (Experiment 3 & 4). These points are important because, for a task to be a useful in the field, as a take-home, self-help strategy or as an adjunct to existing treatments, it must affect craving arising from various triggers and do so sufficiently that people can resist acting upon their desire. Ideally, it should reduce the desire to smoke to the level experienced when satiated.

Experiment 1

We compared the impact of visual and auditory imagery tasks on cigarette craving in continuing smokers who had been deprived of cigarettes overnight and in non-deprived smokers. Two crossed experimental factors were used: smoking deprivation (deprived and non-deprived) and imagery modality (auditory and visual).

Participants gave baseline ratings of cigarette craving and mood, followed by further ratings after each of three blocks of six imagery tasks. We expected that craving intensity in the deprived smokers would initially be high in relation to that of non-deprived smokers. We predicted that craving intensity would fall for those given the visual imagery task, but would be unaffected by the auditory imagery task.

In this and all subsequent experiments, approval was gained from relevant ethics committees operating according to British Psychological Society guidelines (University of Sheffield Psychology Research Ethics Committee and University of Plymouth Faculty of

Science Research Ethics Committee). Written informed consent was obtained from all participants.

Method

The sample comprised 40 students and staff at the University of Sheffield, 18 male and 22 female, recruited through an advertisement on an email distribution list and web notice boards, asking for smokers to participate in a study about cigarette craving, for which it was explained that they might be asked to abstain overnight. The participants had a mean age of 24:6 years, and had started smoking at 16:5 years. They smoked a mean of 15 cigarettes a day (minimum of 10) and had been smoking regularly for a mean of 7:5 years. Since we were interested in cravings in current smokers, there was no requirement that they currently be trying to quit, but 33 participants (82%) had previously tried to quit, and 20 were currently trying to cut down on their smoking. All participants received a payment of £2 for taking part.

Participants were randomly assigned to each of four experimental groups (10 per group). Those in the deprived conditions were asked not to smoke from midnight of the day before they were tested. Those in the non-deprived conditions were not given any instructions about abstention or smoking. Half of each group was then assigned to the auditory imagery condition, half to the visual imagery condition. All participants were tested between 1400 and 1800 hours to minimize the effects of diurnal variations in cravings (West & Schneider, 1987), and testing sessions lasted 20 to 30 minutes. No physiological measures of smoking metabolites (such as exhaled breath carbon monoxide, CO) were taken for this experiment, because any contamination of the deprived group by smokers or the smoking group by abstainers would work in an opposite direction to our hypothesized effects.

On entering the laboratory, participants were briefed and signed consent forms, before completing a questionnaire describing their smoking history. They were then given a multi-sensory urge induction (deprived groups) or neutral script (control groups), which they were asked to read to themselves while imagining the described scenario. Tiffany & Hakenewerth (1991) found these scripts to be rated as equal in vividness, containing the same number of positive and negative affect descriptions. The non-deprived group were given the neutral script in order to equate the two conditions as closely as possible in terms of experience and duration. Drobes and Tiffany (1997) found that the combination of abstinence and urge induction scripts had an additive impact on craving in cigarette smokers; we used the scripts to reinstate any abstinence-induced craving that was dampened by the distracting novelty of coming into the laboratory.

Participants then completed scales to give the baseline ratings of craving strength and mood. Levels of craving strength were measured using the fifteen items comprising Factor 1 from the Questionnaire on Smoking Urges (QSU; Tiffany & Drobes, 1991), assessing intention and desire to smoke (Factor 2 items, which we did not use, measure anticipated relief from negative affect and nicotine withdrawal). A typical item was '*I would enjoy a cigarette right now*'. Participants rated items on a scale ranging from 1 ('strongly disagree') to 7 ('strongly agree'). Six items were reverse scored, and all responses were then summed such that a high score indicated a high desire to smoke. We measured Mood using a 14-item scale (Diener & Emmons, 1984), containing seven positive (e.g., *pleased, joy, delighted)* and seven negative mood adjectives (e.g., *gloomy, frustrated, depressed*). Participants rated how strongly each adjective applied to them at the moment of testing on a scale ranging from 1 (not at all) to 7 (very much). The responses to the negative items were reversed, so that a high score represented positive mood and a low score negative mood.

Next came the imagery task. Participants created auditory or visual mental images, according to experimental condition, from 18 cues based on those used by Baddeley and Andrade (2000), e.g., 'a telephone ringing', 'cows grazing' respectively (see Appendix). The imagery cues were presented in a fixed order, one at a time, in three sets of six. Each cue was printed in 24 point Arial font, on a strip of paper measuring 16.5cm wide by 7cm high. On each imagery trial, the experimenter read the cue aloud, and participants were asked to read the cue silently, close their eyes, and imagine the scene or sound for 10s. On hearing a beep from a timer, they opened their eyes and rated the vividness of the cued image on a scale of 1 ('no image at all') to 9 ('image as clear as normal vision/hearing'). This rating was included primarily to direct the participants' efforts towards the task, because there was no direct way to observe the degree of participants' compliance with instructions. The rating also allowed a comparison of reported vividness between the two imagery conditions.

Following each set of six cues, the participants completed the QSU Factor 1 scale and the Mood scale again. On completion of the final set of questionnaires, the participants were debriefed and given their £2 payment.

Results

Four ratings of craving strength and mood were collected from each participant, one at baseline and one following each of three blocks of imagery trials. As an initial check upon the effects of deprivation and the assignment of participants to imagery conditions, Univariate ANOVAs were conducted upon the baseline measures of mood and craving, with the between subject factors of *Deprivation* (deprived or non-deprived) and *Imagery* (visual or auditory). There were no significant effects upon mood (all Fs < 1), confirming equivalence at baseline (means from 4.4 to 4.9 out of 7). For craving, there were no effects of *Imagery* (F(1,36 = 0.33, MSe = 2.07, $p = .57$, $\eta_p^2 = .01$) or the interaction (F(1,36 = 1.87, MSe = 2.07, $p = .18$, $\eta_p^2 = .05$), but there was a significant effect of *Deprivation* ($F(1, 36) = 4.61$, MSe = 2.07, $p = .039$, $\eta_p^2 = .11$), with the deprived participants feeling stronger cravings (M = 4.9 out of 7, SD = 1.5) than the non-deprived (M = 3.9, SD = 1.3), as intended.

An ANCOVA was conducted with baseline craving as a covariate, and the remaining three measures of craving as dependent variables, with the within-subject factor *Time* and the between-subject factors of *Deprivation* and *Imagery.* This produced a significant overall effect of *Time* ($F(2, 70)=3.17$, MSe=0.14, $p = .048$, $\eta_p^2 = .08$) and an interaction of *Deprivation x Imagery* ($F(1, 35)=9.16$, MSe=3.45, $p = .005$, $\eta_p^2 = .21$). No other effects were significant.

The interaction was investigated by separate ANOVAs examining the effect of *Time* within each of the four experimental groups. The mean craving score of the deprived visual group dropped following the first six cues, and then remained low, $F(3,27) = 16.5$, MSe = 0.34, $p < .001$, $\eta_p^2 = .65$. The mean of the non-deprived visual group rose ($F(3,27) = 3.91$, MSe = 0.53, $p = .019$, $\eta_p^2 = .30$), while the craving scores of the two auditory imagery groups remained unchanged throughout the experiment (Fs < 1). Means are shown on the left of Figure 1.

Insert Figure 1 about here

Vividness of cued imagery was measured at three points, after each six cues. It showed no effects or interactions involving *Deprivation* or *Imagery* (all Fs < 1), so changes in craving could not be attributed to differences in cued imagery vividness between the groups. There was a main effect of *Time* ($F(2,72) = 6.32$, MSe = 0.61, $p = .003$, $\eta_p^2 = .15$), with vividness rising from 5.69 after the first set of six cues to 6.25 after the second set, remaining at 6.20 after the third set. Craving change scores were not correlated with mean cued imagery vividness scores across the three measurement points, $r = .12$, $p = .48$, nor with change in vividness from first to third measurement ($r = .002$, $p = .989$).

Discussion

As intended, the combination of deprivation and urge induction script resulted in a higher level of craving than in the non-deprived conditions. Consistent with EI theory, deprived participants who performed the visual imagery task showed an immediate reduction in their craving for cigarettes, and finished the experiment with the lowest rating of the four groups, whereas auditory imagery had no effect on craving. This was not due to a differential impact of the imagery tasks on mood, nor to an overall difference in vividness of images in the two modalities. These results, which are consistent with Versland and Rosenberg's (2007) findings, support the EI theory prediction that there will be greater interference with craving-related imagery under conditions where the same limited-capacity resource (in this case, visuospatial working memory) is recruited for another concurrent task. In other words, the disruption of craving is not simply a matter of distraction by any concurrent task, but rather by tasks that specifically target the underlying cognitive components of craving.

The absence of a correlation between the cued imagery vividness and the change in craving was not surprising, because we asked participants to complete the cued imagery as their primary task, and so scores were generally high and increased over the experiment as participants became practised in the imagery task. EI theory predicts an association between craving strength and the vividness of the desire-related imagery, which we could not measure in this study, but which is supported by previous research (May et al, 2008; Kavanagh, May & Andrade, 2009). While it might be expected that vivid non-desire imagery might interfere with craving imagery more than weaker non-desire imagery, this is not a prediction of EI theory: It is the degree of competition for working memory resources rather than vividness per se that is held to be the mechanism of interference. A vivid cued image may be one that is easy to produce, needing little effort, and leaving resources for desire-related imagery; or it may require a total dedication of imagery resources, leaving little for desire-related imagery.

We had assumed that there would be low levels of craving and consequently no effect of the concurrent imagery task in the non-deprived groups. Their mean scores throughout the study represent neutral responses on the QSU craving scale, although non-deprived smokers who undertook the visual task showed a slight increase in craving across the experiment, and ended the experiment with equivalent craving to the deprived auditory group. There was no equivalent increase in craving in the auditory non-deprived group, so the result was not due to smoking deprivation during the experiment itself. This unexpected effect was small, and would need to be replicated before any firm conclusions can be drawn.

The apparent, though not statistically significant, difference between the craving levels of the two deprived groups at Baseline could influence the findings reported above. Because the effect of the visual imagery task occurred after the first block of cues, the interaction could be due to spuriously high urge ratings by this group at Baseline, and so that finding also needs replication.

Experiment 2

The imagery task used to interfere with craving in the previous study was obvious to participants, and it is possible that the increase in craving reported by the non-abstaining group was due to the visual imagery task drawing their attention to fleeting tobacco-related imagery. To avoid this, we conducted a second study using a less obvious, passive task that is known to interfere with visual imagery.

The Dynamic Visual Noise display (DVN, Quinn & McConnell, 1996a) consists of a matrix of squares that flicker between black and white randomly and rapidly. This has been shown to impair performance on the pegword mnemonic strategy, which relies on visual imagery (Andrade, Kemps, Wernier, May & Szmalec, 2002; Quinn & McConnell, 1996a,b, 1999, 2006), and to reduce visual image vividness more than a competing verbal task (Baddeley & Andrade, 2000). If visual imagery is as important as the previous experiment suggests, then DVN should also reduce craving, by weakening desire-related imagery, but should not draw participants' attention towards any mental visual imagery. To equate the incidental demands of the DVN task, we used a comparable static visual noise (SVN) display of black and white squares, but without any changes, which has been shown to have no effect upon imagery (McConnell & Quinn, 2000)

The SVN and DVN tasks are passive, with participants being required only to watch the screen. This can be boring, especially in the SVN condition, so they need to be paired with a more active task to maintain the participants' collaboration during testing. We chose to combine the two tasks in a crossed fashion with the imagery tasks from Experiment 1, such that the DVN and SVN displays were paired respectively with the auditory and visual imagery conditions. While not a fully balanced design (the number of available participants meant that a fully crossed design would have had just five participants per cell, giving insufficient power), the adopted design did allow us to administer both noise displays while maintaining participants' involvement, and also to replicate the effect of an overt visual imagery task. Now both deprived groups should experience a reduction in craving: the Auditory–DVN group due to the effect of DVN (auditory imagery alone had no effect in the previous experiment), and the Visual–SVN group due to the effect of visual imagery (replicating the immediate drop in cravings reported by the visual group in the previous experiment). Both non-deprived groups should show no change in craving, and the non-deprived Visual–SVN group allowed us to look for the unexpected increase in craving seen in the non-deprived visual imagery group in the previous experiment.

Method

The sample comprised 40 students and staff at the University of Colombo, Sri Lanka, 24 male and 16 female, recruited through an advertisement on the Psychology Department notice board asking for smokers to participate in a study on cigarette craving. Participants had a mean age of 31:11 years, smoked a mean of 15 cigarettes a day (minimum 10), considered themselves addicted to smoking, and had been smoking regularly for a mean of 17:2 years. Thirty had previously tried to quit, and thirty (75%) were presently trying to cut down on their smoking. All participants received a payment equivalent to £2 in local currency (Rs. 300) for taking part. The materials were the same as those used in the previous study, with the addition of a visual noise display presented on an Apple iBook. The display took up the entire screen height, being 80 squares high and 80 squares wide, with a flicker rate of 1000 squares per second in the DVN condition, and zero per second in the SVN condition. Five visual imagery cues were adapted to use locally relevant items, for example 'Big Ben' became 'Sigiriya', and 'The Queen' became 'Bill Clinton' (see Appendix).

Participants were randomly assigned to each of four experimental groups, such that ten were in each group. Those in the deprived conditions were asked not to smoke any cigarettes, or to use tobacco products or nicotine replacement products for two hours before testing (rather than the overnight deprivation requested in Experiment 1 – this was because selection, random allocation and testing occurred on the same day). Participants in the non-deprived conditions were not given any instructions about smoking or abstention. All the participants were tested between 1400 and 1800 hours to minimize the effects of diurnal variations in cravings (West & Schneider, 1987) and each session lasted 20-30 minutes.

As before, half of the participants in each deprivation condition were allocated either to auditory imagery or visual imagery conditions. Those in the auditory condition were also asked to look at the DVN display while imagining each sound (Auditory–DVN); those undertaking visual imagery looked at the SVN display (Visual–SVN). Apart from this, the urge induction, questionnaires, and imagery cues were presented as in the previous experiment.

Results

A univariate ANOVA upon baseline measures of mood was conducted with the factor *Interference* representing the combination of imagery task and visual noise, and *Deprivation* the abstinence requirement. There were no effects of *Deprivation, Interference* or their interaction, with all groups rating their mood at between 4.6 and 5.1 out of 7.

An ANCOVA was conducted with baseline craving as a covariate, and the remaining three measures of craving as dependent variables, with the within-subject factor *Time* and the between-subject factors of *Deprivation* and *Interference.* This produced a significant overall effect of *Deprivation* ($F(1, 35)=13.1$, MSe=2.48, $p = .001$, $\eta_p^2 = .27$) and interactions of *Time* x *Deprivation* ($F(2, 70)=4.15$, MSe=0.53, $p = .020$, $\eta_p^2 = .11$) and *Time* x *Deprivation* x *Interference* ($F(2, 70)=5.62$, MSe=0.53, $p = .005$, $\eta_p^2 = .14$), with a marginal interaction of *Time* x *Interference* ($F(2, 70)=2.92$, MSe=0.53, $p = .061$, $\eta_p^2 = .08$). No other effects were significant.

To interpret the three-way interaction, separate ANOVAs were then conducted upon each *Interference* x *Deprivation* group. Neither non-deprived group showed any effect of *Time* (Visual–SVN $F<1$; Auditory–DVN $F(3,27) = 1.86$, MSe = 0.34, $p = .161$, $\eta_p^2 = .17$), but the craving scores of both deprived groups did reduce over *Time* (Visual–SVN $F(3,27) = 7.98$, MSe = 0.54, $p = .001$, $\eta_p^2 = .47$; Auditory–DVN $F(3,27) = 15.7$, MSe = 0.73; $p < .001$, $\eta_p^2 = .64$). Inspection of the means shows that the deprived Visual–SVN group showed the same pattern as the deprived visual imagery group in the previous experiment, with cravings falling after the first six imagery cues, and remaining low. Cravings of the deprived Auditory–DVN group fell after the second six cues and ended the session low). Means are displayed in Figure 1.

As in Experiment 1, vividness of cued imagery ratings showed no effects or interactions of *Deprivation* or *Interference*, and there was now only a marginal effect of *Time* ($F(2,72) = 3.10$, MSe = 0.57, $p = .051$, $\eta_p^2 = .08$). Vividness ratings rose from 5.40 after the first set of six cues to 5.72 after the second set, but then fell again to 5.32 after the final set, instead of remaining high as in the first experiment. As before, there was no association between change in craving and mean vividness of cued imagery, $r = -.16$, $p = .33$.

Discussion

Experiment 2 replicated the main finding of the first experiment: deprived smokers who constructed visual images (in this experiment, while looking at a screen of static visual noise) experienced the same immediate reduction in craving. Despite the different populations from which the two samples of smokers were drawn (UK and Sri Lanka), the different abstention periods (14 and 2 hours), and the addition of the SVN in Experiment 2, the effect of concurrent visual imagery was strikingly similar in both sets of results. However, the partially crossed design used in this experiment makes the changes in craving difficult to interpret, unless the main findings of Experiment 1 are accepted as real.

Deprived smokers who viewed DVN while constructing auditory images also experienced a reduction in craving. We infer that this reduction was due to the DVN, because the first experiment showed no effect of auditory imagery on craving (see also Kemps & Tiggemann, 2007b) and previous research has shown effects of DVN on craving for food (Kemps et al, 2005; Kemps, Tiggeman & Grigg, 2008; Steel et al, 2006). DVN took longer to take effect than competing visual imagery, perhaps because it was interfering with craving by reducing vividness of craving imagery rather than by preventing its formation. The small but unexpected rise in craving experienced by the non-deprived visual imagery group in Experiment 1 was not replicated, and so presumably was spurious, although the different samples and abstention requirements, and the pairing of visual imagery with the SVN task require that caution be exercised when interpreting results of the two experiments. In neither experiment did non-deprived auditory imagery groups showed a change in craving ratings, which remained low throughout the session.

Effects of visual imagery and DVN on cigarette craving replicate previous reports of reductions in food or chocolate craving with concurrent visual imagery (Kemps et al, 2005; Kemps & Tiggemann, 2007b) or DVN (Kemps et al, 2004; Kemps et al, 2008; Steel et al, 2006). The findings extend Versland and Rosenberg's (2007) demonstration of reduced cigarette craving with concurrent visual or olfactory imagery, by showing that the effects persist when general task demands are matched by an auditory imagery control task. Experiment 2 extends Versland and Rosenberg's findings by showing comparable effects of a non-imagery visual interference condition, i.e. DVN.

Together, these studies support the key role of imagery in craving proposed by EI theory (Kavanagh et al, 2005) by showing that craving can be reduced by tasks that interfere with or require the use of visual imagery, even in a sample of smokers who are not all currently trying to quit or to reduce their smoking. By extension, the findings support the claim of EI theory that the cognitive processes underpinning craving are similar across a range of motivational states, specifically that craving for a drug such as nicotine is similar in cognitive terms to craving for food. Effects of visual imagery on craving were unlikely to be due to general distraction, because a comparable auditory imagery task had no effect on craving unless it was paired with the DVN task known to disrupt visual imagery. In Versland and Rosenberg's study, a demanding verbal task, serial sevens, also had no effect on cigarette craving.

Experiment 3

A limitation of Experiments 1 and 2 was their choice of craving induction. It is necessary to use some form of craving induction, because the novelty of entering a laboratory may distract attention from thoughts or images of smoking, and temporarily suppress craving even in deprived smokers. Although the smoking imagery script used in this study was intended to be multi-sensory (Drobes & Tiffany, 1997), its effect may have largely been due to the induction of visual images. It is conceivable that our visual imagery manipulations only worked because they removed the effect of the imagery-based craving induction. The use of a neutral script in the non-deprived groups is also potentially problematic, because its non-smoking content might distract participants from smoking. We therefore ran a third experiment in which we did not use an explicitly imaginal induction procedure. Instead, we primed smoking-related thoughts, by asking participants a series of questions about their smoking, and measuring their breath CO. As in Experiment 1, we compared effects of auditory and visual imagery on craving.

Method

A total of 44 undergraduates from the School of Psychology at the University of Plymouth took part (12 male and 32 female; all but three aged 18-22), in response to an advertisement asking smokers to participate in a study into the effects of cigarette craving upon cognition. All reported smoking 10 or more cigarettes a day. The first ten recruited were asked to abstain from smoking after going to bed the night before their testing session until after the session had been completed; this constraint was relaxed for the remainder of the sample due to slow recruitment, with no abstention being required for the remaining 34 participants. All participants received a participation point in return for taking part, which they could use to reward participants in their own research.

Participants were randomly assigned to the auditory imagery or visual imagery condition, with 22 participants in each. The imagery cues were the same as in Experiment 1, with Sheffield landmarks replaced by places familiar to Plymouth students (the lighthouse on the Hoe, the Levinsky building).

At the start of the testing session, participants' breath CO was measured using a Bedfont microSmokerlyzer (Bedfont Scientific Ltd., Rochester UK). In place of the imagery induction script, we asked participants smoking history questions intended to remind them about cigarettes, such as the name of their favourite brand, where and when they usually bought cigarettes, and how long they had been a smoker. To further increase the salience of smoking, we asked them to bring a packet of their usual cigarettes. We took it, counted the cigarettes and put the packet out of sight in a desk drawer during the testing session, returning it at the end.

The craving scale, imagery procedure, and vividness ratings were the same as in the previous two experiments, but the mood scale was shortened to a three item scale of *gloomy,* *glad, angry*, each rated 1-9, with *gloomy* and *angry* being reverse scored (an analysis of the data from the first two experiments having shown that the resulting score correlated $r = .89$, $p < .001$ with the scale total).

Results

Although the ten abstaining participants reported slightly higher baseline cravings (M = 6.0 SD = 2.0) than the rest of the sample (M = 5.4 SD = 1.8), this was not significant ($t(42) = 0.93$, $p = .36$, Cohen's $d = 0.34$), and so the induction procedure alone is as effective as in combination with abstention. The two *Imagery* groups did not differ on breath CO, baseline craving scores, or vividness ratings, but did differ in baseline mood, with the Auditory group being in a better mood than the Visual group (Table 1).

Due to the difference in baseline mood, we assessed the effect of *Imagery* over *Time* upon craving, utilising a doubly multivariate MANOVA followed by a Roy-Bargmann stepdown procedure, and using SPSS 16.0 for Macintosh (SPSS Inc., Chicago Illinois). This allowed us to remove any effects of mood upon craving before looking at the effects of imagery.

The combined measures were significantly affected by an interaction of *Imagery* and *Time*, Wilks $\Lambda = .810$, ($F(2, 41) = 4.82$, $p = .013$, $\eta_p^2 = .10$), and by a main effect of *Imagery,* (Wilks $\Lambda = .774$, $F(2, 41) = 6.00$, $p = .005$, $\eta_p^2 = .12$). There was no effect of *Time* (Wilks $\Lambda = .966$, $F < 1$). A Roy-Bargmann stepdown analysis was performed for each effect by entering the mood scores as covariates, leaving a significant effect of the interaction of *Imagery* and *Time* upon craving ($F(1,41) = 5.23$, MSe = 0.58, $p = .027$, $\eta_p^2 = .11$). The effect of *Imagery* alone upon craving was also significant ($F(1,41) = 5.29$, MSe = 4.87, $p = .027$, $\eta_p^2 = .11$)

Two-tailed paired t tests showed that craving rose significantly in the Auditory group ($t(21) = 2.86$, $p = .009$, Cohen's d=0.88), and fell non-significantly in the Visual group ($t(21) = 1.18$, $p = .253$, Cohen's d=0.36), as shown in Figure 2. A reanalysis excluding the ten abstaining participants produced the same pattern of results.

There were no significant correlations between the vividness of imagery ratings and mood or craving measures (r's = -.12 to .14).

Discussion

Although we had not required all participants to abstain before this experiment, and breath CO showed that a majority had recently smoked, we still observed post-induction craving scores that were comparable to those in the deprived groups of Experiments 1 and 2. While the visual imagery task did not significantly reduce craving during this experiment, it did stop it from increasing, which was the case for the auditory group. We attribute this increase to the fact that participants' cigarettes were available but out of reach, and that non-abstainers would be starting to experience withdrawal symptoms. We infer that the procedure of asking people to reflect on their smoking habits and taking their cigarettes away, was just as effective a way of inducing craving as the methods used in the previous experiments.

Experiment 4

We have now shown a benefit of visual versus auditory imagery in two experiments. Experiment 2 confirmed the benefit of neutral visual imagery and showed that a passive task interfering with visual imagery also reduced craving. In our final experiment, we explore a novel visuomotor task that has been shown to interfere with visual sensory memory. Stuart *et al.,* (2006) showed that making squares and pyramids from modeling clay blocked the development of intrusive memories of visual traumatic material. They concluded that the task recruited the visuospatial resources needed for encoding the material as image-based, rather than verbal, memories. If this task were able to weaken mental imagery, EI theory suggests that it should weaken cravings or to stop them developing, in the same way that it impedes processing of traumatic information. The appeal of the modeling task as a craving blocker lies in its potential for use as a take-home task to tackle craving in the field, being simple, portable, and relatively discreet and pleasant to do.

Method

A total of 34 undergraduates from the School of Psychology at the University of Plymouth took part in response to an advertisement asking for smokers to take part in a study into the effects of cigarette craving on cognition (26 females, 4 males, 4 with sex unrecorded; ranging from 18-52 years, M = 22 years). All reported smoking 10 or more cigarettes a day. All participants received a participation point in return for taking part, which they could use to reward participants in their own research. All were asked to abstain from smoking after going to bed the night before their testing session until after the session had been completed. All testing sessions took place between 10 am and noon. On arrival at the testing session their breath CO was measured using the Bedfont Microsmokerlyzer, and they were asked to take out and count the cigarettes they had left in their packet, or to roll a cigarette if they had loose tobacco, and to then place their cigarettes or tobacco into a tray that was placed out of sight during the testing session and returned to them at the end. They then completed baseline measures of mood and craving, which were used to allocate them in a balanced manner to either the visuomotor modelling clay condition or an articulatory counting back task, such that half of the sample did each task and baseline craving and mood was matched across conditions. As in previous experiments, sessions lasted 20-30 minutes,.

For the modeling clay task, participants were given 500g of 'Lewis newplast' (Newclay Products Ltd, Newton Abbot UK), rolled into a large number of 2cm diameter balls (approximately 4.2 cc). Participants were instructed to use both of their hands to form small cubes or pyramids alternately underneath the table surface, so their hands were out of sight, and to put completed shapes in a container. As the task was concealed from view, participants were assumed to monitor the current state of the shape using visual imagery. Participants were asked to make at least three cubes and three pyramids in two minutes.

Participants allocated to the articulatory task were instructed to count down by one from the number 100 until they reached the number 10 in a continuous loop, and to continue counting even if they made a mistake. This task also lasted two minutes. Participants then completed the craving and mood scales a second time.

Results and Discussion

The two groups did not differ on baseline craving, mood or breath CO (Table 1).

An ANOVA was performed on craving scores with the between-subject factor of *Interference* and the within-subject factor of *Time*. This showed a main effect of *Time* ($F(1,32) = 7.87$, MSe = .12, $p = .008$, $\eta_p^2 = .20$), but not of *Interference* ($F < 1$). As in Experiments 1-3, there was a significant interaction ($F(1,32) = 15.8$, MSe = .12, $p < .001$, $\eta_p^2 = .33$). Post-hoc two-tailed paired t tests showed that craving rose significantly in the Articulatory group from 6.4 to 7.0 ($t(16) = 3.76$, $p = .002$, Cohen's d=1.33), and fell non-significantly in the Visuospatial group from 6.3 to 6.2 ($t(16) = 1.36$, $p = .191$, Cohen's d=0.48), as shown in the right hand section of Figure 2. Thus the effect on craving of the clay modeling task relative to verbal counting closely replicated the effect of visual relative to auditory imagery in Experiment 3.

General Discussion

The four experiments reported in this paper have tested the hypothesis drawn from EI theory (Kavanagh et al, 2005), that visual imagery plays a functional role in craving. Findings supported the prediction that a visual imagery task would reduce craving relative to a competing auditory imagery task (Experiments 1 and 3), and that tasks that load the visuospatial working memory processes needed for visual imagery would have a similar effect on craving (Experiments 2 and 4). Similar findings were obtained when craving was induced with a smoking imagery script or with the temporary confiscation of the smokers' tobacco, although in the latter case the effect was to prevent craving rising rather than reducing it. Inclusion of non-craving groups in the first two experiments showed that effects of visual interventions on craving were equivalent to effects of smoking ad libitum before entering the laboratory.

This work complements research by Kemps, Tiggemann and colleagues who have repeatedly found the predicted effects of visual interference upon a variety of food cravings, and extends that of Versland and Rosenberg (2007) who also demonstrated visual interference with cigarette craving, by including non-abstaining controls, and varying the interference tasks and induction methods. According to the EI theory that motivated these previous studies, the conscious cognitive and emotional processes in drug craving are similar to those in desires for food, drink or exercise, even though the process of addiction alters neural responsiveness to drug stimuli (Robinson & Berridge, 1993). The findings to date support this assumption, with results in the present study replicating those obtained with craving for chocolate and other foods. Similarity of craving across substances and activities is also supported by questionnaire studies with addicted (Kavanagh et al, 2009) and non-addicted populations (May et al, 2004; May, Andrade, Kavanagh & Penfound, 2008).

Limitations

We have noted a number of limitations and problems with each of the experiments reported, and summarise them here. Our samples are mainly of young, moderate smokers, who were not actively trying to quit, and we do not yet know if similar results would be found with more heavily addicted smokers under more severe abstention. However, young, moderate smokers are precisely the group upon whom prevention efforts are being targeted, and so the results are informative. In the first two studies we did not measure breath CO to ensure compliance with our request to abstain, nor could we tell if non-abstainers had actually smoked recently, although any non-compliance would have worked against our hypotheses.

In Experiment 1, the imagery task was very obvious and so a demand effect might have arisen. We tried to deal with this in Experiment 2 by using the DVN task, but the crossed nature of the design was problematic, and the fact that this experiment was conducted in Sri Lanka whereas the others were based in the U.K. could also make it difficult to determine why some findings did not replicate across experiments. The first two studies relied upon induction scripts which, despite being widely used, might have confounded our experiments through artificially emphasising imagery or distracting participants from smoking, and so in Experiments 3 and 4 we used a more naturalistic cue-based induction procedure, which we found to be just as effective in inducing cravings. Any induced craving might differ in processes and nature from a naturally occurring craving, of course, which is a problem for all laboratory studies of craving.

On the basis of self-reports of visual imagery during episodes of craving (May et al, 2004; 2008), we assume that any successful induction would trigger visual images of cigarettes or smoking, whether or not the instructions contained imagery cues. The present experiments show that effects of visual interventions on craving generalise across different craving induction procedures. Although the induction procedure used in Experiments 3 and 4 did not explicitly instruct participants to form mental images, it is conceivable that it encouraged visual imagery of smoking more than auditory imagery. For example, during the experimental phase, participants may have recollected watching the experimenter place their cigarettes in a drawer, and these primarily visual recollections may have triggered further visual images of cigarettes. The strongest test that the effects we report are genuine and not an artefact of the induction procedure would be to use an induction method that really emphasised auditory processing, for instance, listening to someone striking a lighter or taking a drag on a cigarette. Selective effects of visual but not auditory interventions under these circumstances would corroborate our argument that visual imagery supports cigarette craving.

Implications

The findings have implications for the treatment and management of craving episodes in smokers who are attempting to quit. Not only do intensity and duration of craving episodes predict relapse to smoking (Shiffman et al., 1997), but craving also disrupts other cognitive activities (Kemps, Tiggemann & Grigg, 2008; Zwaan and Truitt, 1998). Therefore, techniques for reducing the occurrence, intensity and duration of craving episodes are important in improving both smoking outcomes and functioning during quit attempts, Interfering with visual imagery may be a way to provide relief from craving during the difficult initial abstinence period.

An important point that must be emphasised is that this interference is specifically targeting cognitive processes that have been theoretically identified as being necessary for craving; we do not believe that the interference is working through the addition of a general cognitive load or by distracting the craver from their substance related thoughts, because in each of the experiments we have compared the visuospatial tasks with non-visuospatial tasks rather than using no-task control conditions. In Experiments 1, 2 and 3, the auditory imagery task is identical to the visual imagery task apart from the requirement to imagine and rate sounds rather than sights. This task shows similar non-specific dual-task decrements to the visual imagery task, suggesting the two tasks impose similar loads on general executive or attentional resources (Baddeley & Andrade, 2000). The static visual noise display used in Experiment 2 is the standard control for dynamic visual noise (e.g., Dean, Dewhurst & Whittaker, 2008; McConnell & Quinn, 2000). For the clay modeling task, we used counting aloud as a form of articulatory suppression. Articulatory suppression selectively loads verbal short-term memory by blocking subvocal rehearsal (e.g., Baddeley, 1986) and selectively reduces the vividness of auditory imagery relative to visual imagery (Baddeley & Andrade, 2000). The requirement to count backwards added a novelty component to help compensate for the novelty of the clay modeling task. Although we have no proof that the two tasks in Experiment 4 are matched for general resource loads, we note that the pattern of results is very similar to that obtained in Experiment 3, where the two tasks were well matched.

Adapted for take-home use, concurrent visual working memory tasks may eventually be a useful addition to self-guided quit smoking programmes, providing a way of coping with the acute effects of cue-provoked craving while abstinence is being attempted. The challenge that now faces researchers is to develop interference tasks that are easily applied without awkward or costly equipment, avoiding either interference with functional activities or embarrassment to the user, and to evaluate these in trials with smokers who are trying to quit.

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Acknowledgements:

We would like to thank Damian Eade, Marco Flatau, Alex Wheatley, Claire Blackford & Rebecca Chidley who collected data for Experiments 1, 3 and 4 as part of their undergraduate studies at the University of Sheffield and the University of Plymouth. We thank the University of Colombo for permission to conduct Experiment 2 at the University. Natalie Panabokke is now at the Faculty of Graduate Studies, University of Colombo, Sri Lanka.

Appendix.

		Visual Imagery Cues *"Imagine the appearance of..."*	Auditory Imagery Cues *"Imagine the sound of.."*
Set A	1	Firth Court [The BMICH](Lighthouse on Hoe)	A telephone ringing
	2	The Statue of Liberty	A hair dryer
	3	A rose garden	A cat meowing
	4	A double decker bus	A door squeaking
	5	The Queen [Bill Clinton]	A toilet flushing
	6	Trafalgar Square [The Eiffel Tower]	Engaged signal on the telephone
Set B	7	A lion in a zoo	Someone coughing
	8	A cemetery	Tap dancing
	9	The Arts Tower [Town Hall] (Levinsky Building)	A clock ticking
	10	Big Ben [Sigiriya]	Snoring
	11	A birthday cake	A dog barking
	12	A rainbow	Wood being sawn
Set C	13	A hot air balloon	A police siren
	14	A laundrette	A baby crying
	15	Cows grazing	Horses galloping
	16	A sunset	Church bells ringing
	17	An eagle	A kettle whistling
	18	A baby asleep	A Fire alarm

After Baddeley and Andrade (2000), with visual items 1 and 9, which were familiar locations in Cambridge, replaced by similar items from Sheffield for Experiment 1, Columbo for Experiment 2 (square brackets), and Plymouth for Experiment 3 (round brackets).

Table and Figure Captions

Table 1. In Experiments 3 and 4, the two experimental groups did not differ on breath CO, baseline craving or rated vividness of imagery during the session. Baseline mood did differ in Experiment 3, but not in Experiment 4.

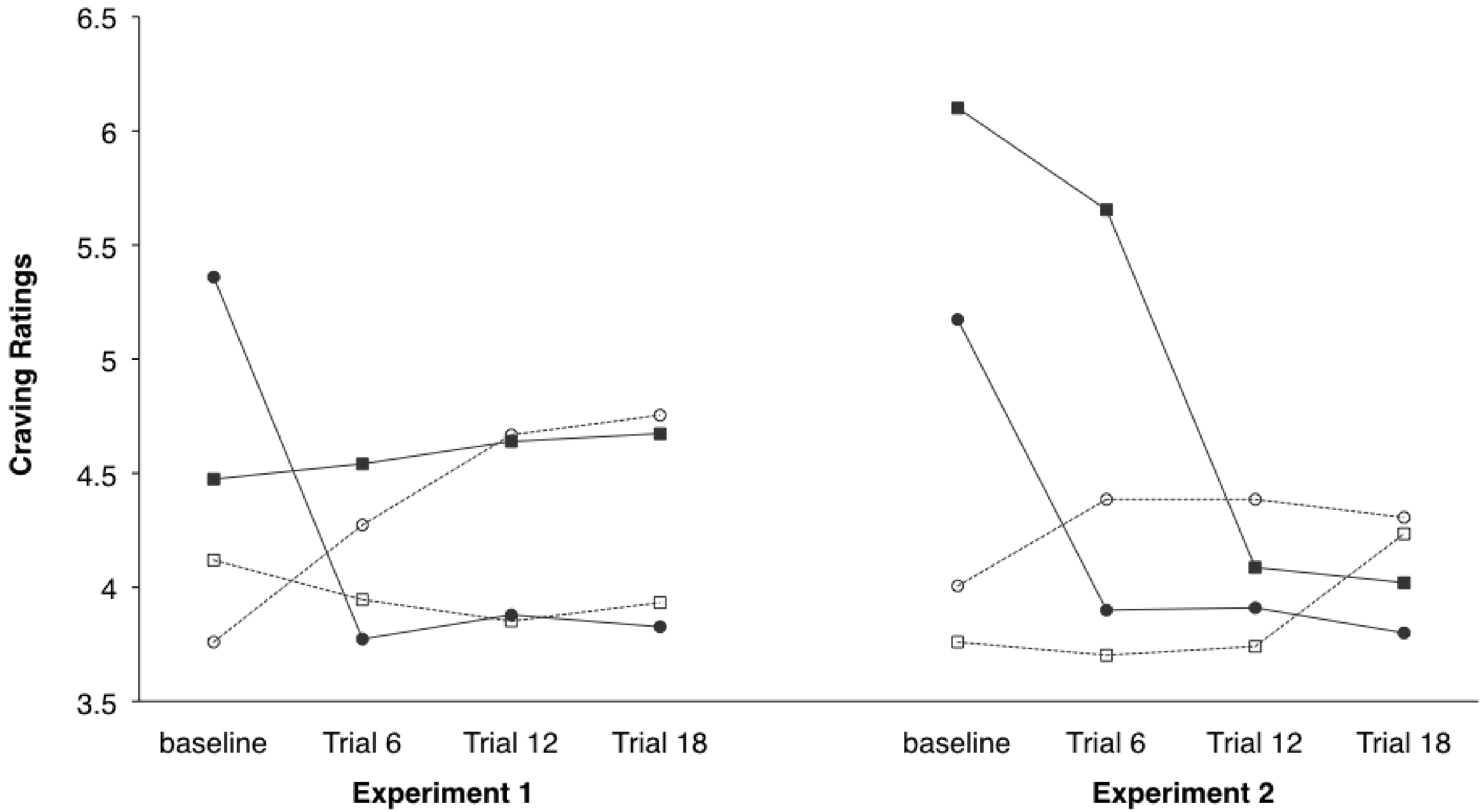
Figure 1. In Experiments 1 and 2 visual imagery (circles) reduced craving for the deprived participants (solid lines; dashed lines = nondeprived). Auditory imagery (squares) did not reduce craving in Experiment 1, but did in Experiment 2 when paired with Dynamic Visual Noise (error bars omitted for clarity).

Figure 2. In Experiments 3 and 4, craving rose during the two minute testing session for the auditory and articulatory groups (dashed lines), but did not change significantly for the visual or visuospatial groups (solid lines). Error bars indicate 1 standard error of each mean.

Table 1.

Experiment 3	Auditory		Visual				
	Mean	SD	Mean	SD	*t*(42)	*p*	*d*
Breath CO (ppm)	9.6	8.4	9.5	7.0	0.02	.98	0.01
Baseline Craving	5.5	1.6	5.6	2.1	0.18	.86	0.06
Baseline Mood	7.0	1.2	5.6	2.2	2.70	.009	0.83
Imagery Vividness	6.0	1.3	6.2	1.3	0.44	.66	0.14

Experiment 4	Articulatory		Visuospatial				
	Mean	SD	Mean	SD	*t*(32)	*p*	*d*
Breath CO (ppm)	3.5	2.2	4.0	3.2	0.50	.62	0.18
Baseline Craving	6.4	1.8	6.3	1.1	0.31	.76	0.11
Baseline Mood	3.0	1.1	3.1	0.8	0.39	.70	0.14



6.5
6
5.5
5
4.5
4
3.5
Craving Ratings
baseline
Trial 6
Trial 12
Trial 18
Experiment 1
baseline
Trial 6
Trial 12
Trial 18
Experiment 2

Figure 1

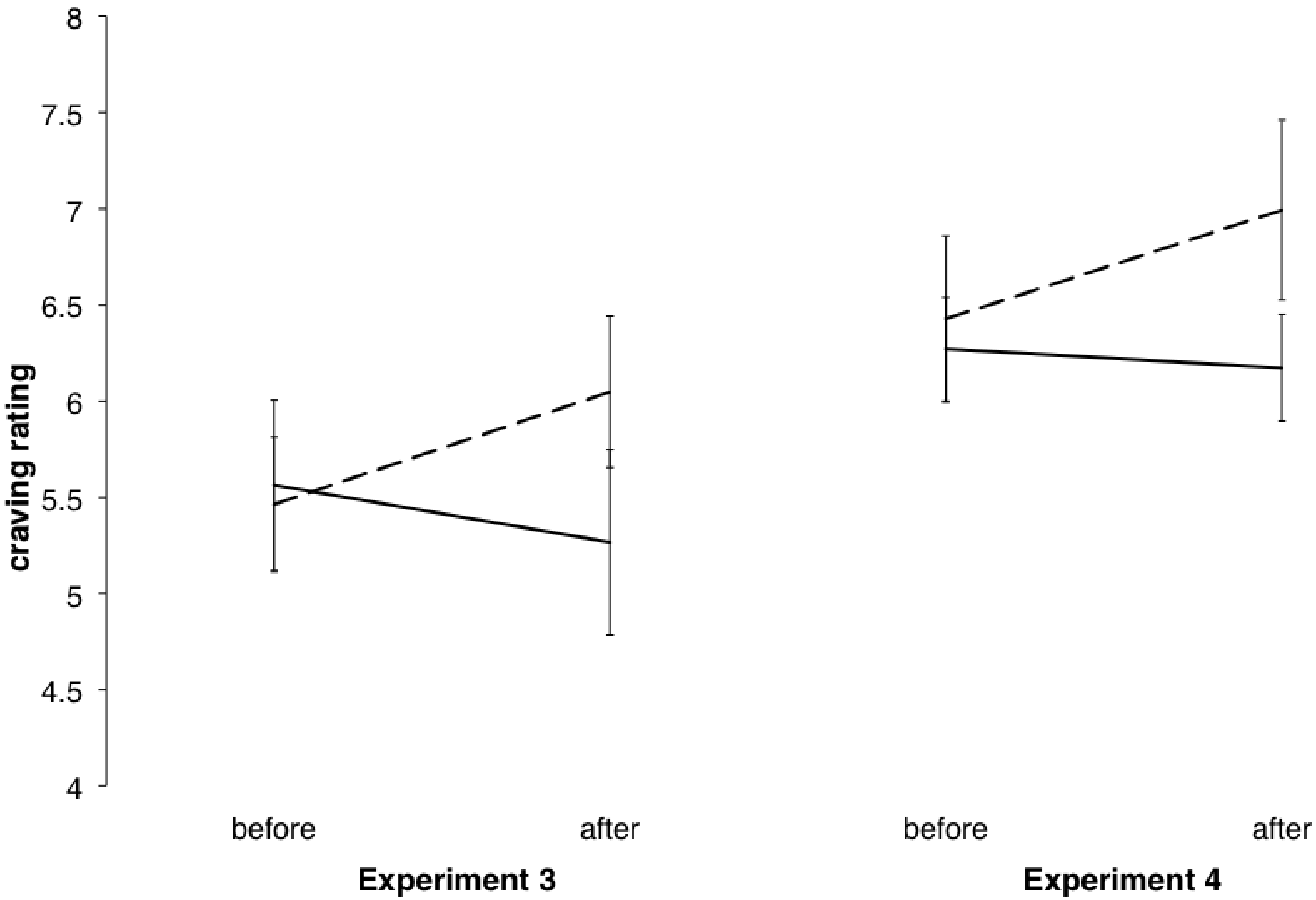

8
7.5
7
6.5
6
5.5
5
4.5
4
craving rating
before
after
Experiment 3
before
after
Experiment 4

Figure 2