Attentional and evaluative biases for smoking cues in nicotine dependence: component processes of biases in visual orienting

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The present study investigated attentional and evaluative biases for smoking-related cues in cigarette smokers and non-smokers. Using a visual probe task, we manipulated the presentation conditions of the stimuli to examine: (1) whether smokers have a bias to allocate attention towards smoking-related pictures that appear below the threshold of conscious awareness; and (2) whether attentional biases for smoking-related pictures that appear above the threshold of awareness operate both in initial orienting and in the maintenance of attention. We also obtained explicit and implicit measures of the valence of the smoking-related pictures from pleasantness ratings and from behavioural responses on a stimulus–response compatibility (SRC) task. Results showed that smokers, but not non-smokers, had an attentional bias for smoking-related pictures which had been presented at two exposure durations (200 and 2000 ms). The bias was not found in a brief (17 ms) masked exposure condition, so there was no evidence that it operated preconsciously. Smokers also showed greater preferences for smoking-related than control cues, compared with non-smokers, on both the explicit and implicit indices of stimulus valence. Results are discussed with reference to incentive and cognitive models of addiction. Behavioural Pharmacology 00:000–000 © 2004 Lippincott Williams & Wilkins.

Keywords: smoking, attentional bias, preconscious processes, drug cues, stimulus valence, human

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Introduction

Reactivity to drug-related cues is a key feature of drug dependence (for a review, see Carter and Tiffany, 1999). The incentive–sensitization theory of drug dependence (Robinson and Berridge, 1993, 2001) predicts that stimuli associated with drug-taking become highly attractive, ‘wanted’ and ‘grab attention’, because such stimuli have acquired high motivational salience for the individual. According to the theory, the incentive–salience mechanism that underlies this process is mediated by dopamine levels in the mesolimbic dopamine system and plays a key role in maintaining drug-taking behaviour. Thus, the extent to which drug-cues capture and hold attention may reflect directly the extent to which the incentive–salience mechanism is being activated by those cues. On the other hand, Tiffany’s (1990) model of addiction views drug-taking behaviour as habitual responding that is controlled by automatic action schemata. However, when drug use is interrupted or blocked, non-automatic processing resources will be directed towards the goal of seeking and obtaining the drug. Hence, this model suggests that attentional processes should be directed towards drug-related cues, particularly when the drug is currently unavailable.

The visual probe task has been used to assess attentional biases for drug-related cues. In pictorial versions of this task (e.g. Bradley et al., 2003), on each trial, two pictures are briefly presented simultaneously side by side on a computer screen (e.g. a smoking-related picture and a control picture). Immediately after the pictures disappear, a probe stimulus (e.g. a small dot) appears in the location of one of them, and participants are required to press a key as quickly as possible in response to the probe. The rationale for the task is that people respond faster to stimuli that appear in an attended, rather than unattended, region of a visual display (e.g. Posner et al., 1980). Thus, the deployment of attention to the pictures can be inferred from the response times (RTs) to the probes. Studies using the visual probe task have indicated an attentional bias for smoking-related pictures in smokers (Ehrman et al., 2002; Bradley et al., 2003), drug-related words in cocaine addicts (Franken et al., 2000a) and drug-related pictures in opiate addicts (Lubman et al., 2000).

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A feature of the visual probe task is that it gives a snapshot view of attentional biases. That is, the RT measure of attentional bias is obtained after the offset of the display of the pictures (i.e. when the probe appears). The exposure duration of the pictures can be manipulated to examine different aspects of attentional processes. For example, one distinction has been made between those processes involved in initial orienting of attention and those involved in the maintenance of attention (e.g. Allport, 1989; LaBerge, 1995). Another distinction has been drawn between relatively fast, automatic shifts of attention (e.g. occurring within 50–200 ms of a novel stimulus appearing in the visual field) and deliberate, intentional shifts of attention, which tend to have a slower time course (e.g. Egeth and Yantis, 1997). Therefore, in the context of a visual probe task, when the picture pairs are shown relatively briefly (e.g. 200 ms), the RT measure of attentional bias is likely to reflect the stimulus to which attention is initially directed. Furthermore, if attention is shifted to a stimulus within 200 ms, this could suggest that rapid, automatic processes may be playing an important role in mediating the attentional bias. When the picture pairs are presented for longer durations (e.g. 2000 ms), there is greater opportunity for attention to shift repeatedly between the pictures while they are displayed, so the bias measure is more likely to reflect maintained attention.

Robinson and Berridge (1993) have argued that drug-related stimuli can capture attention automatically, which suggests that attentional biases operate in initial orienting processes and so should be evident at relatively short stimulus exposure durations, such as 200 ms. LaBerge (1995) proposed that the maintenance of attention is likely to be heavily influenced by motivational processes. As attentional biases in addiction are presumed to be associated with disordered motivation for drugs, it seems reasonable to predict that attentional biases will also operate in the maintenance of attention. However, there has been relatively little research investigating which specific orienting processes are involved in attentional biases in drug dependence. Previous studies using the visual probe task to assess attentional biases in smokers have used long stimulus durations, such as 500 ms or more (e.g. Ehrman et al., 2002; Bradley et al., 2003) which may not be optimally sensitive to biases in the initial orienting of attention. In the present study, we presented smoking-related pictures for 200 and 2000 ms, to examine whether smokers have a bias for smoking-related pictures in initial orienting and in the maintenance of attention.

A further goal of this study was to examine whether smokers have an attentional bias for smoking-related pictures that are presented below the threshold of awareness. Previous studies using the modified Stroop task have failed to demonstrate a processing bias for subliminally presented drug-related words, in samples of smokers (Mogg and Bradley, 2002a) and opiate addicts (Franken et al., 2000b), but no study has so far examined such biases for pictorial stimuli. Thus, we used a masked version of the visual probe task, similar to that used previously in our laboratory to investigate preconscious biases for stimuli related to aversive motivational states (Mogg and Bradley, 1999, Experiment 3). The task was modified here to examine preconscious biases for smoking-related cues. On each critical trial, a pair of pictures (a smoking-related and control picture) was presented very briefly (17 ms) and masked, immediately before the appearance of the probe, so that participants’ awareness of the content of the pictures was restricted under these conditions.

Thus, with respect to the attentional bias measures, the present study differs from previous research in two important respects. First, the unmasked version of the visual probe task includes a much shorter duration (200 ms) than those typically used to investigate attentional biases in smokers, which is more likely to reflect automatic, initial orienting processes than the longer stimulus durations. Secondly, as far as we know, no previous study has examined preconscious biases for drug-related pictorial scenes. As pictures may have greater ecological validity than the single-word stimuli used in previous masking studies in addiction, they may be more effective in revealing a preconscious bias for drug-related cues.

Another goal of this research was to investigate further the motivational and affective valence of the smoking-related pictures. According to incentive models of addiction, drug-related cues should be perceived as ‘attractive’ (Robinson and Berridge, 1993, 2001). Consistent with this, there is evidence that pictorial scenes of smoking are rated as subjectively pleasant by smokers (Mucha et al., 1999; Mogg et al., 2003). In the present study, we used two measures of stimulus valence. One was an explicit rating task, in which participants viewed smoking-related and matched control pictures and rated each picture in terms of its subjective ‘pleasantness’. We also included a ‘stimulus-response compatibility’ (SRC) task, which is thought to provide an implicit measure of the valence of the stimuli and is less likely to be confounded by demand effects than explicit pleasantness ratings (because the SRC task does not require participants to give explicit judgements about the valence of the stimuli). De Houwer et al. (2001, experiment 4) demonstrated that latencies to categorize positively valenced stimuli are faster if the appropriate categorization response is a symbolic approach, rather than avoidance movement, whereas the reverse was true for negatively valenced stimuli. These results suggest that a symbolic approach and avoidance responses provide an
implicit index of the stimulus valence. In the SRC task used here, pictures were presented individually on a computer screen, and participants were asked to decide whether or not each picture was related to smoking, and to respond by moving a manikin figure either towards or away from each picture. If participants evaluate the smoking-related pictures as positive, they should be faster to make approach than avoidance movements to those pictures. Conversely, if they evaluate the smoking-related pictures as negative, the opposite pattern of results would be seen. In an earlier study using the SRC task (Mogg et al., 2003), we demonstrated that smokers were relatively faster than non-smokers to categorize smoking-related pictures when the appropriate response was an approach movement rather than an avoidance movement, which suggests that the smokers perceived the smoking-related pictures as more positively valenced, relative to the non-smokers. Given the paucity of research into implicit evaluative biases in addiction, it is helpful to establish whether the findings from the SRC task are robust, so we investigated here whether they could be replicated.

In summary, the present study assessed biases in preconscious, attentional and evaluative processing of drug-related stimuli in smokers and non-smokers. We hypothesized that smokers would show a preconscious bias for briefly presented, masked smoking-related pictures (i.e. presented under subliminal conditions). We also hypothesized that smokers would show an attentional bias for smoking-related pictures that were presented for longer durations, above the threshold of awareness (i.e. under supraliminal conditions); and this attentional bias would be evident at both 200 and 2000 ms exposure durations. We also examined whether these predicted attentional biases would be accompanied by evaluative biases; i.e. a tendency to evaluate smoking-related stimuli more positively than controls, which would be expected from incentive models of addiction.

Method

Participants
Participants were recruited from the students and staff at the University of Southampton via poster advertisements and through an online experiment booking system. The group of 20 smokers consisted of 10 males and 10 females, with a mean age of 22.7 years (SD = 3.8). On average, they smoked 14.5 cigarettes/day (SD = 3.2), range 10–20, and had been smoking for 8.2 years (SD = 3.3, range 2.5–15 years). The control group consisted of 20 non-smokers (10 males and 10 females). They had a mean age of 23.5 years (SD = 3.2) and they reported never having smoked regularly. The smoker and control groups did not differ significantly in age (t < 1). Additional selection criteria for all participants were that they spoke fluent English and had visual acuity within normal limits.

Materials
The pictorial stimuli used in the computer tasks were similar to those used in our previous studies (Bradley et al., 2003; Mogg et al., 2003). They consisted of 20 colour photographs of smoking-related scenes (e.g. woman holding cigarette to mouth, cigarette beside ashtray). Each was paired with a photograph of another scene matched as closely as possible for content, but lacking any smoking-related cues (e.g. woman applying lipstick, pen beside bowl). An additional 20 picture pairs (unrelated to smoking) were prepared for use as fillers, and three pairs for practice and buffer trials. For the masked version of the visual probe task, a ‘mask’ picture was created by taking one of the filler pictures, cutting it up into 35 pieces of equal size, and then randomly rearranging these pieces. The pictures were digitized and converted to an indexed 256 colour palette. All tasks were presented on a 450 Mhz Pentium III PC, with 15” VGA colour monitor, attached to a MEL version 2 response box and standard keyboard.

Procedure
At the start of the session, participants signed an informed consent form, and then gave a sample of expired carbon monoxide (CO) on a smokerlyzer (Bedfont Scientific Ltd, Bedford, UK). Smokers then completed the brief form of the Questionnaire of Smoking Urges (QSU; Cox et al., 2001). Participants then completed the masked version of the visual probe task. Each trial started with a central fixation cross shown for 1000 ms, which was replaced by the display of a pair of pictures, side by side, for 17 ms. Immediately after picture offset, a pair of mask pictures was presented for 68 ms, in the positions that had been occupied by the original picture pair. Immediately after the offset of the masks, a probe was presented in the position of one of the preceding pictures, until the participant gave a manual response. The probe was a small arrow which pointed either up or down. Participants were instructed to press one of two response buttons to indicate the identity of the probe. They were also instructed to look at the fixation cross at the start of each trial. There was an inter-trial interval of 2000 ms.

There were 14 practice trials, followed by two buffer trials and 120 trials in the main task (80 critical trials and 40 filler trials). During the critical trials, each of the 20 smoking-control picture pairs was presented four times. Each smoking-related picture appeared twice on the left side of the screen, and twice on the right. The probe appeared with equal frequency in the location of either the smoking-related or the control picture, and there was an equal number of trials with each probe type. The 20 filler picture pairs were presented twice each. Critical and filler trials were presented in a new random order for
each participant. Each picture was 95 mm high by
130 mm wide when displayed on the screen, and the
distance between their inner edges was 30 mm. The
distance between the two probe positions was 105 mm.

Next, participants completed an awareness check, in
which the presentation conditions for the pictures and
masks were the same as in the masked version of the
visual probe task. That is, each trial started with a central
fixation cross for 1000 ms, followed by a pair of pictures
for 17 ms, which were immediately replaced by a pair of
masks for 68 ms. Immediately after the offset of the
masks, a question mark (?) was presented in the position
of each of the preceding pictures, until the participant
pressed one of two response buttons, labelled ‘yes’ or ‘no’,
to indicate whether either of the pictures that were
presented before the masks contained smoking-relevant
images. They were also instructed to look at the fixation
cross at the start of each trial. There was an inter-trial
interval of 2000 ms. There were 10 practice trials,
followed by 2 buffer trials and 40 trials in the main task
(20 smoking–control picture pairs and 20 filler pairs,
with each pair presented once).

Participants then completed the unmasked version of the
visual probe task, which was similar to the masked
version, with the following modifications. Picture pairs
were presented for 200 or 2000 ms, and they were not
replaced by a pair of masking pictures. There were 14
practice trials, followed by two blocks of trials, each
consisting of two buffer and 120 experimental trials, with
a short rest break between the blocks. Of the 240 total
experimental trials, there were 160 critical trials and 80
filler trials. During the critical trials, each of the 20
smoking-control picture pairs was presented eight times,
four times for 200 ms and four times for 2000 ms. Within
each stimulus duration condition, each smoking-related
picture appeared twice on the left side of the screen, and
twice on the right. The probe appeared in the location
of either the smoking-related or the control picture with
equal frequency and there was an equal number of trials
with each probe type. The 20 filler picture pairs were
presented four times each, twice for 200 ms and twice for
2000 ms. Critical and filler trials were presented in a new
random order for each participant. The inter-trial interval
varied from 500 to 1000 ms.

Immediately after the visual probe tasks, participants in
the smoker group were asked to indicate ‘how strong your
urge to smoke is right now’ on an anchored rating scale,
which ranged from 0 (not at all) to 10 (extremely).
Participants then completed the picture-rating task and
the SRC task; the order of these tasks was counter-
balanced across participants.

The picture-rating task consisted of two practice trials, in
which filler pictures were presented, followed by 40 test
trials in which each smoking-related picture and control
picture from the visual probe task was presented, one at
a time, in a new random order for each participant. Each
picture (73 mm × 100 mm) was presented for 2000 ms
and, after a pause of 500 ms, a 7-point anchored rating
scale was displayed on the screen until the participant’s
response. The rating scale ranged from –3 (very
unpleasant) to +3 (very pleasant), and participants
were asked to press one of seven keys, which were
correspondingly labelled from –3 to +3, to indicate how
pleasant or unpleasant they found each picture. The
inter-trial interval was 500 ms. The visual probe tasks and
this task were presented using MEL version 2.01
software.

The SRC task consisted of two blocks, each of 100 trials.
In each trial, a picture was displayed in the centre of the
screen and a manikin figure was presented either above
the picture or below the picture. The picture was either a
smoking-related or a control picture (which were those
used in critical trials of the visual probe task). Each block
of trials had a different stimulus–response assignment: in
assignment 1, participants were instructed to move the
manikin towards the picture if it depicted a smoking-
related scene, and away from the picture if the scene was
not smoking-related. In assignment 2, these stimulus–
response relationships were reversed (i.e. participants
were instructed to move the manikin away from smoking-
related pictures, and towards smoking-unrelated pic-
tures). The order of assignments 1 and 2 was counter-
balanced across participants.

For each assignment, there were 20 practice trials, in
which 10 smoking-related and 10 control pictures were
presented, followed by 80 test trials, with a short break
after 40 trials. During the test trials, each of the 20
smoking-related and 20 control pictures was presented
twice. Each picture was 115 mm high × 145 mm wide, and
the manikin (a matchstick figure of a man) was
approximately 18 mm high by 10 mm wide. The manikin
was presented either 25 mm above or below the picture,
and appeared above the picture on 50% of trials, and
below it on the other 50%. Participants responded by
pressing the up or down arrows on the keyboard, which
moved the manikin figure up or down the screen,
respectively. The picture and manikin disappeared as
soon as the manikin reached the edge of the screen or the
picture. There was a 1500 ms interval between trials. The
latency was recorded between each picture onset and the
response. Within each assignment block, the trials were
presented in a new random order for each participant, so
that picture type and manikin position varied over trials.
The SRC task avoids a direct one-to-one mapping
between the required response on each trial and the
address approach/avoid instructions, because, within each block, the manikin appeared above the pictures on half the trials (when ‘approach smoking’ required a ‘down’ response to smoking-related pictures) and below the pictures on the other half of trials (when ‘approach smoking’ required a ‘up’ response to smoking-related pictures). The SRC task was programmed in Turbo Pascal.

After the computer tasks, participants in the smoking group completed the Questionnaire of Smoking Urges – brief form (QSU; Cox et al., 2001), Fagerstrom Test for Nicotine Dependence (FTND; Heatherton et al., 1991), and questionnaires about smoking habits and history. Participants in the non-smoker group answered questions about their smoking experience (e.g. ‘How many cigarettes have you smoked in your lifetime?’). After completion of the questionnaires, participants were debriefed, thanked for their time, and paid £7 sterling.

Results

Questionnaire and carbon monoxide data

Among smokers, the mean time elapsed since smoking their last cigarette before the start of the session was 31.5 min. (SD = 38.0, range 5–120 min), the mean level of expired CO was 19.1 (SD = 13.1) parts per million (p.p.m.), and the mean FTND score was 3.5 (SD = 1.6). Mean scores on the QSU brief, on a seven-point scale, were 2.6 (SD = 0.3) at the beginning of the experiment and 3.9 (SD = 0.3) at the end of the experiment. The mean rating of urge to smoke, on a 0–10 point scale, taken midway through the experiment, was 5.3 (SD = 0.7). Among non-smokers, one participant was excluded from all analyses because he was an extreme outlier (evident from a box and whisker plot), as his expired CO level was 6 p.p.m., whereas the mean for all other non-smokers was 1.7 p.p.m. (SD = 0.7).

Masked version of visual probe task

First, the percentage of correct responses on the awareness check was calculated for each participant. If participants were responding at chance, we would expect them to be able to indicate whether or not a smoking-related picture was present on 50% of trials, so the percentage of correct responses was compared with 50% separately for each participant, using non-parametric binomial tests. Five participants (three smokers and two non-smokers) scored significantly above chance performance (percentage of trials with correct responses was 67% or more for these individuals), and so their data were not included in the analysis of the masked visual probe data. For the remaining participants, the mean percentage of correct scores on the awareness check was 50% (SD = 7.9), which is at chance level.

On the masked version of the visual probe task, RT data from filler trials, and from trials with errors (2% of data), were discarded. To eliminate outliers, RTs were excluded if they were less than 200 ms, greater than 2000 ms, and then if they were more than 2 SDs above the mean (4% of data). A 2 × 2 ANOVA of the probe RT data with group (smokers, non-smokers) as the between-subject variable and probe position (probe in same versus different location to smoking picture) as the within-subject variable, did not detect any significant effects (e.g. predicted Group × Probe Position interaction: F < 1).

Unmasked version of visual probe task

RT data from filler trials, and from trials with errors (2% of data), were discarded. To eliminate outliers, RTs were excluded if they were less than 200 ms, greater than 2000 ms, and then if they were more than 2 SDs above the mean (3% of data). A 2 × 2 × 2 ANOVA of the probe RT data was carried out with group (smokers, non-smokers) as the between-subject variable and probe position (probe in same versus different location to smoking picture) and stimulus duration (200 ms, 2000 ms) as within-subject variables. There was a significant main effect of stimulus duration [F(1,37) = 15.41, P < 0.01], as participants were generally faster to respond to probes replacing pictures shown for 2000 ms rather than 200 ms. There was a tendency for a main effect of probe position [F(1,37) = 3.96, P = 0.054]. This effect was subsumed under a significant Group × Probe Position interaction [F(1,37) = 4.17, P < 0.05], which was not significantly influenced by stimulus duration [Group × Probe Position × Stimulus duration: F(1,37) = 1.03, NS]. Post hoc tests were carried out to clarify the significant two-way interaction. These showed that, averaged across both stimulus durations, smokers were faster to respond to probes that replaced smoking-related pictures than control pictures [634 versus 652 ms: t(19) = 2.23, P < 0.05], with no difference between these conditions in non-smokers [615 versus 615 ms: t(18) = 0.07, NS]. These results are consistent with an attentional bias for smoking-related cues in smokers only. The mean RTs in each condition are shown in Fig. 1.

To allow correlational analyses, an attentional bias score was calculated for each exposure condition, by subtracting the mean RT to probes replacing smoking pictures from the mean RT to probes replacing control pictures, so that positive values of the bias scores reflect relative speeding of RTs to probes replacing smoking pictures. The attentional bias scores from the 200 ms and 2000 ms conditions significantly correlated with each other (r = 0.58, P < 0.01).
Picture-rating task
Mean pleasantness ratings were calculated for the smoking-related and control pictures for each participant. A $2 \times 2$ mixed design ANOVA of the ratings, with group (smokers, non-smokers) and picture type (smoking-related, control) as independent variables, showed significant main effects of group [$F(1,37) = 37.4, P < 0.01$], and picture type [$F(1,37) = 44.4, P < 0.01$], and a significant Group $\times$ Picture type interaction [$F(1,37) = 50.8, P < 0.01$], which is illustrated in Fig. 2. Smokers gave similar ratings for smoking and control pictures, [$t(19) = 0.3, \text{NS}$], whereas non-smokers rated the smoking-related pictures as significantly more unpleasant than control pictures [$t(18) = 10.1, P < 0.01$]. Between-group contrasts indicated that non-smokers rated the smoking pictures as more unpleasant than did smokers [$t(37) = 7.4, P < 0.01$], but there was no between group difference in ratings for control pictures [$t(37) = 1.9, \text{NS}$].

Stimulus–response compatibility task
Due to technical difficulties, data from one non-smoker were missing. RT data from trials with errors were discarded (4.5% of data) and, to eliminate outliers, RTs were excluded if they were less than 200 ms, more than 2000 ms, and then if they were more than 2 SDs above the mean (7.5% of data). One further non-smoker was eliminated from subsequent analyses as box and whisker plots revealed that she had an outlying high rate of missing data (25%) after trials with errors and outliers had been removed. Our main prediction was that smokers would be faster to approach smoking-related and avoid smoking-unrelated pictures (assignment 1), compared with avoiding smoking-related pictures and approaching smoking-unrelated pictures (assignment 2), whereas non-smokers should show the converse (i.e. a group $\times$ assignment interaction effect on RTs). To test this hypothesis, a $2 \times 2$ mixed design ANOVA was carried out with group (smokers versus non-smokers) as a between-subjects variable, and assignment type (1, approach smoking-related and avoid smoking-unrelated pictures; versus 2, avoid smoking-related and approach smoking-unrelated pictures) as a within-subject variable. This showed a significant main effect of assignment type [$F(1,36) = 34.51, P < 0.01$] and a significant Group $\times$ Assignment type interaction [$F(1,36) = 14.70, P < 0.01$]. Mean RTs in each condition are shown in Fig. 3.

The Group $\times$ Assignment type interaction was clarified using paired-samples $t$-tests for each group. Smokers were faster to respond when instructed to approach smoking-related and avoid smoking-unrelated pictures, compared with when they were asked to avoid smoking-related and approach smoking-unrelated pictures [688 ms versus 793 ms: $t(19) = 6.33, P < 0.01$]. This indicates a prefer-
A common underlying mechanism may contribute to both significantly correlated with each other, which suggests that a 200 ms and 2000 ms exposure conditions were significantly different during assignments 1 and 2 (729 versus 751 ms: \( t(17) = 1.65, \text{NS} \)).

**Discussion**

The results from this experiment provide several novel findings, as well as extending the conclusions from earlier research. Smokers had an attentional bias for smoking-related stimuli, and this attentional bias in smokers did not vary significantly across these two exposure conditions of 200 and 2000 ms. Moreover, the bias scores from these two exposure conditions correlated significantly with each other. With respect to the masked condition of the visual probe task, there was no evidence of a processing bias for smoking-related stimuli that were presented under conditions of restricted awareness. With regard to both the implicit and explicit measures of stimulus valence, smokers tended to perceive the smoking pictures as more positively valenced, relative to the non-smokers. These results will be discussed in turn.

On the standard (unmasked) version of the visual probe task, smokers, but not non-smokers, were significantly faster to respond to probes replacing smoking-related than control pictures, which supports the hypothesis of an attentional bias in smokers. The time course of the attentional bias did not change significantly over the two-second time interval studied here (i.e. the group difference in attentional bias for smoking-related cues was not significantly influenced by the stimulus exposure condition). Moreover, the attentional bias scores in the 200 ms and 2000 ms exposure conditions were significantly correlated with each other, which suggests that a common underlying mechanism may contribute to both attentional bias indices. Thus, these findings suggest that the attentional bias is not specific to either initial orienting or sustained attention, and it may operate across these different aspects of attentional processes. The present results seem to be consistent with predictions made by Robinson and Berridge (1993), who argue that drug-related cues grab attention. They are also compatible with Tiffany’s (1990) model, since smokers did not have access to cigarettes during the attentional task and, according to Tiffany’s cognitive model, processing resources should be directed to smoking-related cues under these conditions.

With respect to the masked version of the visual probe task, this showed no evidence of an attentional bias, in smokers, for smoking-related pictures that had been presented briefly (for 17 ms) and masked. One interpretation of this null result is that attentional biases in smokers are only found when stimuli are presented above the threshold of awareness, i.e. the bias does not operate in preconscious processes. This conclusion would be consistent with previous failures to demonstrate preconscious biases in appetitive motivational states, in studies which have so far only used word stimuli, such as modified Stroop tasks using masked smoking-related words in smokers (Mogg and Bradley, 2002a) and masked heroin-related words in opiate addicts (Franken et al., 2000b), and a visual probe study using masked food-relevant words in hungry individuals (Mogg et al., 1998). The present findings for masked pictorial stimuli may suggest that, although attentional biases for smoking-related stimuli may operate, these biases may require conscious identification of the stimuli.

On the other hand, another possible explanation for this null finding is that the masking conditions may have been too restrictive for demonstrating the predicted attentional biases with these stimuli, which included relatively complex scenes (e.g. people smoking, cigarette packets on display). As intended, the majority of participants did not score above chance levels on the awareness check, which suggests that they were not aware of the content of the pictures. However, it is possible that our masking stimuli were too effective, in that they prevented basic perceptual features of the critical stimuli from being processed at all, even at a preconscious level. Future studies may wish to address this issue, for example, by examining individual differences in thresholds of awareness and tailoring the masking conditions to individual participants. However, it is of interest to note that similar masking conditions have been used in visual probe tasks to examine preconscious biases for threat-related pictures (e.g. Mogg and Bradley, 1999, 2002b; for a review, see Mogg and Bradley, 1998), which raises the question of whether such preconscious biases may operate primarily for aversive motivational states (e.g. anxiety), but not for
appeitive motivational states (e.g. addiction, hunger) (see Mogg *et al.*, 1998, Franken *et al.*, 2000b, for more discussion of these issues, which will only be resolved by further research).

The explicit and implicit measures of perceived stimulus valence (from the rating and SRC tasks, respectively) were in line with our hypotheses and with previous research findings. That is, smokers gave higher pleasantness ratings for smoking-related pictures, relative to non-smokers, which is consistent with previous studies using similar rating tasks (Mogg *et al.*, 2003) and with evidence that smokers report higher feelings of momentary pleasure in response to scenes of smoking than in response to control scenes (Mucha *et al.*, 1999). Results from the SRC task demonstrated that smokers were faster to categorize smoking-related pictures if the appropriate response was to approach the pictures rather than move away from them, which is also consistent with findings from this task (Mogg *et al.*, 2003), and suggests that this novel implicit bias measure in smokers may be relatively robust. The results from both the implicit and explicit valence measures are compatible with the incentive–salience account of addiction (Robinson and Berridge, 1993), which postulates that addicts will find drug-relevant stimuli ‘attractive’. Moreover, the present study provides further evidence that the bias to orient attentional resources towards smoking-related cues in smokers is accompanied by a bias to evaluate those cues more positively; which again seems consistent with incentive accounts of addiction which suggest that a common mechanism may underlie the motivational and cognitive effects of drug cues, i.e. to be ‘desired’ and to grab attentional resources. With respect to Tiffany’s model, this does not make explicit predictions regarding biases in the positive evaluation of drug cues, although it implies a cognitive and behavioural approach orientation to smoking-related cues under conditions where cigarettes are not available.

In summary, the present study indicates that smokers have an attentional bias for smoking-related stimuli and that the bias does not significantly vary across the time course assessed here (200–2000 ms). However, there was no evidence of a corresponding bias when the awareness of the stimuli was restricted by visual masking. The attentional bias in smokers was accompanied by a bias to evaluate smoking-related pictures more positively than controls on both implicit and explicit valence tasks, which is consistent with incentive views of drug dependence.

References
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