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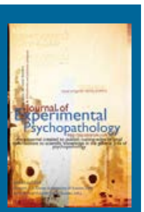

Motivational Mechanisms Underlying the Approach Bias to Cigarettes

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Abstract

Approach Avoidance tasks measure approach bias, a behavioral tendency to be faster at approaching rather than avoiding drug cues. Approach bias has been measured in a number of different drug-using populations and there is evidence to suggest that approach bias measurements correlate with drug use. Little is known, however, about the motivational mechanisms underlying the approach bias. In the current study we assessed whether the approach bias to cigarettes was immediately sensitive to changes in the incentive value of smoking. We examined the change from baseline in a participant group, after half the group had been given the opportunity to smoke. Specifically, we examined whether the approach bias has the characteristics of a cue-elicited behavior or is flexibly modulated by current desire. Results showed that while the baseline approach-bias score in deprived cigarette smokers correlated with craving, smoking a cigarette led to reduced craving but an increased approach bias score. We discuss a possible account of these findings in terms of an ideomotor outcome-response priming mechanism.

Keywords: Addiction, Approach bias, Motivation, Goal-directed Action, Habit, Ideomotor, Pavlovian-instrumental transfer.

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Introduction

One of the paradoxical, destructive characteristics of addiction is continued drug use despite explicit motivations to the contrary. Whilst in the early stages of drug use, drug-seeking actions are arguably voluntary, in some individuals this behavior becomes compulsive and problematic. Individuals who seek treatment for their addiction are often fully aware of the negative consequences and express a desire to abstain from drug use (Sjöberg & Olsson, 1981). Nonetheless, even following prolonged abstinence the risk of relapse remains high (Moos & Moos, 2006). An important factor contributing to this risk may be an ongoing approach bias, that is, the tendency to approach rather than avoid drugs and drug-related stimuli (Stacy & Wiers, 2010).

Approach bias can be measured with a variety of computerized tasks (for an overview see Watson, de Wit, Hommel & Wiers, 2012). Reaction times are measured as participants make approach and avoidance movements in response to stimuli on a computer screen. The difference in approach and avoidance reaction times for a particular picture category (e.g. smoking or neutral pictures) is taken as the bias score for that particular category, with positive difference scores indicating that the participant was faster to approach than avoid (hence, an approach bias). In the current study, smokers were asked to make approach and avoid movements to cigarette-related or neutral pictures by pulling a joystick towards them or pushing a joystick away from them, respectively. Given that pulling and pushing arm movements are relatively ambiguous, a 'zooming feature' ensured that participants experienced the illusion of approach or avoidance - the pictures became larger when participants pulled on the joystick and smaller when they pushed the joystick away from themselves (Rinck & Becker, 2007). Although a fairly abstract task, Rinck and Becker (2007) used the zooming joystick task to measure approach bias to spider pictures and showed that scores predicted approach behavior to real spiders - above that which was predicted with spider-phobia questionnaires. Similarly, using this task Wiers and colleagues showed that the amount that participants drank during a 'taste test' correlated with alcohol approach bias scores (Wiers, Rinck, Kordts, Houben, & Strack, 2010). These results suggest that approach bias as measured with this task does confer relevant information about real-life behaviors. Using a variety of approach/avoidance paradigms, addiction researchers have presented evidence for a relationship between drug approach bias and drug use, demonstrating approach tendencies in users of cigarettes, alcohol and cannabis - often relative to controls (Bradley, Field, Mogg, & De Houwer, 2004; Cousijn, Goudriaan, & Wiers, 2011; Field, Eastwood, Bradley, & Mogg, 2006; Field, Kiernan, Eastwood, & Child, 2008; Field, Mogg, & Bradley, 2005a, 2005b; Mogg, Bradley, Field, & De Houwer, 2003; Schoenmakers, Wiers, & Field, 2008; Thewissen, Havermans, Geschwind, van den Hout, & Jansen, 2007; Wiers, Rinck, Dictus, & van den Wildenberg, 2009; Wiers et al., 2010).

The central aim of the present study was to assess to what degree the approach bias is flexibly modulated by current motivational states. A number of studies have reported a correlation between approach bias and self-reported craving (Field et al., 2008, 2005b, Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008). These findings have generally been interpreted as support for the incentive sensitization model of addiction, which proposes that sensitization processes can increase craving and approach behavior elicited by drug cues even if levels of subjective pleasure decrease over the course of addiction (Robinson & Berridge, 1993, 2000, 2001).

An alternative hypothesis, however, is that appetitive approach behavior is an example of inflexible, cue-elicited responding. Various models of addiction propose that cues previously associated with drug outcomes can trigger drug-seeking behavior – either through habitual stimulus-response associations (Everitt, Dickinson, & Robbins, 2001; Everitt & Robbins, 2005; Tiffany, 1990; Tiffany & Conklin, 2000) or through Pavlovian-to-instrumental-transfer (PIT) processes (Hogarth, 2012; Hogarth & Chase, 2011). PIT refers to the process by which cue-elicited anticipation of an outcome primes the specific response that previously led to that outcome (outcome-specific PIT) or exerts a general motivating effect on responding for any reward (general PIT; Corbit & Balleine, 2005; Estes, 1948; Rescorla & Solomon, 1967). There is some evidence that the general PIT effect is abolished if the outcome is no longer motivationally relevant (e.g. if an animal is tested sated, Pavlovian cues predicting a food reward will not increase instrumental response rates for other food rewards; Corbit, Janak, & Balleine, 2007, but see also Ostlund & Balleine, 2008). In contrast, however, both S-R habits and outcome-specific PIT are insensitive to changes in outcome value and not flexibly modulated by current motivational states (Adams & Dickinson, 1981; Corbit et al., 2007; de Wit & Dickinson, 2009; Hogarth, 2012; Hogarth & Chase, 2011; Holland, 2004; Rescorla, 1994; but see Allman, DeLeon, Cataldo, Holland, & Johnson, 2010). Approach bias, therefore, could reflect a cue-elicited response that is insensitive to a reduction in incentive value of cigarettes. Indirect support of this view comes from a number of studies that have reported dissociations between craving and approach bias (Cousijn et al., 2011; Thewissen et al., 2007; Wiers et al., 2010).

Assessing the relationship between craving measures and the approach bias is one way to investigate the role of motivation in approach. The outcome reevaluation procedure we used in the current study, however, provides a more direct assessment of whether the approach bias to smoking pictures is driven by the *current* desire for cigarettes. This procedure has been developed in the field of associative learning and provides a simple yet unambiguous means of assessing the flexibility of responding for rewards. In this paradigm, behavior is assessed both before and after certain outcomes are devalued (e.g. through feeding on a particular food reward). Unlike behavior that is immediately sensitive to this reduced incentive value, the rate of habitual S-R or outcome-specific PIT responding should not be modified by this manipulation. So far, approach bias studies with such outcome-reevaluation designs have yielded mixed results. Two studies examined the effect of an alcohol dose on approach bias scores, compared to baseline scores taken when participants received a placebo drink. Both studies found that although self-reported craving had increased in the alcohol dose session, approach bias scores remained constant for alcohol pictures (Schoenmakers et al., 2008) and smoking pictures (Field et al., 2005a). These results contrast with that from another study that suggested that approach responses to food pictures were sensitive to the incentive value of the outcome (Seibt, Häfner, & Deutsch, 2007). In the latter study, measurements were taken either before or after lunch and the deprived group did show a stronger approach bias towards food pictures. Different tasks and stimuli were used to measure approach bias in these studies, a fact that may explain the differing pattern of results. Interpretation is further complicated because the study by Seibt et al. (2007) lacked a neutral control picture condition. Accordingly, it is not clear whether hunger motivated the approach movement towards food pictures specifically, or if hunger merely increased general approach tendencies.

In the current study we investigated whether the approach bias to cigarette stimuli pictures in smokers is flexibly modulated by current desire to smoke. To this end, the approach bias to smoking and neutral pictures was measured in a group of smokers abstaining from cigarettes (Session 1). Following this first AAT measurement, approximately half of the group was offered the opportunity to smoke a cigarette and the bias measurement was subsequently repeated for all smokers (Session 2). Self-report craving measures and a picture-rating task were employed as manipulation checks. If the approach bias is sensitive to current cigarette craving, we should predict that both craving scores and the approach bias to smoking pictures would be lower in the smoked-in-the-break group (compared to the deprived group). In contrast, if the approach bias is a cue-elicited response to drug-related stimuli, the approach bias at Session 2 should not differ between the two groups. As nicotine dependence has been shown to be an important factor in determining approach to cigarettes (Mogg, Field, & Bradley, 2005) we additionally compared heavy and light smokers. In addition we employed regression models at Session 1 to investigate the relationship between craving, dependence and the approach bias.

Methods

Participants

Forty-nine smokers were recruited via advertisements around campus or on the website of the University of Amsterdam. This study was approved by the Ethics Committee of the University of Amsterdam and all participants signed informed consent before participation. Participants received either seven Euros or participant credits. Participants had to smoke at least 4 cigarettes per day, be aged between 18-40 years old and remain abstinent from smoking on the morning of the test. Compliance was measured by measuring carbon monoxide (CO) levels with one of two CO meters (a *Bedfont Micro* + or a *Greisinger GCO-100*). Participants were assigned randomly to either the control group (deprived of smoking in the break) or the experimental group (smoking in the break). Sample characteristics can be seen in Table 1.

Table 1: Sample characteristics

Group		Males %	Age (years)	Hours since smoking	Years of smoking	Cigarettes per day	FTND Score	Self report Craving Session 1 (%)	Self report Craving Session 2 (%)	Difference Score Session 1 in ms [smoking bias minus neutral bias]	Difference Score Session 2 in ms [smoking bias minus neutral bias]
Did not smoke in the break	***M***	52%	24.4	13.5	5.4	10.6	2.8	60.4	71.3	-12	-34
	N	21	21	21	21	21	21	21	21	21	21
	SD		5.5	5.7	3.6	5.6	2.4	25.2	24.5	92	56
Did smoke in the break	***M***	40%	22.9	13.3	5.4	11.0	3.0	65.7	13.6	18	32
	N	28	28	28	28	28	28	28	28	28	28
	SD		4.6	3.8	2.8	3.9	1.8	24.6	18.0	93	79
Whole participant group	***M***	45%	23.5	13.4	5.4	10.8	2.9	63.4	38.3	5	4
	N	49	49	49	49	49	49	49	49	49	49
	SD		5.02	4.69	3.1	4.6	2.1	24.7	35.6	93	77

Materials

Questionnaires.

Two general questionnaires were used to collect demographic information and a detailed smoking history including questions on the number of cigarettes smoked per day, time since last cigarette, smoking years, and age of smoking onset.

Subjective craving was measured with a Likert scale (10cm long with no number markings) stating “Please indicate below how much you would like to smoke right now”.

The Fagerström Test for Nicotine Dependence (FTND) was used to measure tobacco use and dependence (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). The FTND questionnaire includes questions probing how soon after waking up people smoke their first cigarette, which cigarette of the day would be the hardest to give up, and whether or not the individual smokes on days when they are too ill to leave their bed. Scores range from 0 to 10.

Approach Avoidance Task (AAT)

Approach bias to cigarette pictures was measured with an irrelevant feature version of the zooming joystick AAT, in which participants make pushing or pulling movements on a joystick in response to pictures on screen. A zooming feature (reducing or enlarging the size of the picture on screen) ensures that participants experience the illusion of stimuli moving towards them when pulling on the joystick and away from them when pushing on the joystick (Rinck & Becker, 2007). In order to make the task less susceptible to explicit participant control, participants were asked to respond to an *irrelevant feature* of the stimuli, namely the angle in which pictures were presented, rather than the content of the picture (Cousijn et al., 2011; Wiers et al., 2010). During each trial of the AAT, a picture was shown on the screen containing a smoking-related scene or a neutral scene matched for color and composition. For example, a smoking-related picture such as an image of a cigarette and a lighter was matched with an image of a pencil and a pencil sharpener. Images of people smoking cigarettes were matched to neutral pictures of people applying lipstick or playing the flute. Each picture was presented four times, twice tilted 3 degrees to the left and twice tilted to the right. Participants were instructed to push or pull on a joystick as quickly as possible, depending on whether the picture was titled to the left or the right. Error trials were repeated and reaction times to push or pull on the joystick were measured.

Participants completed the AAT twice, with different picture sets each time containing 20 neutral and 20 smoking related pictures (80 unique pictures in total). Participants were randomly assigned to one of four (partially overlapping) picture sets for Session 1 and saw the remainder pictures at Session 2. Pictures were presented in a semi-random order (with a maximum of three similar rotations and image categories in a row). Half of the participants were told to push the joystick for pictures tilted to the left and pull for pictures tilted to the right whilst the other half of the group received the opposite instructions. The task started with 15 practice trials, consisting of a grey box in the center of the screen that was titled either to the left or the right.

Picture Rating Task

Participants were asked to rate the appetitiveness of all the pictures that they had seen during the two versions of the AAT. The 40 neutral and 40 smoking related pictures were presented in random order. Each picture was presented in the center of the screen below the text ‘When you see this picture how much do you want to smoke” and a Likert scale ranging from “not at all” to “very much”. The participant used the mouse to indicate the appetitiveness of that picture on the Likert scale and then clicked another button to move through to the next picture at their own pace.

Procedure

Testing took place between 12.00 and 17.00. Each Session took approximately 50 minutes to complete. A laptop and joystick were used for the approach bias measurement. Following informed consent, the participant was asked to fill out demographic information and the CO reading was taken. The participant was then asked to complete the Session 1 craving measure, after which the AAT was carried out. After the AAT, the participant was instructed that there would be a short break. Participants who had been assigned to the ‘smoking-in-the-break’ group were asked to choose between a Marlboro, Camel Light or Lucky Strike cigarette and were taken outside to smoke it. Participants in the ‘deprived’ group were taken outside to the smoking area for two minutes, but were not offered the opportunity to smoke. After returning to the testing room the participant’s craving was once again assessed (Session 2) after which the AAT was performed once more. After the second AAT, the participant continued with the Picture Rating Task. Finally, the smoking history and FTND questionnaires were administered.

Statistical Analyses

Error trials were discarded, as were reaction times (RTs) less than 200 ms or greater than 2000 ms, and more than 3*SD*s above or below the individuals mean (in total, 8.1% of all trials were discarded). The median RT for the ‘push smoking’, ‘pull smoking’, ‘push neutral’ and ‘pull neutral’ scores was then calculated for each participant and Session. Finally, for each picture category (smoking or neutral) an approach bias score was calculated by subtracting the median pull RT from the median push RT. A positive number indicated that the participant was faster to pull than push the joystick, indicating a positive approach bias towards that picture category. Internal reliability of the task was assessed by calculating the bias score for each image in the task and then calculating Cronbach's alpha for the smoking and neutral pictures separately. The mean Cronbach's alpha (across the 4 different picture sets) was 0.41 for the bias to smoking pictures and 0.46 for neutral pictures.

Results

Relationship between nicotine dependence, craving and approach bias - at Session 1. Multiple regression was used to assess whether smoking dependence (as indexed by the FTND score) and Session 1 craving were predictive of smoking bias scores, after controlling for neutral bias scores, at Session 1. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity (max Cook's distance = 0.48, max standard residual = 2.07). The neutral bias score was entered at Step 1, explaining 17% of the variance in the smoking bias at Session 1. After entry of the Session 1 craving and FTND scores at Step 2, the total variance explained by the model was 31%, $F(3, 45) = 6.7$, $p = .001$. The FTND score and craving explained an additional 14% of the variance in smoking bias; R squared change = .14, F change (2, 45) = 4.5, $p = .02$. In the final model, all three variables significantly explained unique variance in smoking bias. The neutral bias score recorded the highest beta value (beta = .493, $p < .001$). After controlling for other factors a higher FTND score was predictive of a weaker bias (FTND score beta = –.387, $p = .009$) whilst the relationship with self-reported craving was positive (craving score beta = .349, $p = .03$).

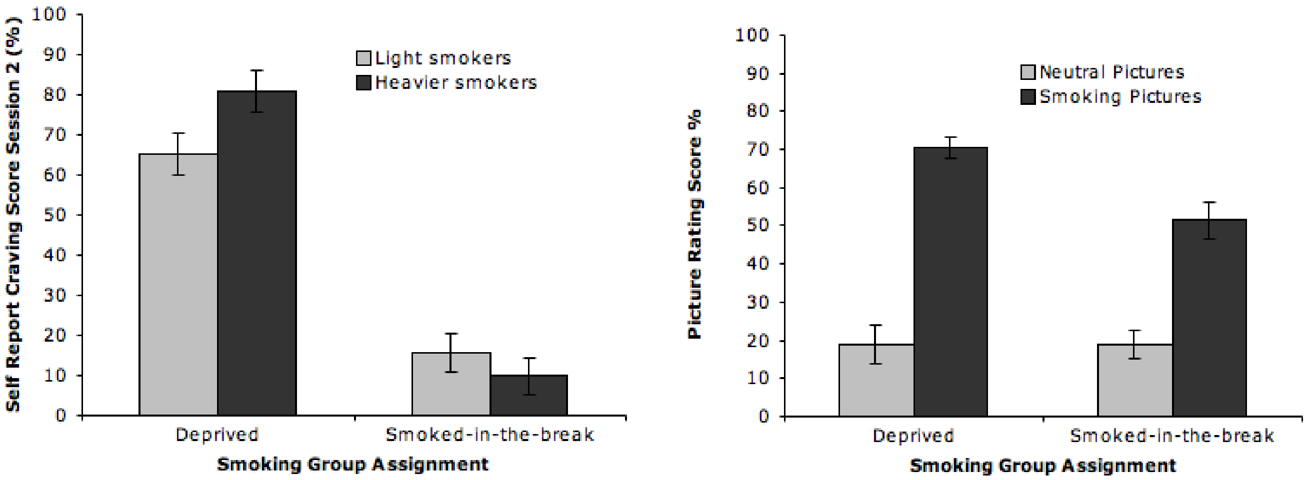

Figure 1: The left panel shows the mean craving scores at Session 2 (after controlling for craving at Session 1). The right panel shows the appetitiveness picture rating scores (at Session 2).

Effect of the smoking break on cigarette craving. In order to maximize statistical power we used ANCOVA to assess whether the satiation manipulation worked as predicted (for a discussion of the statistical advantages of this approach in experimental studies, see Van Breukelen, 2006). We entered the Session 2 Likert craving score as the dependent variable, with smoked-in-the-break (yes/no) and FTND score (high/low) as between-group factors and the Session 1 craving score as a covariate. This analysis revealed a main effect of smoking group assignment $F(1, 44) = 153$, $p < .00001$. As expected, the smoking-in-the-break group reported significantly less craving at Session 2 compared to the deprived group (effect estimate = –60, $SE = 4.8$, $p < .00001$). There was also a main effect of Session 1 craving $F(1, 44) = 17.9$, $p < .00001$, with a moderate relationship between the craving scores at the two Sessions, as indicated by a partial eta squared value of .29. There was also an interaction between smoking group assignment and FTND high/low group $F(1, 44) = 4.83$, $p = .033$, as visualized in Figure 1.[1]

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[1] Similar results were also obtained by entering the Session 1 and 2 craving scores into a mixed-design ANOVA with between-group factors of smoking group assignment (2 levels) and FTND dependence score [2 levels: high/low]. There was a significant interaction between Session and smoking group assignment $F(1, 45) = 106$, $p < .00001$. Independent t-tests revealed that while there were no

Effect of smoking group assignment on picture rating: Due to experimenter error, picture-rating data from two participants in the smoked-in-the-break group were missing from the analysis. For the remaining 47 participants we used repeated measures ANOVA on the picture rating scores with picture type (smoking/neutral) as within-subject factor and smoked-in-the-break (yes/no) and FTND score (high/low) as between-group factors. This analysis revealed a main effect of picture type $F(1, 43) = 128$, $p < .0001$, a main effect of smoking group assignment $F(1, 43) = 4.7$, $p = .036$ and an interaction between these two factors $F(1, 43) = 7.03$, $p = .011$. As can be seen from Figure 1, the mean appetitiveness rating of the neutral pictures for both smoking assignment groups was 19%, but the smoking pictures were rated significantly more positively by the deprived group (71%) compared to the smoking-in-the-break group (51%; independent t-test $t(45) = 3.1$, $p = .004$). The appetitiveness rating of the smoking pictures was thus in line with self-reported craving. Within each of the two smoking assignment groups, these two measures were marginally correlated (deprived group $r = .42$, $p = .060$; smoking-in-the-break group $r = .38$, $p = .055$).

The effect of smoking satiety (or 'cigarette reevaluation') on the approach bias: We used ANCOVA to assess whether smoking a cigarette reduced the approach bias towards cigarette pictures. First we calculated a difference score for both Sessions 1 and 2 by subtracting the neutral bias score from the smoking bias score, such that positive scores indicate that participants showed an approach bias to smoking relative to neutral pictures (see Table 1 for approach bias difference scores). We also calculated a median split on the FTND scores (median = 3) to create high/low smoking dependence groups (same median as in Mogg et al., 2005). These two groups were evenly split across the smoking group assignments (smoked in the break group: 46% light smokers; no smoking in the break group: 52% light smokers). The two groups did not differ in age, years of smoking, or hours since smoking, but the group with the higher FTND scores smoked significantly more cigarettes per day (13.5) than the low FTND group (8.0 per day); $t(47) = 4.7$, $p < .001$.

We entered the approach bias difference score at Session 2 as the dependent variable, with smoked-in-the-break (yes/no) and FTND score (high/low) as between-group factors and the difference score at Session 1 as a covariate. This analysis revealed a significant main effect of smoking group $F(1, 44) = 8.904$, $p = .005$, but no effects of FTND group, Session 1 difference score nor any significant interactions (all *p*s > .14). Contrary to expectations, at Session 2 the smoked-in-the-break group showed a stronger approach bias to smoking pictures than the deprived group (effect estimate 62 ms, *SE* = 20 ms, $p = .005$; see Figure 2).[2]

Effect of smoking group assignment on general reaction times: To ensure that nicotine did not have an effect on general RT, we examined the median 'push' and 'pull' RT for each participant and Session. Repeated measures ANOVA with independent variables of Session (2 levels) and direction of movement (2 levels: push/pull) and between-group factor of smoked in the break yes/no revealed a significant main effect of Session only, $F(1, 47) = 58$, $p < .00001$- crucially no main effect of, nor significant interactions with, smoking group assignment; all *p*s > 0.23.

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group differences at Session 1, $t(47) = < 1$, $p = .46$, at Session 2 craving was significantly less in the group who had just smoked a cigarette compared to the deprived group, $t(47) = 9.5$, $p < .000001$ (Table 1 contains descriptive statistics of craving scores at both sessions for both smoking-assignment groups).

[2] Similar results were also obtained by entering the approach bias difference scores at Sessons 1 and 2 into a mixed-design ANOVA with between-group factors of smoking group assignment (2 levels) and FTND dependence score [2 levels: high/low]. This analysis revealed a main effect of smoking group assignment, $F(1, 45) = 6.63$, $p = .013$, but no interaction with Session ($p = .23$). Nonetheless planned comparisons (independent T-tests) revealed that this main effect was driven by the group difference at Session 2 where the smoked-in-the-break-group showed a significantly stronger approach bias to smoking-related stimuli compared to the deprived group, $t(47) = 3.25$, $p = .002$. There was no difference between the two groups at Session 1, $t(47) = 1.14$, $p = .26$ (Table 1 shows descriptive statistics of approach bias scores at both sessions, for both smoking-assignment groups).

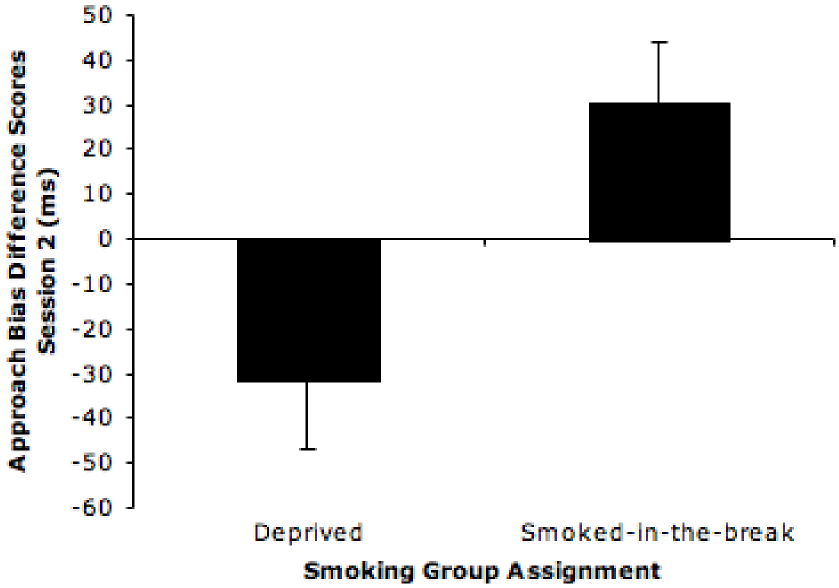

Figure 2: The approach bias difference scores at Session 2 (after controlling for approach bias scores at Session 1). A positive score indicates that participants were faster to approach smoking compared to neutral pictures.

Discussion

The aim of this study was to assess whether approach behavior towards cigarettes in smokers is flexibly modulated by the current incentive value of cigarettes or is an inflexible, cue-elicited response. At the baseline measurement we replicated earlier demonstrations that self-reported craving is a positive predictor of the approach bias, while level of nicotine dependence is a negative predictor (Mogg et al., 2005). Following the outcome-reevaluation procedure however, the approach bias was unexpectedly *stronger* in the group who had just smoked a cigarette, compared to the control group. The implications of these results will be discussed in the remainder of the discussion.

If the approach bias would be consistently elicited by drug-related cues that have gradually become associated with drug reward in real life, we could expect it to be stronger in heavier users. However, at Session 1 we found that nicotine dependence scores (FTND; Heatherton et al., 1991) were a *negative* predictor of the strength of the approach bias to cigarettes in deprived smokers. Using an irrelevant-feature version of the AAT, we therefore replicated prior research with a feature-relevant manikin task suggesting that lighter smokers show a stronger approach bias than heavy smokers (Mogg et al., 2005). This suggests that the approach bias is capturing the incentive salience of drug cues, which may be stronger in the early phases of addiction (Everitt & Robbins, 2005; Hogarth, Mogg, Bradley, Duka, & Dickinson, 2003; Mogg et al., 2005). Furthermore, we found that after controlling for nicotine dependence scores, self-reported craving was a positive predictor (Bradley et al., 2004; Field et al., 2005a; Van Gucht et al., 2008). These results suggest, therefore, that the approach bias is not merely a cue-elicited response but is sensitive to the current value of the cigarettes – in line with incentive sensitization theories of addiction (Berridge, 2007).

This study used an outcome-reevaluation procedure (namely, a cigarette break between Session 1 and 2) to assess whether the approach bias is flexibly modulated by motivation. As highlighted previously, three studies that have previously used an outcome reevaluation paradigm to assess changes in approach bias scores, have yielded mixed results (Field et al., 2005b; Schoenmakers et al., 2008; Seibt et al., 2007). We found at Session 2 that the approach bias was stronger in the group who had just smoked cigarettes, suggesting a degree of flexibility to the approach bias that is not in line with a habitual S-R account of the approach bias. This finding of an increase was surprising, especially in light of the negative effect of the reevaluation procedure on self-reported craving and cigarette picture ratings. We discuss, below, the possibility that the increased bias is the result of an ideomotor 'priming effect' related to the recent exposure to the smoking outcome. We also outline considerations for future research into the effects of satiety on approach bias measurements.

The Session 2 AAT measurement was taken minutes after participants in the smoking group had experienced the (presumably pleasant) smoking outcome. Many animal studies have demonstrated that consumption of a reward can act to prime the response that previously yielded that reward (as reviewed by Stewart & de Wit, 1987). This is usually within the context of reinstatement paradigms, in which small amounts of reward are administered to examine reacquisition of a previously extinguished response (e.g. Ostlund & Balleine, 2007). This effect is thought to be mediated by a primed outcome-response association and it is noteworthy that this effect has been observed even in satiated animals (Eiserer, 1978; Ostlund & Balleine, 2007). Konorski (1967) famously described this as the "salted peanut" phenomenon, based on the observation that even in the absence of desire, after eating one peanut an individual is compelled to keep eating them. A number of studies have also investigated the ideomotor priming effect in humans and shown that outcomes that have no motivational significance, can prime the responses that previously led to them (Elsner & Hommel, 2001; Hommel, Alonso, & Fuentes, 2003). In the current study, the satiety induced by smoking one cigarette may not have been sufficient to counteract this outcome-response priming effect through exposure to cigarettes, leading to a relatively strong approach bias in the smoked-in-the-break group.

It should be noted that this priming effect was only observed in the current study using ANCOVA - the mixed-design ANOVA did not reveal a significant interaction between Session and smoking-group assignment (though planned comparisons did reveal that the main effect of smoking-group assignment was driven by the group difference at Session 2). Given that participants were assigned randomly to either the experimental or control group, ANCOVA offers more statistical power when assessing group differences at Session 2. Unlike ANOVA, the ANCOVA does not contain a redundant parameter in the model – the pretest variability between the groups - and is thus a more efficient approach (Van Breukelen, 2006). Nonetheless, replication studies may benefit from including larger participant groups when investigating this priming effect.

Future research should determine whether smoking multiple cigarettes *does* lead to a reduction of the approach bias, or perhaps whether a certain amount of time is required to elapse after smoking a cigarette in order to observe complete satiation. Although participants in the smoked-in-the-break group reported reduced desire for cigarettes after smoking, there was considerable variation within the group. A less explicit measure of satiation could also be used (e.g. giving participants the opportunity to freely respond to gain cigarette rewards until they no longer do so) in order to better assess how individual differences in satiation may affect the measurement of approach bias after smoking. In addition, the control group in the current study was exposed to smoking cues during the break but were not offered the opportunity to smoke, which may have further increased their cigarette craving – this group could be compared in the future to a control group who are not exposed to any smoking cues during the break.

Outcome reevaluation paradigms require that the crucial choice test after reevaluation be carried out in extinction (no presentation of the outcome contingent on responding). The rationale for this procedure is to ensure that responding reflects the associations established during training (and that any reduction in responding is not due to experience with the now devalued outcome). In fact, habitual responses *have* been shown to be sensitive to outcome reevaluation if participants experience the (now devalued) outcomes on each trial (Klossek, Russell, & Dickinson, 2008). In the current study, the stimuli of interest were presented as antecedent triggers and were not contingent on a response (Adams & Dickinson, 1981). It could, however, be argued that the zooming feature in the current task provides some modest feedback to the participant (although it is unlikely that this would drive a satiety effect). The advantage of the zooming feature is that the perceptual feedback reduces ambiguity of the arm movements – however on the flip side, the participant is receiving some (limited) feedback contingent on their responses and as such, future studies could address the effect of this task feature on responding following satiation.

An alternative account of the current set of results could look to a moderating factor (such as increased reward sensitivity following nicotine exposure), to explain the fact that smoking increased the approach bias. Unfortunately, however, a lack of research in this field renders these suggestions speculative. For example, although nicotine is argued to increase sensitivity to reward (Chaudhri et al., 2006; Kenny & Markou, 2006; Zachariou et al., 2001), little is known about how reward sensitivity moderates approach bias scores. A better understanding of how various moderating factors such as reward sensitivity or impulsivity affect approach bias measurements would be beneficial.

In the current study, we focused on differentiating between a number of dominant accounts in the literature- namely the habit or outcome-specific PIT accounts on one hand and the incentive sensitization model of addiction on the other. It should be noted that, in line with the latter, expectancy models of addiction would also predict that the approach bias would be flexibly modulated by the current value of smoking - as drug-seeking is argued to be a goal-directed choice based on the expected positive effects of smoking (Goldman, 2002; Goldman, Brown, & Christiansen, 1987). It is unfortunately not possible to fully disentangle the motivational mechanisms that underlie approach behavior using this task, given that a number of behaviors are sensitive to outcome reevaluation - namely Pavlovian conditioned approach responses (Colwill & Rescorla, 1988), goal-directed behavior (Adams & Dickinson, 1981) and possibly general PIT (Corbit et al., 2007) while, as discussed previously, S-R habits and outcome-specific PIT processes are not. Although the current paradigm is not able to differentiate between all of these possibilities, the results of this study go somewhat towards addressing outstanding questions regarding whether the approach bias is sensitive (or not) to outcome-reevaluation. The dissociation observed between cigarette craving and the cigarette approach bias at Session 2, suggests that the approach bias can be elicited regardless of the current incentive value of cigarettes. In this case, however, this appears to be more than a simple S-R habit and instead the current results may be best explained as an ideomotor O-R priming effect, following the exposure to cigarette smoking.

The approach-avoidance task has not only been used to investigate approach tendencies, but also as a clinical tool to manipulate the approach bias. Two studies have now shown that joystick re-training (repeatedly pushing on a joystick in response to alcohol cues) reduces the alcohol approach bias and leads to an immediate reduction in amount of alcohol consumed by students (Wiers et al., 2010) and to increased abstinence up to one year after treatment for alcoholism in patients (Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011). By understanding the motivational mechanisms that underlie the approach bias, we may ultimately gain a better understanding of the treatment effects of approach bias retraining and possibly refine this as a treatment strategy.

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