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Acute Cigarette Smoking Reduces Latencies on a Smoking Stroop Test

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Abstract

Rationale—Sensitivity to addiction-related cues, a type of attentional bias, may interfere with executive functions that are important in sustaining abstinence from drug abuse. Assessments of attentional bias in research participants who smoke cigarettes have used Smoking Stroop tasks, which are variations of emotional Stroop tasks in which the stimuli are smoking-related and neutral words.

Objectives—We aimed to determine the effect of resumption of smoking by deprived cigarette smokers on attentional bias.

Methods—Testing occurred twice on each of two test days. One test day began after overnight abstinence (13–16 h) and the other after <1 h of abstinence. The participants (n = 51) smoked a cigarette between the two test sessions on each test day.

Results—Smokers exhibited attentional bias for smoking-related words and had longer response times after overnight abstinence than after brief abstinence. Cigarette smoking between sessions reduced response times on both test days with no interaction by stimulus type.

Conclusions—Smoking-related cues have distracting effects in smokers, and smoking reduces response latency, with no specific effect on attentional bias. The increase in response speed may contribute to a smoker's impression that abstinence hinders performance and that smoking reverses impairment.

Keywords

Smoking; Attention; Smoking Stroop; Human

Cognitive bias theories of addiction posit that inherent or acquired biases in beliefs, attention, and memory processes contribute to the initiation and maintenance of addictive behaviors (West, 2006). A bias in attention or hypersensitivity to addiction-related cues, whether they are visual, situational or social, may contribute to the addiction by triggering

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personal memories and expectations related to the addictive behavior. These cues may interfere with strategies and coping mechanisms that are involved in committing to abstinence. In this way, cues can prevent someone who is engaged in drug abuse from initiating abstinence, or can place an individual who is abstinent from drug abuse at risk for relapse. Imaging data support this view, showing that attentional biases of cigarette smokers activate the insula and amygdala, brain regions associated with emotional memories, which can increase relapse vulnerability (Janes et al., 2010b).

A type of emotional Stroop task, known as a Smoking Stroop task, can assess the degree to which smoking-related stimuli capture the attention of cigarette smokers. Stroop tasks generally evaluate the ability to focus attention and to suppress a prepotent response in favor of an atypical one. Commonly, the task is to name the font color of a word while suppressing the natural tendency to read the word. In Smoking Stroop tasks, the stimuli are smoking-related and neutral words. Degradation of performance, operationalized as longer response times when the stimuli are smoking-related words compared to neutral words, reflects a bias in attention. The degree to which addiction-related stimuli capture attention is an indicator of susceptibility to relapse. For example, pre-treatment attentional bias successfully predicted relapse of opiate users at 3 months and time to relapse in cigarette smokers (Marissen et al., 2006; Waters et al., 2003; Janes et al., 2010a).

One of the earliest studies to use a Smoking Stroop task compared performance of abstinent and active smokers, finding a significant interaction between smoking status and stimuli type, with abstinent smokers exhibiting attentional bias for smoking words (Gross, Jarvik, & Rosenblatt, 1993). Three subsequent studies used variations of the task, and found no significant differences between the smoking conditions in response times to smoking-related words versus neutral words (Mogg & Bradley, 2002; Munafo, Mogg, Roberts, Bradley, & Murphy, 2003; Waters & Feyerabend, 2000). The authors of these studies concluded that temporary abstinence does not augment existing attentional bias of smokers to smoking-related cues, but increases overall response times. However, an examination of the responses of adolescents to resumption of smoking after brief abstinence used the early version of the Smoking Stroop task and found that resumption of smoking reduced response times when the stimuli were smoking-related words more than when they were neutral words (Zack, Belsito, Scher, Eissenberg, & Corrigan, 2001). In another study of adolescents, resumption of smoking did not improve performance on other tests of selective attention (Colby et al., 2010). Using these studies of adolescents as guides (Colby et al., 2010; Zack et al., 2001), and using an early version of the Smoking Stroop task (Gross et al., 1993), we aimed to assess whether deprived adult cigarette smokers exhibit reduced attentional bias upon resumption of smoking following either overnight or brief abstinence from smoking.

Method

Participants

Recruitment materials included flyers and newspapers advertising this study conducted at the University of California, Los Angeles. The following exclusion criteria were used: current use of medications that may affect cognition, any medical condition that may interfere with cognition, any psychiatric condition, age < 18 yr or > 50 yr, a history of head trauma, color-blindness, smoking marijuana more than once per week, drinking more than 10 alcoholic drinks per week, regularly abusing substances other than alcohol or marijuana, being ambidextrous or left-handed, and scoring < 47 on the Wender-Utah Rating Scale assessing childhood attention deficit hyperactivity disorder.

Additional exclusion criteria were self-reports of smoking fewer than 15 or more than 40 cigarettes per day, or of not smoking regularly for at least 2 years before participating.

Carbon monoxide (CO) in expired air served as an objective measure of recent smoking (Micro Smokerlyzer II, Bedfont Scientific Instruments). The inclusion criteria were < 5 parts per million (ppm) of CO for nonsmokers, 10 ppm for smokers at the start of the test session in which they were not to be deprived of smoking, and < 10 ppm at the start of the session that was to follow overnight abstinence (Perpina, Hemsley, Treasure, & de Silva, 1993; Stormark, Laberg, Nordby, & Hugdahl, 2000). Participants received a detailed explanation of the study and signed a consent form that approved by the University of California Los Angeles. Fifty-one smokers passed screening, completed testing, and received \$20 per hr (maximum 9 hr) for their participation. Some of the participants from a previous study by our group (Domier et al., 2007) were included in the current study.

Procedures

The study involved a within-subject comparison of smokers tested with a Smoking Stroop task. Testing on one day followed overnight (13 – 16 h) abstinence from smoking; on the other day, smoking continued *ad libitum*, and testing began after only 15 – 60 min of abstinence. Overnight abstinence was counterbalanced to control for effects of session order. At the beginning of each test day, participants provided a measure of CO in expired air to verify smoking or abstinence, and then received training on the task. All participants completed Test Session 1, then took a 10-min break in which they left the testing room and smoked one cigarette of their usual brand. Test Session 2, which repeated the measures administered in Test Session 1, started immediately following the break. Participants also completed measures of cigarette craving, withdrawal symptoms, and CO level before the smoking break at Test Session 1 and after the smoking break at Test Session 2.

Measures

Smoking severity was quantified using the Fagerström Test for Nicotine Dependence (Heatherton, Kozlowski, Frecker, & Fagerström, 1991). Self-report measures of negative symptoms associated with withdrawal from cigarette smoking were collected using the 25-item Shiffman/Jarvik Withdrawal Scale (SJWS) (Shiffman & Jarvik, 1976). Cigarette craving was assessed using the 10-item Urge to Smoke (UTS) scale (Jarvik et al., 2000).

Smoking Stroop Task

The Smoking Stroop task was presented using SuperLab (Cedrus Corporation 1997) on a Macintosh laptop computer with a 10-inch monitor. To reduce the effects of learning from repeated administrations of the test, participants received training on which finger of their right hand corresponded to each of the three response options (red-index finger, green-middle finger, or blue-ring finger) on the keyboard, and they repeated training with blocks of 15 neutral stimuli until they achieved accuracy of 80%. The training session did not include testing with the smoking-related stimuli. Participants completed the Smoking Stroop task immediately after training.

The task consisted of blocks of 26 trials of neutral words followed by 26 smoking-related words displayed in the colors red, green, or blue. Neutral blocks preceded smoking blocks to prevent carryover effects (Waters & Feyerabend, 2000). The words were taken from a prior study that matched the smoking-related and neutral words for frequency, number of syllables, and number of letters (Gross et al., 1993). Other studies used these stimuli as well (Hendricks, Ditte, Drobles, & Brandon, 2006; Zack et al., 2001) with divergent results. The smoking-related words were *addiction, ashes, burn, butt, cancer, carton, cigarette, death, filter, fire, flavor, habit, hot, lighter, match, nicotine, odor, pack, paper, pipe, puff, smell, smoke, tar, taste, and tobacco*. The neutral words, in the order of their match to the smoking words, were *saddlebag, mouse, king, toll, nettle, locker, tablespoon, laugh, trophy, hair, shiver, metal, man, pennant, pause, glycerin, envy, fold, fifty, debt, damp, clock, chair, bug,*

board, and *arrival*. The program presented stimuli, one word at a time, in Helvetica font size 72, for 2000 ms with a fixation cross presented for 3000 ms between trials. The total time of the test was 6 min.

Analyses

Repeated measures ANOVAs tested the effects of smoking abstinence and resumption of smoking on the expired CO levels, withdrawal, and craving variables among smokers. The interactions between the smoking-related and neutral stimuli and test session were included to test for effects specifically related to attentional bias. The analyses included the data from participants who completed all four test sessions and who had response times ≥ 200 ms and ≤ 1500 ms, or response times ± 2 standard deviations from the overall mean (Ratcliff, 1993).

To assess the effect of overnight abstinence on task performance, a repeated measures ANOVA compared performance when abstinent overnight vs. briefly, using only response time data from the test session before the smoking break. Stimulus (neutral vs. smoking-related) was the within-subject independent variable. Analysis of whether smoking a cigarette during the break affected Smoking Stroop task performance was complicated by the fact that smoking was confounded with test order; the first test always preceded smoking and the second test always followed smoking. Repeated measures ANOVAs compared the performance of smokers before and after the break. The analysis tested the interaction between Test Session (1, 2) and stimulus type (neutral vs. smoking-related) to determine whether smoking affected attentional bias. These analyses included data from performance of smokers on both test days (briefly and overnight abstinent), with stimulus type included as a within-subjects independent variable.

Results

Participants

Table 1 presents the demographic characteristics of the sample. Smokers consumed an average of 20 cigarettes (one pack) per day ($SD = 6.3$) for 16 years ($SD = 9.8$). They also showed moderate nicotine dependence, with an average score on the Fagerström Test for Nicotine Dependence of 5.3 ($SD = 2.5$).

Measures of Negative Symptoms and Cigarette Craving

Table 2 presents the mean expired CO levels, and mean scores on the UTS and SJWS scales, recorded at the beginning of each test session on each test day. Seven smokers did not have complete data in all four test sessions; therefore, data from 44 smokers were used in the analyses. Transformations applied to the CO levels and SJWS subscale scores helped approximate normal distributions. Repeated measures ANOVAs assessed the effects of test day, session, and their interactions. The UTS data were not normally distributed, and transformations could not bring the distributions to normal. Therefore, Wilcoxon signed-ranks matched-pairs tests assessed the significance of these data.

There was a significant interaction between test day and test session on the expired CO data ($F_{(1, 41)} = 76.83, p = .000, \eta^2 = .84$). Smokers abstinent overnight exhibited lower CO levels before Test Session 1 and greater increases in CO levels from Test Session 1 to Test Session 2 (when smoking one cigarette occurred) than briefly abstinent (15–60 min) smokers. Data from the SJWS indicated a significant interaction between test day and test session on each of the five subscales (all p 's < 0.001). Smokers abstinent 13–16 h exhibited higher scores in the first session of the day, indicating more severe negative symptoms and craving than briefly abstinent smokers. Scores decreased considerably after resuming smoking on the day of overnight abstinence, but increased slightly on the day of brief abstinence from smoking

(craving, $F_{(1, 41)} = 53.14, p < .001, \eta^2 = .56$; psychological, $F_{(1, 41)} = 36.18, p < .001, \eta^2 = .47$; physical, $F_{(1, 41)} = 128.40, p < .001, \eta^2 = .76$; appetite, $F_{(1, 41)} = 166.58, p < .001, \eta^2 = .80$). During the first session of the Brief Abstinence day, scores on the sedation subscale were lower than in the first session of the Overnight Abstinence day, and after resuming smoking on both days, scores increased ($F_{(1, 41)} = 83.07, p < .001, \eta^2 = .67$). The UTS data also revealed a significant interaction between test day and test session ($z = -3.86, p < .001$) with higher scores on the day of overnight abstinence than the day of brief abstinence, indicating greater smoking urges, and a greater reduction in scores after resuming smoking on the day of overnight abstinence than the day of brief abstinence.

The Effect of Smoking Abstinence

Analysis of the response time data for smokers in the first test session on each test day combined revealed a main effect of stimuli ($F_{(1, 50)} = 22.02, p < 0.001, \eta^2 = .31$), indicating that smokers had significantly longer response times to smoking-related than to neutral words (mean = 805 ms, $SE = 18.4$; and mean = 770 ms, $SE = 16.8$, respectively) (see Table 3). Analysis of these data revealed a main effect of abstinence (collapsing the data across stimulus type, mean = 802, $SE = 09.0$, and = 773 ms, $SE = 17.8$, respectively; $F_{(1, 50)} = 4.87, p = .03, \eta^2 = .09$), indicating that smokers had significantly longer response times after overnight abstinence than after brief abstinence from smoking. All results presented in Table 3 are significant. However, there was no significant interaction between test day (Brief Abstinence and Overnight Abstinence) and stimulus type ($F_{(1, 50)} = .002, p = .96$) on performance in the session before the break, confirming that overnight abstinence did not create differential attention bias; rather it increased overall response time.

The Effect of Resuming Smoking

Analysis of the response time data comparing Test Sessions 1 and 2 from the Overnight Abstinence test day indicated a main effect of stimulus type ($F_{(1, 50)} = 15.98, p < .001, \eta^2 = .24$; smoking-related mean = 768 ms, $SE = 17.27$; neutral mean = 799 ms, $SE = 19.38$) and a main effect of Test Session ($F_{(1, 50)} = 13.55, p < .001, \eta^2 = .21$; Session 1 mean = 802 ms, $SE = 19.01$; and Session 2 mean = 765 ms, $SE = 18.18$), but no significant interaction between the two variables ($F_{(1, 50)} = .33, p = .56$). Analysis of the response time data comparing Test Sessions 1 and 2 from the Briefly abstinence test day indicated a main effect of stimulus type ($F_{(1, 50)} = 27.47, p < .001, \eta^2 = .35$; smoking-related mean = 777 ms, $SE = 19.33$; neutral mean = 743 ms, $SE = 17.54$) and a main effect of Test Session ($F_{(1, 50)} = 5.25, p < .05, \eta^2 = .09$; Session 1 mean = 773, $SE = 17.90$; Session 2 mean = 748, $SE = 20.01$), but no significant interaction between the two variables ($F_{(1, 50)} = .04, p = .84$).

Discussion

This is the first report on the effects of resumption of smoking in nicotine-dependent adults performing the Smoking Stroop task. The results indicate that although smokers exhibit an attentional bias toward smoking-related cues, overnight abstinence does not increase this bias. Furthermore, smoking one cigarette following overnight abstinence reduces overall response time but does not significantly reduce attentional bias.

The general effect of an overall slowing of response times with overnight abstinence from smoking corroborates findings of two of the prior studies using Smoking Stroop tasks (Waters & Feyerabend, 2000; Rusted, Caulfield, King, & Goode, 2000), of studies with color-word Stroop tasks (Domier et al., 2007; Pomerleau, Teuscher, Goeters, & Pomerleau, 1994), and of assessments of sustained attention in smokers (Hendricks et al., 2006; Wesnes & Warburton, 1983; Hatsukami, Fletcher, Morgan, Keenan, & Amble, 1989; Sacco et al., 2005; Dawkins, Powell, West, Powell, & Pickering, 2007; Hughes, Keenan, & Yellin,

1989). Our findings provide support for prior observations that smokers are distracted by smoking-related stimuli, and that this effect is not exacerbated by overnight abstinence (Mogg & Bradley, 2002; Munafo et al., 2003; Wertz & Sayette, 2001).

The finding that consuming one cigarette reduced response latencies of smokers under both smoking-related and neutral conditions of the task is consistent with findings from abstinent adolescents performing the Smoking Stroop task (Zack et al., 2001) and overnight abstinent adult smokers (smoking two cigarettes) performing a numerical Stroop task (Hasenfratz & Battig, 1992). They also corroborate findings from a similarly designed study using the Color-Word Stroop test with smokers (Domier et al., 2007). Previous results of indicated that acute smoking between test sessions reduced the Stroop effect in smokers after overnight abstinence but not when they were briefly abstinent (Domier et al., 2007). To substantiate the effect of cigarette smoking, we obtained data on healthy nonsmokers who were tested using the same experimental design but who did not smoke between sessions. The data showed no shortening of RT in Session 2, demonstrating no learning effect.

The general improvement in response times after smoking in the current study may be an effect of nicotine *per se*, as observed in previous research using Stroop tasks. Researchers applied nicotine patches or placebo patches to abstinent smokers and assessed their performance differences on a Color-Word Stroop task (Mancuso, Andres, Ansseau, & Tirelli, 1999) and Smoking Stroop task (Waters et al., 2003). In these studies, nicotine reduced overall response times but did not significantly influence attentional bias. These results are consistent with the hypothesis that nicotine improves the intensity rather than the selectivity feature of attention.

It is unclear whether the improvement in response times observed here is due to nicotine, secondary factors associated with smoking, or a combination of both. Substantial research indicates that non-nicotine components, such as other chemical, sensory, and motor components, are important contributors to nicotine dependence (See (Rose, 2006; Robinson, Houtsmuller, Moolchan, & Pickworth, 2000) for reviews). As several studies have shown, smoking denicotinized cigarettes provides relief from craving and withdrawal symptoms in abstinent smokers (Pickworth, Fant, Nelson, Rohrer, & Henningfield, 1999; Westman, Behm, & Rose, 1996; Gross, Lee, & Stitzer, 1997). In one study, smoking denicotinized cigarettes did not, however, reduce the cognitive deficits associated with abstinence in smokers (Baldinger, Hasenfratz, & Battig, 1995). Abstinent smokers ($n = 25$ females) smoked regular and denicotinized cigarettes on separate test days and completed the Rapid Visual Information Processing Test of sustained attention. Smoking nicotine cigarettes reduced response time more than smoking denicotinized cigarettes.

The inclusion/exclusion criteria of this study were among the most stringent of the relevant studies published; but while this sample was larger than all but one other study, it is still modest and is not adequate to detect small effects. With the current study sample size, the minimum effect size for which power is 80% is 0.22. It also is likely that the dose of nicotine delivered following overnight abstinence was greater than delivered from smoking after only 15–60 min abstinence, as indicated by the tendency for CO increases to be larger after overnight abstinence than after brief abstinence (Table 2). Providing an opportunity to smoke only one cigarette between test sessions may have been an inadequate manipulation to restore a state of smoking satiety, as CO levels remained below those observed following brief abstinence from smoking. Finally, some of the stimuli in the smoking-related stimuli condition may not have adequately elicited smoking-related thoughts. Given the wide variety of tests used in this area of research, we used the early version of the Smoking Stroop task, which produced positive findings before (Zack et al., 2001; Gross et al., 1993). Standardization of test measures would help this area of research.

In summary, the positive findings with the behavioral measure used here help to clarify a literature that has been inconsistent, primarily because of low statistical power in many studies. Smokers exhibited attentional bias toward smoking-related cues and smoking reduced response time but had no specific effect on attentional bias. The performance boost may contribute to a smoker's impression that resumption of smoking reverses performance deficits induced by abstinence.

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Table 1**Characteristics of Participants^a**

Age (mean years)	36.7 (10.5)
Sample composition (% women)	37%
Education (mean years)	14.2 (2.2)
WURS score (mean score) ^c	14.6 (9.3)
BDI score (mean score)	2.9 (4.1)
Race (%)	
European	57
African American	25
Hispanic	6
Asian	8
Other	4

^aThe participants were 51 paid volunteers who were cigarette smokers.

^bNumbers in parentheses are standard deviations.

^cMaximum scores on the WURS (childhood ADD/hyperactivity) and Beck Depression Inventory were 100 and 16, respectively.

Table 2 Measures of Expired CO, Negative Symptoms, and Craving in Smokers ^a

	1 h Abstinence Test Session 1	1 h Abstinence Test Session 2	13–16 h Abstinence Test Session 1	13–16 h Abstinence Test Session 2
Expired CO (ppm)	23.86 (1.82) ^b	24.74 (1.58)	7.62 (.92)	13.43 (.83)
Urge to Smoke (UTS) ^c questionnaire	4.24 (.23)	1.85 (.17)	5.76 (.19)	2.31 (.17)
Shiffman-Jarvik Withdrawal Scale (SJSW)				
Categories:				
Craving	4.01 (.16)	4.06 (.21)	6.07 (.15)	4.42 (.15)
Psychological	2.55 (.08)	3.03 (.10)	3.72 (.18)	3.11 (.15)
Physical	1.56 (.11)	1.58 (.12)	2.37 (.19)	1.72 (.14)
Sedation	2.32 (.19)	3.26 (.19)	2.63 (.20)	3.73 (.24)
Appetite	3.73 (.15)	4.17 (.19)	4.25 (.18)	4.24 (.16)

^aThe interaction of test day and test session were significant for all variables, $p < 0.001$.^bNumbers indicate the means (standard errors of the means).^cBoth the UTS and SJWS have a maximum score of 7, with higher scores indicating more severe symptoms.

Table 3

Response Times: Effect of Resumption of Smoking

Response Time (ms) ^{a,b,c}	1 h Abstinence	13–16 h Abstinence
Neutral Words		
Test Session 1	755 (17.6)	784 (18.4)
Test Session 2	732 (19.3)	752 (17.7)
Smoking Words		
Test Session 1	790 (19.6)	820 (21.2)
Test Session 2	764 (21.5)	779 (19.8)

^aMain effects of test day and of Stroop stimuli, $p < .01$.

^bInteraction between test day and test session for analyses involving smokers on both test days, $p < .001$.

^cNumbers represent mean values of RT in ms (standard errors of the means).