TOP-DOWN AND BOTTOM-UP ATTENTIONAL BIASES FOR SMOKING-RELATED STIMULI: COMPARING DEPENDENT AND NON-DEPENDENT SMOKERS

ABSTRACT

Introduction: Substance use causes attentional biases for substance-related stimuli. Both bottom-up (preferential processing) and top-down (inhibitory control) processes are involved in attentional biases. We explored these aspects of attentional bias by using dependent and non-dependent cigarette smokers in order to see whether these two groups would differ in terms of general inhibitory control, bottom-up attentional bias, and top-down attentional biases. This enables us to see whether consumption behaviour would affect these cognitive responses to smoking-related stimuli. *Methods:* Smokers were categorised as either dependent (N=26) or non-dependent (N=34) smokers. A further group of non-smokers (N=32) were recruited to act as controls. Participants then completed a behavioural inhibition task with general stimuli, a smoking-related eye tracking version of the dot-probe task, and an eye-tracking inhibition task with smoking-related stimuli. *Results:* Results indicated that dependent smokers had decreased inhibition and increased attentional bias for smoking-related stimuli (and not control stimuli). By contrast, a decreased inhibition for smoking-related stimuli (in comparison to control stimuli) was not observed for non-dependent smokers. *Conclusions:* Preferential processing of substance-related stimuli may indicate usage of a substance, whereas poor inhibitory control for substance-related stimuli may only emerge if dependence develops. The results suggest that how people engage with substance abuse is important for top-down attentional biases.

Keywords: attentional bias; incentive salience; automaticity; smoking; inhibition; current concerns;

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1. INTRODUCTION

Attentional bias is typically considered the preferential processing of stimuli which have developed increased saliency (e.g. alcohol-related stimuli for heavy drinkers: Cox, et al., 2002). This is normally inferred from measuring the propensity to attend one stimulus-type over another (e.g. smoking-related vs. neutral control stimuli). Attentional biases are considered a product of repeated pairings between stimulus and rewarding effects which leads to related stimuli becoming hypersensitive for attention (e.g. Robinson & Berridge, 1993). This in turn implies bottom-up, salience-driven cognitive processes are involved. However, some research has considered the role of top-down control for substance-related stimuli (e.g. Wilcockson & Pothos, 2015: Field & Cox, 2008) which may indicate that attentional biases are affected by higher-order cognitive functions and could even be the product of a goal-state to consume substances which impairs the ability to supress craving and inhibit attention (e.g. Brown, Duka, & Forster, 2018). This paper considers whether bottom-up and top-down related attentional bias processes are analogous or whether they are involved in substance usage behaviour differently.

In what follows, we employ three terms, which may appear somewhat similar, but they have distinct meanings: attentional biases, preferential processing, and bottom-up processes. Attentional bias is a broad term which can imply attention toward or away from a target. It is typically considered an alteration in the allocation of attention for a stimulus because of previous experience with that stimulus. Preferential processing is a type of attentional bias and represents favourable processing of a stimulus, i.e. our attention is drawn *toward* a stimulus. It is the opposite of attentional avoidance. Whilst bottom-up processing is the cognitive processing of sensory information, typically in a salience-driven manner, where cognitive processing capacity is automatically allocated to salient stimuli (cf. top-down processing, which is a more deliberate allocation of cognitive processing). Attentional bias as preferential processing has been extensively demonstrated in the literature (e.g. Field & Cox, 2008). However, impaired top-down control is also evident in relation to substance abuse related-stimuli. Typical findings demonstrate that substance abusers have impaired capacity to deliberately control or supress automatic behaviours (Groman, et al., 2009; Billieux, et al., 2010). Previous research on heavy drinkers has found a positive correlation between inhibitory control and attentional bias (Field, Christiansen, Cole, & Goudie, 2007), suggesting that impulsive individuals are less able to resist the attention-grabbing properties of alcohol-related stimuli. Furthermore, Wilcockson & Pothos (2015) demonstrated that heavy drinkers were less able to control their attentional biases for alcohol-related stimuli than light drinkers. These findings imply a close relationship between attentional allocation and response inhibition (e.g. Wilcockson & Pothos, 2015) and that addictive behaviours are associated with compromised inhibitory control (Klinger & Cox, 2004; Dawe et al., 2004; Lubman et al., 2004; Olmstead, 2006; Wiers et al., 2007). One might conjecture that this inability to inhibit attention may manifest itself as an inability to control the consumption substances (e.g. Gullo & Dawe, 2008). Typically it is considered that the process of attentional bias and subjective craving could in turn weaken inhibitory control and contribute to impulsive decision making, i.e., there would be a causal relationship between these cognitive processes and substance seeking (Field & Cox, 2008). Therefore, decreased inhibitory control for substance-related stimuli specifically may be a contributing factor for substance seeking behaviours (see Figure 1). Figure 1 demonstrates the model of attentional biases and inhibition hypothesised by Field and Cox (2008). This model suggests that attentional bias is affected by two separate factors relating to inhibition: attempts to supress attentional bias (and craving) and compromised inhibitory control. Therefore, according to this model, attentional biases and related inhibitory control mechanisms should be considered as separate elements of a larger model.

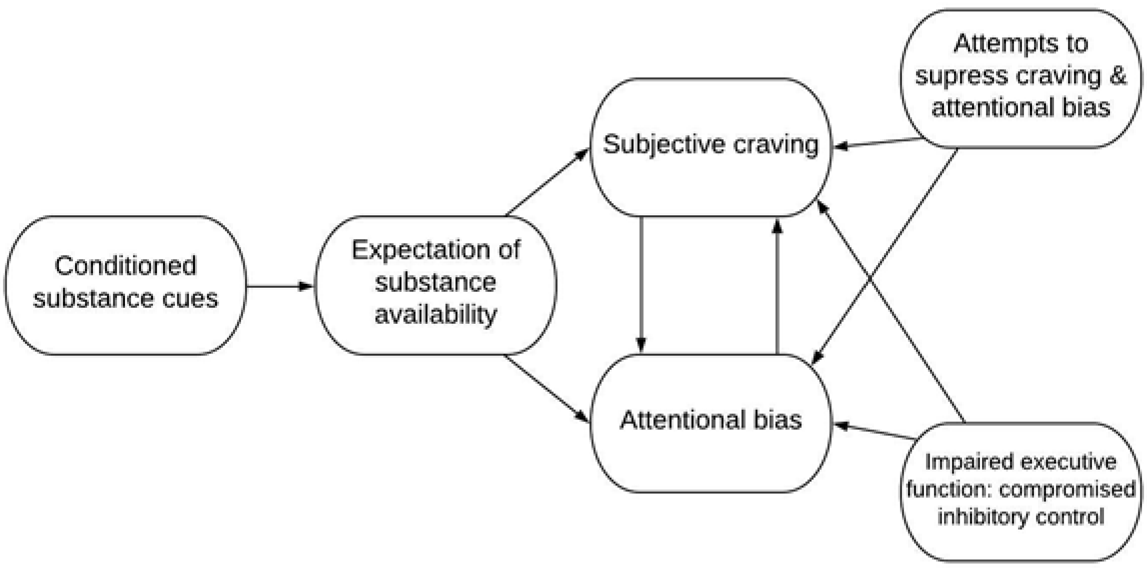

Figure 1. Schematic overview of the model proposed by Field & Cox (2008). In this model, through classical conditioning, substance-related cues indicate the availability of a substance. This causes subjective craving and attentional bias for the substance-related cues. Craving and attentional bias have a mutual excitatory relationship. Attempts to suppress craving and attentional bias may have relative success but they may also paradoxically increase the strength of craving and attentional bias. Impaired inhibitory control would contribute towards increased attentional biases and higher levels of subjective craving. The Orienting Bias Inhibition Task (OrBIT: Wilcockson & Pothos, 2015) enables measurement of the ability to supress attentional biases.

Previous research is unclear regarding whether cigarette smokers are impaired in general inhibitory control with the majority of studies finding no differences between smokers and nonsmokers in inhibitory control (e.g. Dinn et al., 2004; Reynolds, et al., 2007; however, cf. Billieux, et al., 2010; Masiero, et al., 2019). Wilson and MacLean (2013) observed a negative correlation between nicotine dependence and self-control. But they also observed a distinction between components of nicotine dependence. They suggest that self-control may modulate smoking-related behaviours. Shiffman et al (2005) observed that smoking-related behaviours can be used to identify two forms of smokers; dependent smokers (smokers who are nicotine dependent) and non-dependent smokers (who frequently smoke around 5 cigarettes a day, but are not nicotine dependent: Shiffman et al., 1994). The fact that non-dependent cigarette smokers engage in smoking may suggest that for this group of smokers, cigarette use is regulated by cravings to use cigarettes. Whereas dependent smokers use cigarettes in a manner which is designed to reduce the likelihood of experiencing craving (de Ridder, et al., 2012). We would therefore assume that dependent smokers have a goal-state to smoke to avoid craving, whereas non-dependent smokers may be more salience-driven in their smoking behaviour. In this case it may be that dependent smokers have an attentional biases which is goal-driven (Brown, Duka, & Forster, 2018), whereby top-down search goals may be contributing toward attentional bias rather than bottom-up saliency of the stimulus alone (cf. Klinger & Cox, 2002). Therefore, for example, dependent smokers may have a goal to smoke, which would lead to fewer attempts to supress craving and attentional biases.

A key component in this investigation is this distinction between dependent and non-dependent smokers. For this purpose, we employed the NDSS (Shiffman, et al., 2004; 2005). By grouping participants as either dependent or non-dependent using the NDSS, we will examine individual differences relating to the pattern of smoking behaviour as a potential factor in the kind of attentional biases experienced by each participant. Measures of inhibition/self-control and attentional biases will enable us to examine whether cigarette smoking is associated with impaired inhibitory control of attentional biases. Even though a putative causal relationship between the two cannot be examined on the basis of our data, this possibility is clearly an interesting priority for future research.

There are three key aims in this study: First, we establish whether non-smokers, non-dependent smokers, and dependent smokers differ in terms of a conventional behavioural measure of self-control, using a simple inhibition task, the Go/No-Go. This is a task which has previously successfully been used to demonstrate differences between populations in terms of general inhibition (Easdon, et al., 2005). Second, we examine whether a preferential processing bottom-up attentional bias is observed for smoking-related stimuli in the smoking groups, which is the standard expectation from the attentional bias literature. This will examine whether smokers process smoking-related stimuli preferentially in comparison to control stimuli. For this we employed a standard measure of attentional bias in substance abuse, the dot-probe task, with smoking-related stimuli. Finally, we considered whether the two smoking groups differ in their ability to inhibit their attentional biases for smoking-related stimuli.

This way we can explore how compulsory it is for the different smoker types to attend to smoking-related stimuli i.e. the degree to which each group has top-down control over smoking-related attentional biases. To investigate this we employed the Orienting Bias Inhibition Task (OrBIT: Wilcockson & Pothos, 2015) which measures inhibitory processes for attentional biases, specifically the ability to inhibit the initial orientation of attention toward peripherally appearing stimuli. Previous results using this task have suggested that attentional biases toward a substance does not just involve substance-related stimuli becoming prioritised, but in addition, it involves compulsory processing of such stimuli. By utilising these three tasks our aim was to ascertain whether the different ways in which smokers engage in substance abuse is associated with different patterns of inhibition, preferential processing attentional biases, or top-down attentional biases. It is hypothesised that non-dependent smokers will demonstrate a preferential processing bias, whereas the dependent smokers will show a preferential processing bias but also show evidence of top-down control deficits for smoking-related stimuli. Note, in the experimental protocol, we did not include a measure of craving, but rather assume that attentional biases are typically associated with craving (e.g. Ramirez, et al., 2015). The problem with including a craving measure is that such measures involve exposure to smoking-related stimuli, which might interfere with the OrBIT task (if presented prior to the task) or might be unreliable (if presented after the task).

2. METHODS

2.1. Participants

92 participants (29 male, 63 female) aged 18-54 (M=21.98; SD=6.66) were recruited through student and staff populations at Lancaster University (see Table 1). Participants received subject-pool credits or a £3 reimbursement. NDSS criteria (described below) were used to allocate participants into three groups: non-smokers (n=32), non-dependent smokers (n=34), and dependent smokers (n=26). The three groups did not differ in terms of age or sex ($p>.05$). The number of cigarettes smoked per day by the dependent (M=17.29; SD=13.06) and non-dependent (M=8.57; SD=9.47) smokers was found to differ significantly ($t(58)=2.997$; $p=.004$). Full ethical approval was obtained from the Department of Psychology, Lancaster University prior to data collection.

Table 1. Participant descriptive statistics for the different smoking classification groups. The P column indicates between group test statistics differences (ANOVA for comparisons of three groups and t-test for comparisons of two groups).

	Non-Smokers	Non-dependent smokers	Dependent smokers	P
N	32	34	26	
Age (SD)	20.19 (4.0)	22.9 (7.4)	23.0 (7.6)	.160
Sex (male)	19%	35%	42%	.135

Cigarettes smoked alone per day	N/A	2.4 (4.3)	5.9 (5.1)	.002
Cigarettes smoked with friends per day	N/A	5.7 (5.6)	11.6 (9.0)	.003
Total smoked per day	N/A	8.6 (9.5)	17.3 (13.1)	.004
Hours since last smoked	N/A	2.2 (1.1)	1.5 (1)	.040
Hours until next cigarette	N/A	2.3 (1.4)	1.6 (.9)	.059

2.2. Apparatus

Eye movements were recorded using EyeLink Desktop 1000 (SR Research Ltd., Ontario, Canada) at 1000Hz. The distance between the participants and the monitor (60Hz) was approximately 55cm. A chin rest was used to minimise head movement. Stimulus events were controlled by Experiment Builder Software Version 1.10.1630 and eye movement metrics were extracted using DataViewer.

2.3. Materials

2.3.1 Questionnaires

Nicotine dependence was assessed using the Nicotine Dependence Syndrome Scale (Shiffman, et al., 2004). The NDSS consisted of 19 statements to which participants indicated how much the statement is applicable to their smoking habits on a five-point response scale. The NDSS overall score has been demonstrated to be effective in discriminating non-dependent smokers and dependent smokers (Shiffman & Sayette, 2005). Overall scores under -1.5 are regarded as non-dependent whilst scores over this threshold are regarded as dependent smokers (see Shiffman & Sayette, 2005).

A further brief smoking demographic questionnaire was used to quantify the cigarette usage of participants. The questions were designed to measure the frequency of smoking, quantity of smoking, and amount of time since last cigarette.

2.3.2. Go/No-Go

A Go/No-Go paradigm was used to measure self-control/inhibition, irrespective of particular substance. A Go/No-Go paradigm was used to measure self-control/inhibition, irrespective of particular substance. We used a modified version of our Go/No-Go task from Smith-Spark et al (2019). In general, the Go/No-Go task has been found to be a reliable measure of inhibition (see Wright, et al., 2014). The task was programmed using ExperimentBuilder (SR Research). Two images were used, each 225mm x 225mm. A picture of a tree was specified as a "go" response whilst a picture of a football was specified as a "no-go" response. For "go" trials the space bar was pressed. The go/no-go task consisted of 200 trials. 180 of the trials were "go" (90%) whilst 20 of the trials were "no-go" (10%). To build up the anticipation of an expected (or prepotent) response, the initial 40 trials of the task consisted entirely of stimuli which required the motor response for "go" to be made. After this initial phase, the experiment shifted to an inhibition phase with randomised stimulus presentation, without the participant being made aware of this change. The inter-stimulus delay between each trial was 200ms and each picture was displayed for 500ms. Reaction time and accuracy were recorded. The inter-stimulus delay between each trial was 200ms and each picture was displayed for 500ms. Reaction time and accuracy were recorded.

2.3.3. Dot-probe

We implemented an eye tracking version of the standard dot-probe task, as this is generally considered to provide more sensitive measures of attentional bias (Field, et al., 2016). The task comprised 52 trials. Each trial consisted of a smoking-related stimulus and a neutral control stimulus. The stimuli were all selected from the International Smoking Images Series (ISIS: Gilbert & Rabinovich, 1999). Smoking-related pictures (e.g. people smoking, cigarettes, etc.) and a contextually matched neutral picture (e.g. a pen in a mouth). During each trial participants were first instructed to fixate on a central fixation point for 2000ms. Following this, two pictures were presented on either the left or right side of a distal display for 1000ms. A probe would then appear on either the left or right side of the screen and participants would have to respond to the location of the probe. We were primarily interested in the eye movements (specifically fixation counts) as these give us the greatest insight into attentional biases (see Field & Cox, 2008), so button presses were not analysed. The fixation count variable was the number of fixations for each picture-type which is a measure of increased processing of a stimulus i.e. a preferential processing attentional bias.

2.3.4. Smoking-related OrBIT

The modified smoking-version of the OrBIT (Wilcockson & Pothos, 2015) is an eye tracking task which is comprised of 104 trials; 52 smoking-related and 52 neutral control. The stimuli for this task were also selected from the ISIS (Gilbert & Rabinovich, 1999), but differed from the ones which appeared in the dot-probe. Each trial began with a 162mm diameter prompt. The participant was instructed to fixate on this prompt throughout the duration of the trial. After the participant had fixated on the prompt for 1000ms, a distracting stimulus was displayed on the screen. Each stimulus measured 162mm x 162mm and could appear in one of ten locations on the screen (see Figure 2). This stimulus was on the screen for 1000ms before the trial ended. During this time the participant had to refrain from looking at the stimulus. If the participant looked away from the prompt, then the stimulus was removed through a gaze-contingent design. Therefore, the participant was unable to fixate on the stimulus. For the main analyses, we considered only the distractor trials for which distractors were four degrees away from the prompt. This is because these stimuli are more likely to have been processed covertly but still produce overt attentional shifts (see Hogarth, et al., 2009). The stimuli presented further away than 4 degrees cannot be covertly attended to and were merely included as foils 'Break frequency', i.e. whether the prompt threshold was breached, was measured on these trials for both the smoking-related and neutral trials by using the DataViewer 'interest area skip' variable. This provided us with a measure of the compulsory nature of an attentional bias. Therefore, we call this variable top-down attentional bias; higher top-down attentional bias means lower inhibitory control for smoking-related stimuli.

2.4. Procedure

The OrBIT was completed first, followed by the dot-probe, and the Go/No-Go task was completed last. Upon completion of the computer tasks, participants were asked to complete the NDSS and smoking questionnaire.

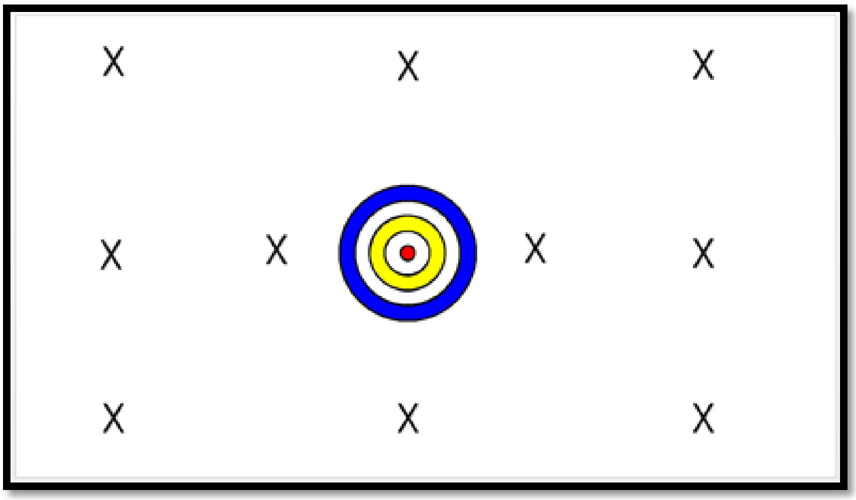

Figure 2. The crosses indicate the locations where the distracting stimuli (both smoking and control) would appear. The fixation target would appear either in the centre, or in the place of a cross on the periphery. When the fixation target was in the middle, the distracting stimuli either appeared in the cross locations immediately to the left and right of centre. For the analyses, only the central trials were included. Note, the crosses are only notional, and were not visible to the participant.

3. RESULTS

In order to establish whether smoking behaviour was associated with differences in inhibition and attentional biases a number of analyses were undertaken. Of interest was whether the different ways in which the participant groups utilised cigarettes was associated with different patterns of inhibition and attention for smoking-related stimuli. We explored inhibition using the Go/No-Go, attentional bias using the dot-probe, and attentional bias compulsivity using the OrBIT.

3.1. Go/No-Go

We examined performance on the Go/No-Go tasks between the three types of smokers (dependent, non-dependent, and non-smoker) using a one-way ANOVA. Performance on the Go/No-Go task did not differ between the three groups in terms of RT ($F(2,89)=.010$; $p=.990$; $\eta p^2<.005$), correct responses ($F(2,89)=.560$; $p=.573$; $\eta p^2=.01$), nor false positives i.e. failures to inhibit ($F(2,89)=.117$; $p=.890$; $\eta p^2<.005$). These results indicate that there were no differences between the groups using the Go/No-Go behavioural inhibition task.

3.2. Dot-Probe

We next ran a mixed ANOVA with the between-subject factor of group (dependent, non-dependent, and non-smoker) and a within-subject factor of stimuli-type (smoking or control stimuli). An interaction between stimulus-type and group would indicate a processing attentional bias. For fixation counts there was a significant interaction between group and stimulus-type ($F(2,86)=10.832$;$p<.0005$; $\eta p^2=.20$). There was also a significant main effect of group ($F(1,86)=4.653$; $p=.012$; $\eta p^2=.10$). But there was not a significant main effect of stimulus-type ($F(2,86)=.908$; $p=.343$; $\eta p^2=.01$), overall indicating that the groups performed differently in the task, with differing levels of processing attentional bias. A Tukey post-hoc analysis indicated that non-smokers and non-dependent smokers differed significantly in performance on the dot-probe at $p < .05$, but there was no difference between non-dependent smokers and dependent smokers. A series of paired-samples t-tests were performed to establish whether a processing attentional bias was evident in each group (see Figure 3). For the non-smokers, smoking-related stimuli ($M=1.01$; $SD=.32$) differed significantly from control stimuli ($M=1.18$; $SD=.40$, $t(31)=3.266$; $p=.003$; $d=1.17$), thus revealing an attentional bias, but the means suggest the processing attentional bias was for the control stimuli and not the smoking-related stimuli (see footnote[1]). For the non-dependent smokers, smoking-

[1] Regarding the non-smokers and the evidence for an attentional bias towards the control stimuli, as this is a type of forced choice viewing task, it may be that the participants were demonstrating attentional avoidance for the smoking-related stimuli which would lead to an increase in viewing of the control stimuli. Indeed, it has been observed (Mogg, et al., 2003) that non-smokers rated smoking-related stimuli as being significantly more unpleasant than control pictures. For a subset of our participants, we included a short questionnaire regarding the desirability of all the picture stimuli from the study on a 5-point scale. Lower scores indicated that the stimuli was undesirable and higher scores indicated desirable. Smokers ($n=20$; $M=105.05$; $SD=21.05$) and non-smokers ($n=17$; $M=66.00$; $SD=16.61$) significantly differed in terms of their ratings of desirability for smoking-related stimuli ($t(35)=-6.183$;$p<.0005$; $d = 2.09$), but not control stimuli ($t(35)=1.690$; $p=.100$; $d = .57$). Further, smokers considered smoking stimuli ($M=105.05$; $SD=21.05$) more desirable than control stimuli ($M=89.55$; $SD=16.65$, $t(19)=-2.605$; $p=.017$; $d = 1.20$). By contrast, non-smokers deemed smoking stimuli ($M=66.00$; $SD=16.61$) much less desirable than control stimuli ($M=98.71$; $SD=16.14$, $t(16)=6.656$;$p<.0005$; $d=3.33$). Additionally, smoking-related stimuli desirability and smoking dot-probe fixation counts significantly correlated ($r(34)=.383$;$p=.021$) whilst control stimuli desirability and control dot-probe fixation counts did not significantly correlate ($r(34)=-.135$;$p=.433$).These results indicate

related stimuli (M=1.40; SD=.38) differed significantly from control stimuli (M=1.29; SD=.30, t(32)=2.298; p=.028; *d* =.81). The results indicate an attentional bias in the direction of the smoking stimuli. For the dependent smokers, smoking-related stimuli (M=1.30; SD=.39) differed significantly from control stimuli (M=1.15; SD=.36, t(23)=2.384; p=.026; *d* =.99). The results show an attentional bias for the smoking-related stimuli (see Figure 3).

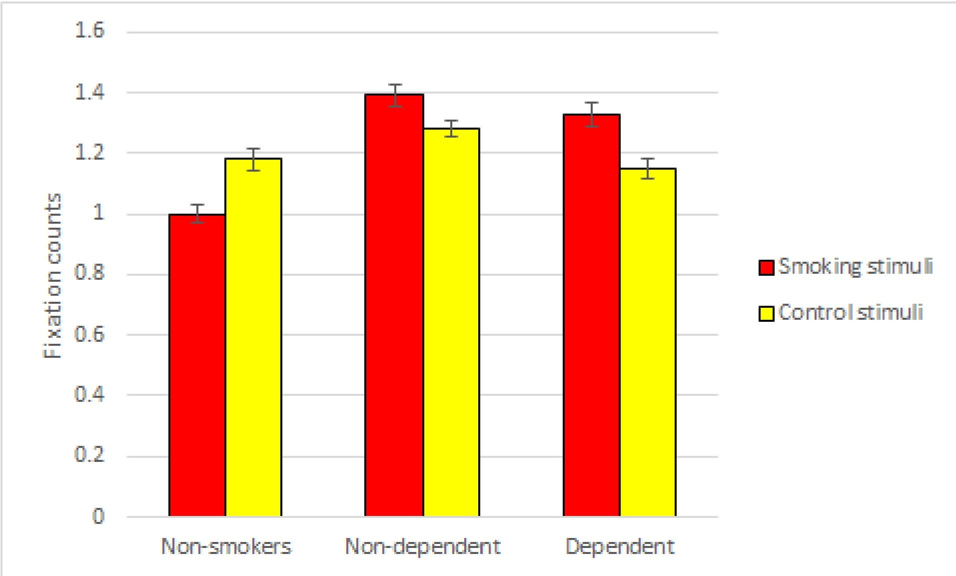

Figure 3. Dot-probe fixation counts for both smoking-related and control stimuli for each group. Error bars indicate 1 standard error of the mean.

3.3. OrBIT

For the OrBIT there was a significant interaction between group and stimuli-type (F(2,89)=3.166; p=.047; ηp^2=.07), a significant main effect of group (F(1,89)=4.994; p=.009; ηp^2=.10), and also a significant main effect of stimulus-type (F(2,89)=6.707; p=.011; ηp^2=.07). The results indicate that the groups performed differently in the task and the different stimuli-types were responded to differently. A Tukey post-hoc analysis indicated that non-smokers and non-dependent smokers did not differ significantly (p =.125) but non-smokers differed significantly from dependent smokers (at $p < .05$); a significant difference between dependent and non-dependent smokers was not found (p =.404). A series of paired-samples t-tests were performed to establish whether a top-down attentional bias was found in each group (see Figure 4). For the non-smokers, smoking-related stimuli (M=3.97; SD=3.54) did not differ significantly from control stimuli (M=3.78; SD=3.15, t(32)=-.411; p=.684; *d* =.15), that is, for this group a top-down attentional bias was not observed. For the non-dependent smokers, smoking-related stimuli (M=6.06; SD=4.59) did not differ significantly from control stimuli (M=5.79; SD=3.96;

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that the non-smokers in the attentional bias task were avoiding smoking stimuli, and this plausibly explains the attentional bias results for the non-smokers in our population sample.

t(33)=-.489; p=.628; *d* =.17), so likewise there was no evidence for a top-down attentional bias. For the dependent smokers, smoking-related stimuli (M=8.31; SD=6.03) differed significantly from control stimuli (M=6.39; SD=5.41, t(25)=-3.307; p=.003; *d* =1.32) and for this group there was evidence for a top-down attentional bias for smoking-related stimuli (see Figure 4).

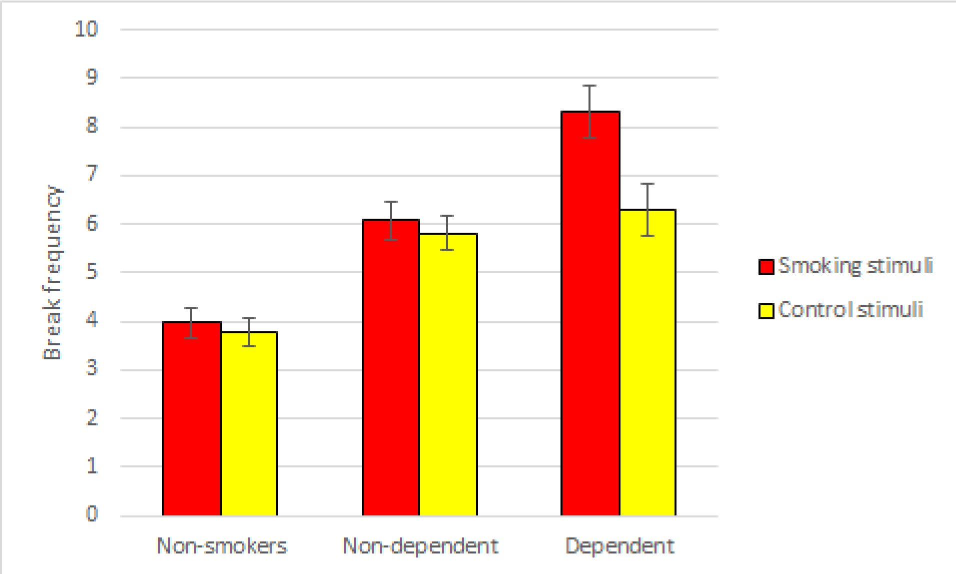

Figure 4. OrBIT break frequency for both smoking-related and control stimuli for each group. Error bars indicate 1 standard error of the mean.

4. DISCUSSION

The aim of this study was to explore smoking behaviour group differences in self-control and attentional bias of groups of smokers who engage with cigarette use differently. We found the Go/No-Go measure of self-control yielded analogous results across groups. An attentional bias for smoking-related stimuli was measured using the dot-probe for both the smoking groups, but not the control group. Critically, when an eye tracking inhibition task involving smoking-related stimuli was used (the OrBIT), there were between-groups differences. Dependent smokers had an increased top-down attentional bias (that, is decreased inhibitory control), whilst the non-dependent smokers did not demonstrate a top-down attentional bias. It therefore seems that attempting to supress attentional biases is more problematic if usage of a substance reflects dependence (see Figure 1; cf. Field & Cox, 2008). These results imply that preferential processing is observed if a stimulus is used and/or liked (cf. Robinson & Berridge, 1993), whereas measures of top-down control may be better at discriminating between dependent and non-dependent usage. Dependent smokers may have developed a goal-state of smoking because of an increased wanting to smoke, which would lead to top-down attentional bias deficits (and a corresponding attentional bias).

Whereas, non-dependent smokers may demonstrate a preference for smoking stimuli on a forced-choice attentional bias task, but show no evidence of top-down attentional bias deficit. Therefore, dependent smokers may be impaired in top-down control of behaviour for smoking-related stimuli, whilst non-dependent users, although still attracted in a bottom-up fashion to smoking-related stimuli, retain a relatively intact top-down control over behaviour.

In terms of attentional bias research in general, it would seem that the manner with which a substance is consumed is an important factor concerning the nature of attentional biases. Preferential processing may be evident for users of a substance, but impaired inhibitory control for substance-related stimuli may only be apparent for those with dependence on a substance and (we speculate) an active goal-state to consume the substance. The results may imply that cognitive bias modification programmes may be improved if they focused on inhibitory control of attention rather preferential processes. Cigarette use did differ between the dependent and non-dependent groups. Dependent users engaged in more cigarette usage. However, it is the very nature of the non-dependent smoker that they would engage in lower cigarette use than dependent users, as non-dependent users would typically only use cigarettes when they are either available or in specific contexts. Further study should aim to address this issue by obtaining a better balance between the two smoking groups. Additionally, future study would benefit from controlling for time since the last cigarette was smoked. This was found to vary between our current smoking groups as we did not want to impede normal smoking behaviours. However, it is plausible that if craving is indeed associated with attentional biases (see Field & Cox, 2008) then we would expect those who had just smoked a cigarette to have decreased cigarette craving and potentially a decrease in attentional bias for cigarette stimuli also. Therefore, in the future, it would be better to ensure smokers have abstained for a fixed amount of time before entering the lab, to control for this potentially confounding variable, or a craving measure be utilised (however, note, that including a craving measure involves exposure to smoking-related stimuli, which might interfere with the OrBIT task and the attentional bias tasks).

Regarding the attentional bias measures, it is worth noting that different attentional bias measures do not appear to correlate with each other as much as one would have expected (e.g., Pothos et al., 2009). This raises the possibility that our concept of attentional bias might in fact consist of a collection of processes, with different measures better tuned to different processes. For example, in future work, it would be worth utilising a dot-probe task with different stimulus onset asynchronies, to examine initial attentional orientation vs. sustained attention. Also, it would be worth piloting the attentional salience of the control stimuli we employed with non-smoking participants, to ensure that the results are not complicated by baseline differences in salience. In the present work, we followed standard procedure by matching smoking-related stimuli with broadly similarly looking neutral ones, but it is unclear whether such level of control is entirely adequate. A final limitation is that the actual extent of smoking might not be the most critical cause in producing attentional biases, but rather preoccupation with smoking (Klinger & Cox, 2004). Preoccupation with smoking might be a function of several factors, e.g., an early life experience with smoking, an attempt to curb smoking behaviour, or a relative with health problems related to smoking. Clearly, measuring preoccupation in some standardised way is not straightforward, still, an adequate measure in this direction might reveal insights about attentional biases over and above those obtained just from the measures based on use, which have been employed so far.

In closing, research has previously led to the suggestion that there are distinctions between dependent and non-dependent smokers in terms of inhibitory control and attentional biases. By categorising participants in this manner we were able to explore whether different substance usage behaviours were associated with both bottom-up and top-down attentional biases. It was found the dependent smokers had a top-down attentional bias for smoking-related stimuli, whereas this was not observed in the other groups. The results indicate that dependent users of a substance are impaired in inhibiting attentional biases. Previous literature offers a possible explanation for this pattern of results: we can speculate that impairment in the inhibition of attentional biases may be due to dependent users having a current concern-style for (e.g.) smoking which causes top-down attentional biases for smoking-related stimuli (current concerns are motivational states which can impact on attention; Klinger & Cox, 2004). Even though the present data do not allow us to directly support (or not) such a suggestion, there is an accumulating body of research about how increased preoccupation with substances can lead to increased top-down attentional biases (e.g. Klinger & Cox, 2004: Wilcockson & Pothos, 2015; Brown, Duka, & Forster, 2018).

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