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Visual Search for Smoking Stimuli: Detection and Distraction

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by

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Abstract

Extensive research has shown that the attentional systems of addicted individuals are biased towards drug-related stimuli, but despite several decades of effort these results have frequently been inconsistent. Though commonly believed to result from addiction and dependence, cognitive research would suggest that frequent exposure to drug-related stimuli could affect the attentional processing of drug-related cues even if no actual drug use occurs. The present investigation examined attentional bias for smoking cues using a novel visual search paradigm amongst smokers currently in nicotine withdrawal and fully satiated smokers, as well as a non-smoker control group. Variables related to smoking behavior, as well as exposure to smoking stimuli independent of drug use were examined as predictors of task performance. Results revealed that participants were faster to detect smoking cues amongst a grid of distracting images relative to neutral cues, but that this effect was not specific to smokers. No consistent pattern emerged when smoking cues were used as distractors, indicating that attentional bias mainly operated to facilitate initial orienting to smoking cues on this task. Smoking-behavior variables were not associated with task performance. However, the amount of environmental exposure to smoking stimuli was strongly associated with performance, independent of smoking status. As environmental exposure has not been directly assessed in prior research on attentional bias, this raises questions about the interpretation of previous findings including the notion that it accurately taps constructs directly related to drug dependence. Future research should determine if exposure serves as an equally powerful predictor across traditional measures of attentional bias. If so, theoretical work should be reformulated to account for the notion that attentional bias may not develop as a result of addiction, though may still play a role in maintaining addictive behavior.

Introduction

In light of evidence that drug cues serve as a precipitant to relapse (Shiffman, Paty, Gnys, Kassel, & Hickcox, 1996), research on the role of drug cues in the development, maintenance and cessation of addictive behaviors has expanded rapidly over the past two decades (e.g. Carter & Tiffany, 1999). However, failure to consistently tie drug-cue reactivity, at least as it has typically been studied, to behavioral outcomes of interest has led to debate about the clinical relevance of such research (Perkins, 2009; Shiffman, 2009; Shoaib, 2009; Tiffany & Wray, 2009). One possible reason for this lack of consistency is the failure to account for the role of cognitive processing in studies of cue reactivity (Tiffany, 1999). Indeed, contemporary theories of addiction have increasingly emphasized the role that cognition may play in driving addictive behavior, including responses to drug cues (Franken, 2003; Kavanagh, Andrade, & May, 2005; Robinson & Berridge, 1993, 2000, 2003; Ryan, 2002b; Tiffany, 1990; Wiers et al., 2007). One of the earliest of these models, the incentive-sensitization theory, posited that with repeated use, drugs of abuse become ñwantedò and cues associated with prior drug use are able to grab the attention of the dependent user. They suggest it is this ñwantingò that drives continued drug use despite the frequent negative consequences and diminished hedonic value of drugs associated with long-term use. This theoretical advance contributed heavily to the development and proliferation of research on attentional bias for drug cues.

Attentional bias is defined as the notion that drug-related stimuli are capable of both grabbing and holding the attention of drug users, independent of conscious control (Field & Cox, 2008; Waters & Sayette, 2006). In addition to attentional biasô potential to serve as an index of the subconscious ñwantingò process described previously, additional theories have been formulated that address it explicitly. One such model suggests that attentional bias for drug cues can increase craving by enhancing processing of a drug cue, increasing the likelihood of detecting new cues, increasing drug related cognitions, and limiting attentional resources for alternative cognitions (Franken, 2003). Another has incorporated research on attentional subcomponents (see LaBerge, 1995), and identified separable roles for each in the onset and maintenance of craving and drug use (Ryan, 2002). Attentional bias has also been suggested to have a role in the development of dependence itself, particularly in adolescents whose underdeveloped executive systems may be unable to override appetitive motivational forces (Wiers et al., 2007). At present, these models are largely theoretical, though potential clinical utilities for research on attentional bias have begun to emerge.

One example of potential clinical utility is the development of interventions directly targeting attentional bias to aid attempts to control drug use. Cognitive bias modification programs have been tested across a number of disorders (e.g. Koster, Fox, & MacLeod, 2009). Specific to addiction, modification of drug-related attentional bias has been shown to result in reduced craving in response to smoking cues (Attwood, O'Sullivan, Leonards, Mackintosh, & Munafo, 2008), reductions in alcohol consumption amongst heavy drinkers (Fadardi & Cox, 2009), and greater time to relapse amongst patients in alcohol recovery (T. M. Schoenmakers et al., 2010). Unfortunately, not all interventions targeting attentional bias have had positive outcomes (Field, Duka, Tyler, & Schoenmakers, 2009; McHugh, Murray, Hearon, Calkins, & Otto, 2010; T. Schoenmakers, Wiers, Jones, Bruce, & Jansen, 2007). Even in the event modification of attentional bias does not prove to be a plausible treatment strategy, attentional bias may still predict treatment outcome (W. M. Cox, Hogan, Kristian, & Race, 2002; Marissen et al., 2006; Powell, Dawkins, West, & Pickering, 2010; Spiegelhalder et al., 2011; Waters et al., 2003). Measurement of attentional bias in treatment-seeking smokers could potentially aid treatment selection and tailoring.

Measurement of Attentional Bias

A number of tasks for assessing attentional bias for drug cues have been employed to date (for reviews, see Field & Cox, 2008; Waters & Sayette, 2006). The earliest work on this topic used a modified version of the Stroop task, where participants are presented with a series of words in color print from both drug-related and neutral categories (e.g. Drobes, Elibero, & Evans, 2006; Gross, Jarvik, & Rosenblatt, 1993; Waters & Feyerabend, 2000). Addicted individuals tend to be slower at naming the color print of words related to their addiction, relative to words from a neutral category (W. M. Cox, Fadardi, & Pothos, 2006). However, test format appears to play a critical role, with blocked formats enhancing effect sizes, presumably due to carry-over effects (Waters, Sayette, Franken, & Schwartz, 2005), thus clouding interpretation.

Given the limitations of the Stroop task, the potential utility of various other measures of attentional bias have been explored. Foremost among these is the visual-probe (dot-probe) task, where two images are presented simultaneously on a computer screen, followed immediately by a cue (response probe) that replaces one of the images (Field & Cox, 2008). By comparing reaction time on trials where participants respond to a drug-related image relative to trials where they respond to a neutral image, inferences can be made about the spatial allocation of attention. Given evidence that motivational salience may play a particularly important role in the maintenance of attention (LaBerge, 1995) researchers have also modified the presentation time of the images to distinguish between initial orienting and maintenance subcomponents of attention (Bradley, Mogg, Wright, & Field, 2003). Unfortunately, the visual-probe only truly measures where attention is allocated at picture offset which, similar to the Stroop, has resulted in some ambiguity surrounding interpretation of attentional subcomponents (Bradley, Field, Mogg, & De Houwer, 2004; Bradley, et al., 2003; Robbins & Ehrman, 2004). Recently, researchers have also begun to express concerns about the reliability of this task (Munafo, Adams, Alaya, & Mullings, 2011, February; Schmukle, 2005). Other established paradigms for assessing attentional bias in addiction include flicker paradigms (Jones, Jones, Smith, & Copley, 2003), attentional blink (Chanon, Sours, & Boettiger, 2010), dual-task paradigms (Sayette et al., 1994), and passive viewing (Bonitz & Gordon, 2008).

Visual search paradigms, where participants are asked to locate a particular type of image embedded amongst irrelevant ĩdistractoròimages, have been adapted to assess attentional bias for both anxiety and eating disorders (e.g. Hollitt, Kemps, Tiggemann, Smeets, & Mills, 2010; Lobue & DeLoache, 2008; Ohman, Flykt, & Esteves, 2001; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005; Smeets, Roefs, van Furth, & Jansen, 2008), but have not yet been used to study drug-related attentional bias. Though typically used to assess negatively-valenced (threatening) stimuli, recent evidence indicates effects may be driven by biological relevance of the stimuli, not emotional valence (Brosch, Sander, & Scherer, 2007). This raises the possibility that similar effects might be observed for stimuli with acquired biological relevance and high degrees of motivational salience, such as drugs of abuse. Failure to adapt such tasks for the study of drug-related attentional bias is unfortunate, because such tasks differ from traditional approaches in potentially critical ways. As with working memory load (Evans, Craig, Oliver, & Drobes, 2011), perceptual load may play an important role in the emergence of biases in visual attention and visual search tasks allow for greater taxation of perceptual load than traditional measures. Relatedly, greater perceptual load may better reflect the complexity of real-world environments and effects on paradigms of this type may have stronger associations with actual behavior. Visual search tasks also require active processing of stimuli content rather than passive (as in the visual-probe) or suppression (as in the stroop, see Klein, 2007). Finally, independent manipulation of both target types and distractor types allow for unambiguous differentiation of attentional subcomponents.

Common Associates of Attentional Bias

A number of drug-use variables have been identified as potential moderators of attentional bias. In accordance with theoretical models that posit attentional bias and craving may have a mutually excitatory effect on one another (Franken, 2003; Ryan, 2002), a recent meta-analysis concluded there is a weak, but significant correlation between these two variables (Field, Munafo, & Franken, 2009). Others have documented elevation of attentional bias by abstinence/withdrawal (Field, Mogg, & Bradley, 2004; Gross, et al., 1993; Leventhal et al., 2007; Waters & Feyerabend, 2000), as well as positive associations with frequency of drug use (Field, Mogg, Zetteler, & Bradley, 2004; Sharma, Albery, & Cook, 2001; Townshend & Duka, 2001; Yeomans, Javaherian, Tovey, & Stafford, 2005). Attentional bias may also be related to motivation to quit or current treatment status, with cognitive biases existing primarily in those with a current desire or plans to quit (Noel et al., 2006; Stormark, Field, Hugdahl, & Horowitz, 1997;

Vadhan et al., 2007). Similar effects have been documented for craving and other measures of cue-reactivity (Dempsey, Cohen, Hobson, & Randall, 2007; McDermut & Haaga, 1998).

Although the majority of literature on drug-related attentional bias has understandably focused on drug use behavior as the underlying cause, some have also suggested a potential role for mere familiarity (Ryan, 2002a). This is not surprising in light of cognitive research indicating differential processing of familiar and novel stimuli (Malinowski & Hubner, 2001; Mruczek & Sheinberg, 2005; Wang, Cavanagh & Green, 1994), but has remained an area of limited study within the addictions field. Researchers have also began to consider the possibility that attentional bias effects may depend in part on individual differences and state-dependent influences on cognitive control more generally (Field, Wiers, Christiansen, Fillmore, & Verster, 2010). Though work on this topic within addiction has been limited research in other areas of psychopathology has demonstrated moderation of attentional bias effects by cognitive control (Derryberry & Reed, 2002; Eysenck, Derakshan, Santos, & Calvo, 2007; Pessoa, Kastner, & Ungerleider, 2002).

Current Study

Given the prominent role of attentional bias in contemporary addiction theory, evaluation of new attentional bias paradigms may help identify reasons for inconsistent findings, leading to a better understanding of the causes and consequences of attentional bias. Attentional bias effects may depend heavily upon the particular attentional subcomponent being examined, so it will be particularly critical that newly developed tasks are able to properly differentiate the initial orienting response (or *detection*, as it is commonly called in visual search tasks) from the maintenance of attention (or *distraction*). The purpose of the present study was to adapt a version of a visual search tasks that is commonly used to assess attentional bias within the literature on anxiety and eating disorders for use in the addiction field, and to evaluate potential mediators and predictors of attentional bias effects. The following hypotheses were made: 1) Smokers will exhibit greater attentional bias for smoking cues, and this effect will be further exacerbated by withdrawal, 2) Differences in attentional bias amongst smokers will be mediated by current craving and withdrawal, and 3) Attentional bias will be associated with smoking-behavior, smoking-exposure, and cognitive variables. Specifically greater nicotine dependence, motivation to quit, pack-years, familial smoking history, environmental smoke exposure, and lower attentional control will all predict larger attentional bias effects.

Method

The present study employed a 3 (Group: Non-smokers, Satiated Smokers, Deprived Smokers) x 2 (Trial Type: Smoking, Neutral) design. This design will be applied to both detection and distraction indices on an attentional bias task, across both primary (reaction time) and secondary (accuracy) indices of performance.

Participants and Procedures

Participants were 106 adults (70 smokers, 36 non-smokers) recruited from the Tampa Bay community via online advertisements, flyers, and an existing participant database (see Table 1 for sample characteristics). All participants were between 18 and 55 years of age, able to speak and read English fluently, not currently pregnant or breastfeeding, had normal or corrected vision, and were free from any ocular diseases or other visual deficits (e.g. color-blindness). Smokers had to 1) smoke a minimum of 10 cigarettes per day for at least 2 years, 2) be free from any smoking-related illnesses, 3) not be actively trying to quit or have made a quit attempt in the past 6 months, and 4) report no use of smoking cessation products or medication in the past month. Non-smokers were required to have smoked fewer than 100 cigarettes in their lifetime with no history of a regular smoking pattern (regardless of rate) at any point in their life.

Participants who were eligible based off a telephone screening were scheduled to attend an initial laboratory session individually, or in small groups. After providing informed consent and photo identification to confirm their age and identity, participants completed a series of baseline questionnaires. All participants completed a demographic form and a trait measure of attentional control. Smokers completed additional forms about their smoking behavior, including measures of dependence, smoking history, and current motivation to quit. Participantsôsmoking status was confirmed with expired-air Carbon-Monoxide (Vitalograph; Lexington, KY). In accordance with established guidelines, non-smokers were required to have a CO Ò8 ppm, and smokers were required to have a CO Ó10 ppm (Benowitz et al., 2002). Prior to scheduling their second appointment, smokers were randomized to either abstain from smoking for 12 hours prior to their second session, or continue smoking *ad libitum*. Randomization was stratified by sex and smoking rate (Ò20 or > 20 cigarettes per day). Sample characteristics are presented in Table 1.

At the second session, all participants provided an additional expired-air Carbon Monoxide sample. Criterion for eligibility were identical, except smokers randomized to the 12-hour deprivation group were required to have a CO < 10 ppm or half the value of their CO level at the initial session, whichever was higher. Participants were also required to have a blood-alcohol level of zero, confirmed by an Alco-Sensor FST (Intoximeters; St. Louis, MO). To control for exposure to smoking-related information, all participants (including non-smokers) completed measures of nicotine withdrawal and craving to smoke. In order to standardize the time since last cigarette, smokers randomized to the *ad libitum* smoking condition were then required to smoke a cigarette in the laboratory. To control for time, non-smokers and smokers in the 12-hour deprivation condition were provided magazines and instructed to relax during this time period while the computer task was configured. After this time period ended, participants were taken to a second room and seated 60 cm from a 19-inch LCD computer monitor. Participants were given instructions for the task (described below), and completed a series of practice trials under experimenter guidance. After completing the practice trials successfully (66.6% minimum criterion), but before beginning the experimental trials, all participants completed measures of craving to smoke and withdrawal a second time. Once experimental trials were complete, participants completed interviews assessing their family smoking history and environmental tobacco smoke exposure. Participants were paid a total of $30 for participating, and all procedures were approved by the University of South Florida Institutional Review Board.

Measures

All scale scores employed exhibited adequate to excellent internal consistencies in the present sample (Ŭĉs Ó0.85) with the exception of nicotine dependence measures, which were comparatively weaker (FTND Ŭ= .649; NDSS Ŭ= .697). All participants provided basic demographic information (Appendix A) in addition to completing the below measures.

Smoking-Behavior Measures. At the initial session, participants reported the age they began smoking, number of previous quit attempts, and other single-item smoking history measures (Appendix B), as well as a continuous, single-item measure of motivation to quit smoking (Biener & Abrams, 1991; Appendix C). Participants also completed the Nicotine Dependence Syndrome Scale (NDSS), a 19 item, multi-dimensional measure of nicotine dependence that consists of five factors: Drive, Priority, Tolerance, Continuity, and Stereotypy (Shiffman, Waters, & Hickcox, 2004; Appendix D). The Fagerström Test of Nicotine Dependence (FTND) was completed for purposes of sample description, and comparison with earlier studies (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991; Appendix E).

At the second session, participants reported their current level of nicotine withdrawal using the Wisconsin Smoking Withdrawal Scale (WSWS), a 28-item measure of nicotine withdrawal that consists of 7 subscales (anger, anxiety, concentration, craving, hunger, sadness, and sleep; Welsch et al., 1999; Appendix F). Craving was assessed using the Questionnaire on Smoking Urges ï Brief (QSU-B), a 10 item measure of craving to smoke (L. S. Cox, Tiffany, & Christen, 2001; Appendix G).

Smoking-Exposure Measures. In addition to measures of smoking behavior, two interviews were conducted by trained raters to assess exposure to smoking by others. The Family Smoking Index (FSI) was used to assess familial smoking, including both environmental and genetic components (Drobes, Munafo, Leigh, & Saladin, 2005; Appendix H). The proportion of smokers among all known first and second-degree blood relatives is calculated, weighted accordingly (.66 for 1^{st}-degree relatives, .33 for 2^{nd} ï degree relatives) and summed. Overall environmental exposure was assessed using a modified version of the Environmental Tobacco Smoke Exposure interview (Cummings, Markello, Mahoney, & Marshall, 1989; Appendix I). Participants provided information on passive smoke exposure from household members and work settings throughout their lifespan, including both years of exposure and severity (rated from none to heavy on a 0-3 scale based on the frequency and proximity of othersô smoking). For reliability purposes, only exposures of one year or more are included. Exposure to oneòs own smoke was not included. This information is used to arrive at an overall estimate of exposure for three discrete categories ï childhood household, adulthood household, and workplace. Years of exposure and severity are then multiplied within each category to produce subscale scores for each category, and summed for an overall index.

Cognitive Measures. All participants completed the Attentional Control Scale (ACS), a continuous, 20-item measure of attentional control comprised of two factors: attention-focusing, and attention-shifting (Derryberry & Reed, 2002; Appendix J).

Attentional Bias Task

Attentional bias was assessed using an adaptation of an odd-one-out visual search task that has previously been used to examine attentional bias in other forms of psychopathology (e.g. Rinck et al., 2005, Smeets et al., 2008). On each trial, participants were presented with a centrally-located fixation cross for 500 ms, followed immediately by a 5 x 4 matrix of 20 images. Images belonged to one of three different categories: 1) Smoking (e.g. cigarettes), 2) Office Supplies (e.g. pens, pencils), and 3) Toiletries (e.g. toothbrushes). Participants had up to 20 seconds to respond to whether all pictures were from a single category, or one image from a deviant category was embedded amongst 19 images from another category. Participants responded by pressing a button on a response box, with left vs. right button position counter-balanced across participants. Deviant images were presented once in each of the 18 possible locations for all category combinations, never occurring in the two locations immediately above or below the fixation cross. Images consisted of the stimulus of interest overlaid on a simple background, and were selected based on extensive pilot testing to balance images on perceptual characteristics (color, brightness, clarity) as well as the ease with which the objects could be identified and sorted into the appropriate category. After creating an initial set of 60 images that were matched across categories, ten participants sorted the images into categories as quickly as possible, then rated each image on the aforementioned characteristics using a 1-7 scale. Images that deviated substantially from the matches in other categories were altered or replaced. This process was repeated two additional times before the final image set was reached.

The attentional bias task consisted of 18 practice trials, followed by a total of 216 experimental trials (50% target-present trials) presented in a pseudo-random order, with a 1 second inter-trial interval. Trials were divided into two blocks, with a 60 second rest period between blocks. The task was scripted in Superlab 4.0 and participants responded using an RB-730 response box (Cedrus Corporation, San Pedro, CA).

Previous work employing this task has emphasized reaction time as the primary performance index, though accuracy is also recorded and serves as a secondary index in the present study. Within each index, separate scores can be derived by aggregating data for each target-distractor combination. Biased detection (i.e. initial orienting subcomponent) of a cue is determined by comparing trials with different target categories but the same distractor category (e.g. speed and accuracy of responding to a target smoking cue relative to a target office supply cue, each embedded amongst toiletry distractors). Similarly, biased distraction (i.e. maintenance subcomponent) of a cue is determined by comparing trials with the same target category, but different distractor categories (e.g. the speed and accuracy of responding to target office supply cues when embedded amongst smoking cue distractors relative to toiletry distractors). Composite scores for both detection, distraction, and neutral trial types can also be calculated by aggregating data across both target-distractor combinations that make up each type (e.g. smoking detection composite score combines data from smoking targets embedded amongst office supply distractors, and smoking targets embedded amongst toiletry distractors).

Data Processing and Analysis

Prior to aggregating data for individual trials, trials on which the participant failed to respond, and trials with reaction times faster than 150 ms or larger than ± 3 SDs from the individual trial-type (target-present and target-absent) mean were removed from the dataset (< 8.6% of data). Accuracy and correct-response reaction time data were then aggregated separately for each target-distractor combination, as well as the composite scores. Following aggregation, a signal detection approach (Macmilan & Creelman, 2005) was used to transform raw accuracy scores to a sensitivity index (A′), a non-parametric measure of accuracy correcting for response bias.

Comparisons on key demographic variables were done using a series of univariate ANOVAs with uncorrected post-hoc tests for continuous variables. A comparable method with chi-square analyses was used for dichotomous variables. Mixed-model ANOVAs were used to examine group differences on withdrawal and craving and confirm the efficacy of the deprivation manipulation. Task performance was also assessed using mixed-model ANOVAs with group (non-smoker, satiated smoker, deprived smoker) as the between subjects factor and target type (smoking, neutral) as the within-subjects factor. Separate models were run for each composite score, as well as individual target-distractor combinations. Predictors of the primary index of task performance (reaction time) were assessed using hierarchical multiple regression. Potential predictors included smoking-behavior variables (nicotine dependence, craving, withdrawal, pack-years, current motivation to quit), smoking-exposure variables (environmental tobacco smoke, family smoking index) and cognitive variables (attentional control). Predictor and group status interactions were also examined to determine if predictors differed significantly across groups. Each predictor was tested individually against both detection and distraction scores, with group status dummy-coded and entered into the first block, the predictor of interest into the second block, and the interaction terms in the third block.

Results

Sample Comparison and Manipulation Checks

As seen in Tables 1 and 2, significant differences across groups were observed for education, FSI, ETSE and ACS, as well as the second time point for the QSU-B and WSWS. When the task performance analyses presented below were repeated with all of these variables (excluding QSU-B and WSWS) included as covariates, the pattern of findings remained unchanged. As expected, at the start of session 2 deprived smokers had significantly higher scores for both QSU_{total} [$F(1,68) = 41.0$, $p < .05$], and the $WSWS_{total}$ [$F(1,68) = 4.9$, $p < .01$]. Satiated smokers also exhibited a significantly greater reduction in both QSU_{total} [$F(1,68) = 24.9$, $p < .001$], and the $WSWS_{total}$ [$F(1,68) = 6.0$, $p < .05$] following smoking.

Table 1.
Sample Characteristics with Mean (SD) or Percentage

Variable	Non-Smokers[a] (n = 36)	Satiated Smokers[b] (n = 35)	Deprived Smokers[c] (n = 35)
Demographic Variables			
Gender (% female)	44.4%	40.0%	42.9%
Education (ÒHS degree)	19.4%[bc]	45.7%	57.1%
Household Income (% < $20,000)	42.9%	62.9%	68.6%
Race (% non-white)	25.0%	14.7%	28.6%
Ethnicity (% hispanic)	16.7%	20.0%	5.2%
Age	34.4 (11.7)	37.6 (9.9)	35.7 (11.2)
Smoking-Related Variables			
Cigarettes Per Day	----	18.9 (4.6)	19.5 (7.9)
Years of Daily Smoking	----	19.7 (9.5)	18.0 (12.2)
Number of quit attempts	----	2.7 (3.7)	1.4 (1.4)
FTND	----	5.5 (1.8)	5.4 (2.3)

Note. Differences were tested using chi-square for categorical variables, and ANOVA for continuous variables. Significant overall effects were followed up with contrasts. Superscript letters indicate significant effects for specific group contrasts at the .05 level.

Table 2.
Means (SDs) of Predictor Variables by Group

Variable	Non-Smokers[a] (n = 36)	Satiated Smokers[b] (n = 35)	Deprived Smokers[c] (n = 35)
Smoking-Behavior Variables (n = 70)			
Pack-Years	----	19.08 (10.06)	19.05 (15.31)
Craving (QSU-B Time 2)***	----	22.66 (10.98)[c]	52.66 (14.36)[b]
Nicotine Withdrawal (WSWS Time 2)**	----	45.51 (14.18)[c]	57.8 (16.67)[b]
Motivation to Quit (CL)	----	5.49 (2.29)	4.77 (2.53)
Nicotine Dependence (NDSS)	----	-0.002 (0.77)	0.15 (0.94)
Smoking-Exposure Variables (n = 106)			
Family Smoking Index (FSI)[A]	0.40 (0.26)[b]	0.53 (0.25)[a]	0.48 (0.20)
Environmental Smoke Exposure (ETSE)***	33.88 (33.85)[bc]	77.95 (48.07)[a]	74.18 (62.45)[a]
Cognitive Variables (n = 106)			
Attentional Control (ACS)[A]	60.56 (7.90)[b]	56.29 (7.16)[a]	57.43 (8.55)

Note. Differences were tested using ANOVA. Significant overall effects were followed up with contrasts. Superscript letters indicate significant effects for specific group contrasts at the .05 level. [A]*p*< .10, * *p* < .05, ***p* < .01, *** *p* < .001.

Task Performance

Overall accuracy was relatively high (92.2%, SD = 5.96) indicating that in general, participants were performing the task appropriately. Despite this, three participants had outlying values for overall accuracy (< 3 SDs below the mean), and several additional participants had outlying values on one or more dependent variables for specific trial types. Repeating analyses after excluding these participants did not alter the pattern of findings. Analyses presented below include data from all participants. Although reaction time was normally distributed in this sample, the high levels of accuracy resulted in a distorted distribution for sensitivity (A′) indices. Arcsine-root transformations were applied to enhance normality (Osborne, 2002), and analyses were repeated. Again, no change in findings was observed and analyses of raw A′ indices are presented here.

Detection. Means of all task performance indices are presented in Figure 1. A significant effect of target type (smoking versus neutral) was observed for the detection composite index [F (1,103) = 36.8, $p < .001$, partial $\eta^2 = .26$], indicating that participants responded faster on trials with smoking targets. When broken down, results revealed consistent effects of target type on both trials with office supply distractors [F (1,103)=10.5, $p < .01$, partial $\eta^2 = .09$], and trials with toiletry distractors [F (1,103)=39.4, $p < .001$, partial $\eta^2 = .28$]. Post-hoc comparisons were ran to confirm that this main effect of target type was present within each separate group, and all tests were significant (all *p*'s $< .05$), with the sole exception of non-smokers on trials with office distractors ($p = .740$). Accuracy effects paralleled these results, with a significant effect of target type on both trials with office supply distractors [F (1,103) = 12.2, $p < .01$, partial $\eta^2 = .11$], and trials with toiletry distractors [F (1,103) = 54.8, $p < .001$, partial $\eta^2 = .35$], each indicating that participants responded more accurately on trials with smoking targets after adjusting for response bias. The post-hoc comparisons again revealed significant differences in target type for each group (all *p*'s $< .05$), with the exception of non-smokers on trials with office distractors ($p = .40$). No effects of group or group x target type interactions were found in any of the models (all *p*s > .1), indicating that effects were not limited to smokers.

Distraction. Counter to hypotheses, no effect of distractor type was found for the distraction composite index [F (1,103) = 2.3, $p > .1$, partial $\eta^2 = .02$]. When broken down, results revealed this was due to significant effects in opposing directions across the two scores making up this composite index. As hypothesized, participants responded slower to office supply targets amongst smoking distractors (versus toiletry distractors) [F(1,103)=32.6, $p < .001$, partial $\eta^2 = .24$]. However, participants responded significantly *faster* to toiletry targets amongst smoking distractors (versus office supply distractors) [F(1,103)=78.8, $p < .001$, partial $\eta^2 = .43$]. Post-hoc comparisons confirmed that once broken down into the two composite indices, significant distractor type differences were present for each group individually (all *p*'s $< .05$). Again, accuracy results paralleled those for reaction time. Inconsistent findings revealed participants responded less accurately to office supply targets embedded amongst smoking distractors (versus toiletry distractors) [F(1,103) = 78.3, $p < .001$, partial $\eta^2 = .43$], whereas they responded *more* accurately to toiletry targets embedded amongst smoking distractors (versus office supply distractors) [F(1,103) = 35.1, $p < .001$, partial $\eta^2 = .25$]. As above, post-hoc comparisons revealed a significant difference between distractor types for each group individually (all *p*'s $< .01$). Again, no effects of group or group x distractor type interactions were observed (all *p*s > .1).

Predictors of Task Performance

Although the absence of group differences raises questions about whether effects are due to a true attentional bias, prediction of these effects by smoking-related variables would provide some support that these effects are not merely due to perceptual characteristics of the images. Given similar results for cue type across both detection trials, predictors were tested against the composite index only. Due to the conflicting results for distraction trials, moderators were tested separately for comparisons involving office supply targets, and comparisons involving toiletry targets. Although craving and withdrawal were originally hypothesized as mediators of experimental effects, the absence of significant group differences renders any mediation of minimal clinical significance. Instead, the assessments of each of these variables immediately prior to the computer task (Time 2) were examined as additional moderators of attentional bias.

Detection. Main effects for each predictor are presented in Table 3. The only significant predictor of detection bias was environmental smoke exposure, indicating that detection bias increased with additional smoke exposure. The regression model with the ETSE included was significant [F (3,105) = 2.82, $p < .05$]. The association between the ETSE and detection bias was strong, retaining significance even when a conservative Bonferroni adjustment for multiple comparisons across all eight predictors was applied (adjusted Ŭ = .00625). There was also a weak trend indicating *less* nicotine dependence predicted greater detection bias, though the overall regression model was not significant [F (2,67) = 1.455, $p = .241$]. No significant interactions between the predictor variables and group were observed when using an adjusted alpha level to account for the number of tests being conducted. As each of these measures consist of several subscales, in order to better understand the nature of these findings additional models were ran utilizing each subscale score (see Table 4). Both adulthood and workplace exposure were associated with detection bias, while childhood exposure was not. Among the NDSS subscales, although a trend was observed for Drive, none of the other subscales achieved significance.

Distraction. Main effects for each predictor are presented in Tables 4 and 5. The only significant predictor of distraction bias was again, environmental smoke exposure though in this case indicating that bias *decreased* with additional smoke exposure for the comparison of

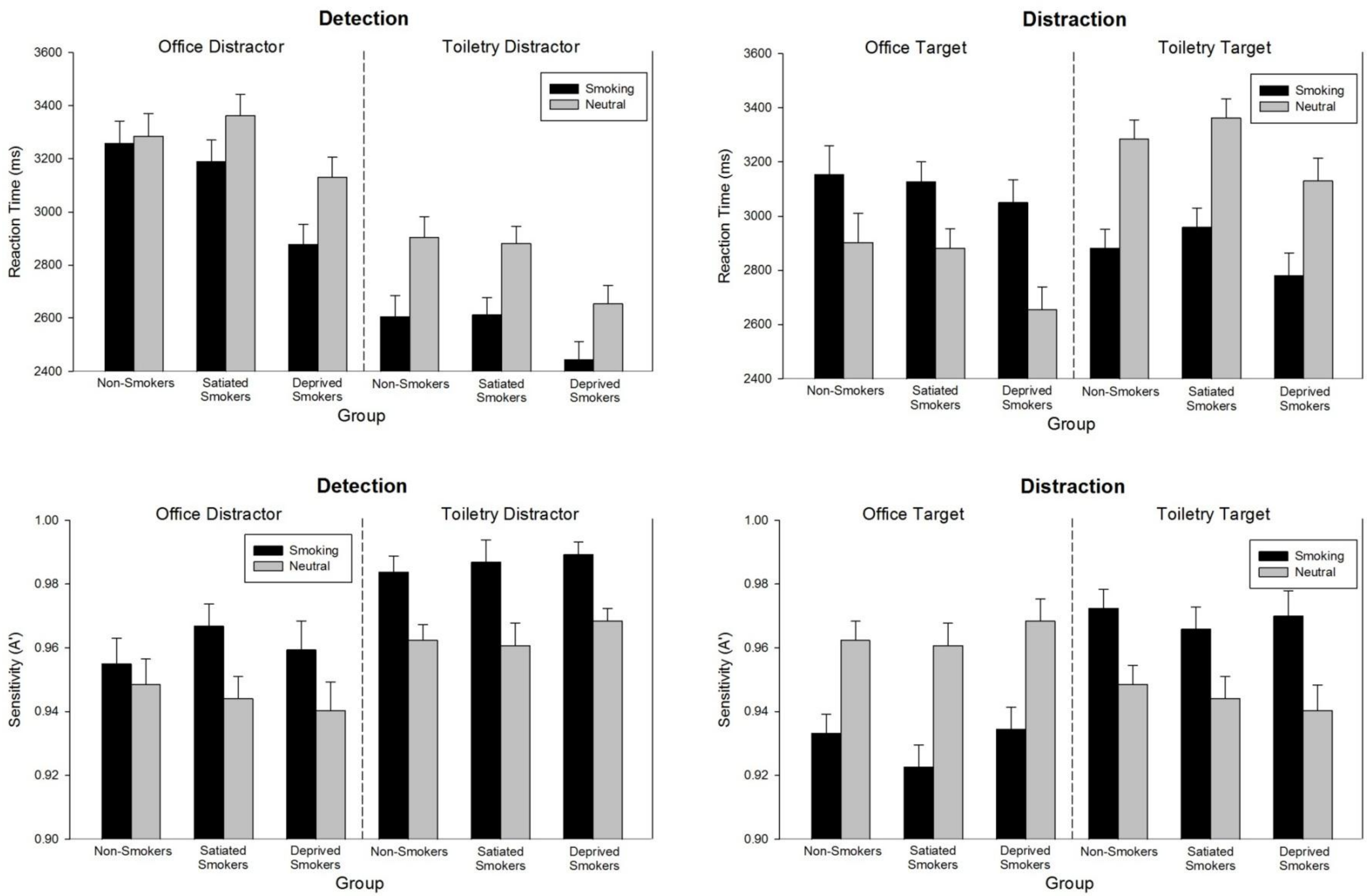

Figure 1. Means for reaction time and sensitivity indices of task performance for all target/distractor combinations. Error bars represent standard error of the within-subjects comparison for each separate group.

smoking distractors and toiletry distractors with office targets. However, this effect was somewhat weaker and the regression model was only a trend [F (3, 105) = 2.478, *p* = .065]. Again, no significant interactions between predictor variables and group were observed after adjustment of the alpha level. When ETSE subscales were examined, workplace exposure was the only variable that emerged as significant (see Table 4).

Table 3.
Multiple Regression Analyses Predicting RT Detection Bias

Variable	ΔR^2	B	SE	β	*p*-value
Smoking-Behavior Variables (n = 70)					
Pack-Years	.031	4.58	3.15	0.175	.151
Craving (QSU-B Time 2)	.006	2.00	3.24	0.117	.538
Nicotine Withdrawal (WSWS Time 2)	.012	-2.43	2.66	-0.119	.365
Motivation to Quit (CL)	.002	-6.90	17.15	-0.050	.689
Nicotine Dependence (NDSS) [A]	.041	-80.50	47.27	-0.205	.093
Smoking-Exposure Variables (n = 106)					
Family Smoking Index (FSI)	.021	222.57	151.12	0.149	.144
Environmental Smoke Exposure (ETSE)**	.077	1.98	0.70	0.290	.006
Cognitive Variables (n = 106)					
Attentional Control (ACS)	.003	-2.56	4.57	-0.057	.576

Note. Predictors above were tested individually, in separate models. All analyses controlled for group status.
[A] *p*< .10, * *p* < .05, ***p* < .01.

Table 4.
Multiple Regression Analyses For Environmental Exposure and Dependence Subscales

Variable	ΔR^2	B	SE	β	*p*-value
Detection Bias					
Environmental Smoke Exposure (n = 106)					
Childhood Home Exposure	.011	1.73	1.59	0.109	.281
Adulthood Home Exposure*	.039	3.41	1.66	0.219	.043
Workplace Exposure**	.097	4.87	1.51	0.324	.002
Nicotine Dependence (n = 70)					
Drive [A]	.051	-72.18	38.12	-0.225	.063
Priority	.015	60.85	61.17	0.122	.323
Tolerance	.003	17.66	39.55	0.055	.657
Continuity	.008	30.39	40.11	0.092	.451
Stereotypy	.008	-33.61	46.52	-0.088	.473
Distraction Bias – Office Targets					
Environmental Smoke Exposure (n = 106)					
Childhood Home Exposure	.021	-3.47	2.33	-0.147	.140
Adulthood Home Exposure	.020	-3.63	2.47	-0.157	.145
Workplace Exposure*	.062	-5.93	2.34	-0.258	.013

Note. Predictors above were tested individually, in separate models. All analyses controlled for group status.
[A] *p*< .10, * *p* < .05, ***p* < .01.

Table 5.

Multiple Regression Analyses Predicting RT Distraction Bias – Office Targets

Variable	ΔR^2	B	SE	β	*p*-value
Smoking-Behavior Variables (n = 70)					
Pack-Years	.014	-4.32	4.40	-0.118	.329
Craving (QSU-B Time 2)	.001	-1.10	4.48	-0.046	.806
Nicotine Withdrawal (WSWS Time 2)	.002	-1.48	3.70	-0.052	.690
Motivation to Quit (CL)	.006	-15.71	23.65	-0.081	.509
Nicotine Dependence (NDSS)	.012	-60.14	66.31	-0.109	.368
Smoking-Exposure Variables (n = 106)					
Family Smoking Index (FSI)	.026	-438.69	221.32	-0.198	.153
Environmental Smoke Exposure (ETSE)*	.068	-2.47	1.05	-0.244	.020
Cognitive Variables (n = 106)					
Attentional Control (ACS)	.019	-9.37	6.67	-0.140	.163

Note. Predictors above were tested individually, in separate models. All analyses controlled for group status.
^*p*< .10, * *p* < .05, ***p* < .01.

Table 6.

Multiple Regression Analyses Predicting RT Distraction Bias – Toiletry Targets

Variable	ΔR^2	B	SE	β	*p*-value
Smoking-Behavior Variables (n = 70)					
Pack-Years	.001	1.10	4.34	0.031	.802
Craving (QSU-B Time 2)	.016	4.57	4.36	0.197	.299
Nicotine Withdrawal (WSWS Time 2)	.006	2.32	3.62	0.084	.525
Motivation to Quit (CL)	.002	8.70	23.25	0.046	.710
Nicotine Dependence (NDSS)	.027	88.39	64.54	0.165	.175
Smoking-Exposure Variables (n = 106)					
Family Smoking Index (FSI)	.003	-98.50	187.87	-0.05	.601
Environmental Smoke Exposure (ETSE)	.001	-0.33	0.90	-0.04	.710
Cognitive Variables (n = 106)					
Attentional Control (ACS)	.000	-1.04	5.61	-0.019	.853

Note. Predictors above were tested individually, in separate models. All analyses controlled for group status.
^*p*< .10, * *p* < .05, ***p* < .01.

Discussion

Overall, results reveal a bias in detection (initial orienting) towards smoking cues, though this effect was also present for non-smokers in most circumstances. Results did not show a consistent bias for distraction (disengagement), with effects in opposite directions emerging depending on the particular neutral target type. Contrary to expectations, the only significant predictor of attentional bias was environmental tobacco smoke exposure. Although hypotheses were largely unconfirmed, a number of important implications can be drawn from the present investigation. Despite the general absence of group differences, the results of the present study do replicate prior work demonstrating an attentional bias for smoking cues using a novel paradigm. The inconsistency of the findings for distraction trials is mysterious, and similar results across both reaction time and accuracy measures indicate that this is not likely to be an incidental finding. Studies of attentional bias examining the maintenance or disengagement of attention would be well-advised to consider the selection of neutral cues carefully, as opposing findings may reduce or wash out observable effects in the data.

The failure to observe group differences was surprising in light of previous work in this area. Experimental control procedures and other unique characteristics of the present study may have contributed to the lack of group differences. For instance, participants were primed with smoking-related information prior to task completion by nature of the experiment taking place in a facility dedicated to tobacco research, and completion of smoking-related questionnaires prior to the task. In-session cigarette use has been associated with decreases in attentional bias in smokers (Waters et al., 2009). Although half of the smokers in the present study did not smoke during the laboratory portion of the experiment, it is possible that this priming effect also reduced their attentional bias to a level comparable to that of the non-smokers. Characteristics of the non-smokers in the present study also may have played a role. A significant portion of the non-smoker sample came from low-income backgrounds and had significant history of exposure to smoke. In light of the association between environmental exposure and attentional bias, this may have been a critical factor, but since environmental exposure has not been reported in previous research, we cannot compare our sample of non-smokers to those in prior studies. Whether a non-smoker sample with minimal exposure to smoking-related stimuli would have differed from smokers on this task remains an open question. Of course, even if attentional bias for smoking cues is present in both non-smokers and smokers, it is possible that this bias may emerge for different reasons. Even if we accept that smokers develop an attentional bias as a function of the increased incentive motivation of the cues, this would not rule out the possibility that attentional bias may develop in non-smokers if cigarettes are perceived as aversive or threatening. Indeed, attentional biases for such stimuli are commonplace and well-documented, particularly in the context of anxiety disorders (e.g. Mathews, & Mackintosh, 1998). Future studies should explore this matter further by examining the relationship between attentional biases and both explicit (e.g. ratings of valence and arousal) and implicit (e.g. an Implicit Association Test; Greenwald, McGhee & Schwartz, 1998) of smoking cues in both non-smokers and smokers.

The use of a signal-detection approach for analysis of task performance is also novel to the study of attentional bias in addiction, and is a potentially important and under-utilized technique. The simplicity of traditional tasks has resulted in a necessary emphasis on reaction time over accuracy, but significant effects were observed in the present study despite relatively small variance in accuracy. Given inconsistencies in the literature at the present time, the ability to examine multiple related outcome variables may help in the identification of consistent results not due to chance in the context of a single investigation.

The association of attentional bias with environmental exposure is also a novel finding, and one that raises serious questions about the interpretation of prior studies of attentional bias. Although the nature of the design resulted in smaller sample sizes for smoking-behavior variables, examinations of the variance accounted for by these variables (Tables 3 and 4) clearly indicates that lack of significance for smoking-behavior variables was not due to reduced statistical power. Analysis of subscales revealed that this effect was driven primarily by the adult home and workplace exposure subscales. One possibility is that recent exposure is more salient, and that effects of childhood exposure dissipate over time. However, it is also possible that poor memory may preclude participants from being able to accurately report on their childhood, and that this lack of reliability is responsible for the absence of a significant association with childhood exposure. If true, the association between environmental exposure and attentional bias would likely be even stronger than seen in the present report.

Previous conclusions about the causal role of attentional bias based on its positive association with frequency of use (e.g. Cox et al., 2006; Field & Cox, 2008) do not consider that use may only be serving as a proxy for drug exposure. If exposure were to increase attentional bias, the negative association between environmental exposure and bias would be counterintuitive, but research on basic perception may help clarify this finding. Findings have shown that search is more efficient when either the target or distractors are familiar (Wang, Cavanagh, & Green, 1994). Given reaction times in the presence of smoking-related distractors were greater than those for neutral cues, as the familiarity of smoking cues increased, one would expect search speed to increase, reducing the observed attentional bias effect. Thus, it is possible that exposure might increase biased detection while decreasing biased distraction. This may help explain some of the inconsistencies in tasks that do not fully distinguish attentional subcomponents, and should be given careful consideration in future work.

While it is premature to make definitive conclusions about the role that environmental exposure to drug-related stimuli may play in attentional bias, if it results from environmental exposure and not drug use, that raises important questions about its relevance to addiction and call into question the assumption that it can serve as an index of the incentive-sensitization concept of drug ñwantingò (Robinson & Berridge, 1993). However, even if drug use is not necessary for the development of attentional bias, it could still play a role in maintaining addictive behavior in addicted individuals. Replication of this finding will be particularly critical, as the present sample was relatively transient, with many participants having an unstable work history and living environment. To provide some assurance that participants are able to reliably report historical information, the ETSE only accounts for exposures that were at least a year in duration and participants in the present study may have had frequent exposures of shor duration. Furthermore, the role of familiarity of drug-stimuli should also be explored using other attentional bias tasks, to insure that these effects are not unique to visual search.

Although weak and counter to findings for other drugs of abuse, the negative association between attentional bias and nicotine dependence is actually consistent with some previous in attentional bias for smoking (Hogarth, Mogg, Bradley, Duka, & Dickinson, 2003; Mogg, Field, & Bradley, 2005). Such a finding is also consistent with models suggesting that incentive value of smoking cues may decrease as responses to cues become ritualized and automatic (Di Chiara, 2000; Tiffany, 1990). If attentional bias plays a role in driving drug use behavior, it may emerge early in the development of dependence to foster continued drug use prior to the emergence of withdrawal symptoms and other negatively reinforcing properties (Baker, Morse, & Sherman, 1986; Baker, Piper, McCarthy, Majeskie, & Fiore, 2004). Of course, the reason why this effect would be limited to smoking and not other drugs of addiction is unclear.

Limitations

A number of important limitations need to be considered when interpreting the results of the present study. Analyses of Aôindices were not fully normal even after transformation, so replication of this finding will be important. Recent evidence has also indicated a distinct influence of co-morbid diagnoses on attentional bias (Sinclair, Nausheen, Garner, & Baldwin, 2010). While the present sample has a high degree of external validity, results may have differed if participants with co-morbid conditions were excluded from participation. Perhaps foremost among the limitations, failure to observe group differences means there remains a possibility that perceptual characteristics and not attentional bias are responsible for the effects, though careful pilot testing and a strong association with environmental smoke exposure render this unlikely. This is not unique to the current study, given many studies of attentional bias have not even included appropriate control groups (Robbins & Ehrman, 2004). Similarly, a recent paper indicates that attentional bias effects may only be present when simple stimuli are used (Miller & Fillmore, 2010). While the current study employed simple images, they were embedded amongst a large number of similarly simple images which may have had comparable effects relative to image complexity. Regardless, the task used is ideally suited for testing the influence of complexity by modification of the grid size used, and this will remain an important future direction.

Conclusions

Overall, results confirm the presence of attentional bias smoking cues within a visual search paradigm, though effects were present for both smokers and non-smokers. These results were consistent only for detection trials. No clear reason for the inconsistency among distractor trials was found. Critically, environmental exposure to tobacco smoke proved to be the strongest and most consistent predictor of attentional bias. Future work should assess the degree of environmental exposure and other measures of familiarity, which may help explain the inconsistent findings in the literature.

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