Published in final edited form as:

Psychol Addict Behav. 2014 September ; 28(3): 752–760. doi:10.1037/a0035122.

The effects of nicotine dose expectancy and motivationally relevant distracters on vigilance

Jason D. Robinson, Jeffery M. Engelmann, Yong Cui, Francesco Versace, Andrew J. Waters, David G. Gilbert, Ellen R. Gritz, and Paul M. Cinciripini

Jason D. Robinson, Jeffery M. Engelmann, Yong Cui, Francesco Versace, Ellen R. Gritz, and Paul M. Cinciripini, Department of Behavioral Science, The University of Texas MD Anderson Cancer Center; Andrew J. Waters, Department of Medical and Clinical Psychology, Uniformed Services University of the Health Sciences; David G. Gilbert, Department of Psychology, Southern Illinois University

Abstract

The imminence of drug use (i.e., drug availability) has been found to be related to intensity of drug craving, but its effects on attentional bias to drug cues are unclear. This study investigated the effects of nicotine availability on attentional bias to smoking, affective, and neutral cues in a sample of adult smokers during a vigilance task. At the beginning of each of four laboratory sessions, overnight nicotine-deprived smokers ($n = 51$) were instructed that they would smoke a cigarette containing either nicotine (Told-NIC) or no nicotine (Told-DENIC) after completing the rapid visual information processing task with central emotional distracters (RVIP-CED). The RVIP-CED presented digits at a rapid pace, with participants instructed to respond with button presses to every third consecutive even or odd digit. Some digits were preceded by smoking, pleasant, unpleasant, or neutral distracter slides. During Told-NIC conditions, participants produced significantly longer RT latency than during Told-DENIC conditions. RT sensitivity (d'), a measure of the ability to discriminate true positives from false positives, was significantly lower during the Told-NIC than during the Told-DENIC conditions to targets following cigarette distracters. These results suggest that nicotine-deprived smokers expecting to imminently smoke a cigarette experience greater distraction, particularly to smoking-related stimuli, than when expecting to smoke a denicotinized cigarette.

Keywords

smoking; expectancy; vigilance; reaction time; RVIP

Introduction

Substance-dependent individuals typically experience greater self-reported craving during drug cue exposure when expecting an imminent opportunity to use their drug, compared to

subjects who do not anticipate use of their drug (Wertz & Sayette, 2001a). Smokers report more craving to smoking-related cues when led to believe that smoking is imminent rather than distant (Carter & Tiffany, 2001; Droungas, Ehrman, Childress, & O'Brien, 1995; Juliano & Brandon, 1998). Neutral cues conditioned in the laboratory to signal smoking availability elicit greater craving than cues signaling smoking unavailability (Dols, Willems, van den Hout, & Bittoun, 2000; Dols, van den Hout, Kindt, & Willems, 2002; Lazev, Herzog, & Brandon, 1999; Payne, Etscheidt, & Corrigan, 1990; Thewissen, van der Meijden, Havermans, van den Hout, & Jansen, 2008). In addition to self-reported craving, physiological indices of arousal to conditioned drug cues have been found to be increased among smokers expecting to smoke imminently rather than distantly, including electroencephalography (Zinser, Fiore, Davidson, & Baker, 1999), heart rate (Lazev et al., 1999), and skin conductance (Carter & Tiffany, 2001). Imaging studies have found that smoking availability increases brain reactivity in areas associated with evaluating stimulus reward salience (e.g., orbital frontal cortex; McBride, Barrett, Kelly, Aw, & Dagher, 2006; Wilson, Sayette, Delgado, & Fiez, 2005), with decision making (e.g., rostral prefrontal cortex; Wilson, Sayette, & Fiez, 2012), and with response inhibition (e.g., caudate; Gloria et al., 2009).

Despite the evidence for its relationship to craving, it is unclear whether smoking availability increases attentional bias to drug-related cues. Several addiction models have postulated that drug craving and attentional bias towards substance-related cues function as a mutually excitatory positive feedback loop, temporarily mitigated only when the drug is sought out and used (Field & Cox, 2008; Franken, 2003; Robinson & Berridge, 1993; Ryan, 2002). Though correlations between craving and attention bias are typically small, this relationship has largely been supported in the literature (Field, Munafo, & Franken, 2009). One might expect that perceived smoking availability, which has been shown to increase craving, should also increase attentional bias to drug cues. However, the two studies that have investigated the effects of smoking availability on cognitive measures of attentional bias report inconsistent results. In a modified smoking Stroop task, smokers expecting to smoke (Expect-Yes) had increased smoking Stroop interference effects compared to those not expecting to smoke (Expect-No), suggesting that smoking availability increases attentional bias to smoking cues (Wertz & Sayette, 2001b). However, another study that used a dual-task reaction time (RT) paradigm to evaluate the effects of availability on attentional bias found that participants in the Expect-No condition exhibited increased RT to smoking cues compared to participants in the Expect-Yes condition, suggesting that smoking unavailability increased attentional bias to smoking cues (Juliano & Brandon, 1998).

One task designed to measure attentional bias to smoking-related and affective cues is the rapid visual information processing task with central emotional distracters (RVIP-CED). The traditional RVIP task, in which participants push a button if either three consecutive even or odd digits are shown during a series of rapidly presented single digits, has been used extensively as a measure of sustained attention (Warburton & Wesnes, 1978; Wesnes & Warburton, 1983). Performance on the RVIP has been reliably found to be impaired in smokers during nicotine abstinence compared to nonabstinence (Baldinger, Hasenfratz, & Bättig, 1995; Foulds et al., 1996; Hendricks, Ditte, Drobes, & Brandon, 2006; Leventhal,

Waters, Moolchan, Heishman, & Pickworth, 2010; Mancuso, Andres, Ansseau, & Tirelli, 1999; Zack, Belsito, Scher, Eissenberg, & Corrigan, 2001). The RVIP-CED is a modified version of the traditional RVIP task developed by Gilbert and colleagues (Gilbert et al., 2005; Gilbert et al., 2007) to evaluate the impact of smoking-related and affective distracter slides on sustained attention. In the RVIP-CED, the task is to identify 3 consecutive even or odd digits while ignoring smoking-related and affective distracter slides periodically presented during the stream of digits. Gilbert and colleagues found that when wearing a placebo patch, compared to a nicotine patch, overnight-deprived smokers produced decreased accuracy to target digits following smoking and unpleasant slides, suggesting that nicotine-deprived smokers experience more distraction to smoking-related and unpleasant stimuli (Gilbert et al., 2005).

Given that it is unclear how smoking availability affects attentional bias to drug cues, we sought to determine whether the expectation of imminent nicotine use increases the attentional distraction by smoking and affective cues using the RVIP-CED paradigm. Participants ($n=55$) attended four sessions, as part of a larger study, where they were told at the beginning of two sessions that they would smoke a “regular” cigarette (Told-NIC), and told at the other two sessions that they would smoke a “placebo” (Told-DENIC) cigarette, immediately following the RVIP-CED. We hypothesized that overnight deprived smokers Told-NIC, compared to when Told-DENIC, would demonstrate decreased RT performance on the RVIP-CED task. We also hypothesized that instructed dose would interact with distracter type such that Told-NIC would reduce RT performance more to cigarette distracters compared to pleasant, unpleasant, and neutral distracters.

Several aspects of our approach improve upon the two previous studies that examined this question but found conflicting results (Juliano & Brandon, 1998; Wertz & Sayette, 2001b). First, we used pictorial smoking cues, which have been found to be even more evocative of craving than in vivo cues (Wray, Godleski, & Tiffany, 2011). Second, in our RVIP-CED task we compared attentional bias to intrinsically motivationally relevant stimuli (i.e., pleasant, unpleasant) in addition to smoking cues. This allowed us to determine whether smoking availability's effects on attentional bias are specific to smoking cues, as is predicted by several addiction theories (e.g., Franken, 2003), or are more global in nature. Finally, we used signal detection theory metrics (e.g., sensitivity and response bias). Unlike RT latency, these metrics take into account misses and false alarms, both of which may be influenced by the presence of distracters, thus providing a more complete assessment of attentional bias.

Method

Participants

We randomized 55 adult smokers ($n=24$ female) from among the 457 people we phone screened who responded to our advertising in the Houston metropolitan area. Smokers were included if they were between the ages of 18 and 65, smoked 10 or more cigarettes per day, produced an expired carbon monoxide (CO) level 8 ppm or greater at the screening session, demonstrated fluency in spoken and written English, as determined by the Rapid Estimate of Adult Literacy in Medicine (REALM; Davis et al., 1993), and agreed to not use marijuana or other illicit drugs during the course of the study. Smokers were excluded if they were

interested in quitting smoking in the next 45 days, were involved in current smoking cessation activity, were taking psychotropic or narcotic medication, met criteria for a current psychiatric disorder, as indicated by the Patient Health Questionnaire (PHQ; Spitzer, Kroenke, & Williams, 1999), reported uncorrected visual acuity loss, lacked a working telephone, used marijuana or other illicit drugs within the week preceding screening, or, if female, reported being pregnant or breast-feeding. Participants expressing interest in quitting smoking were provided with referrals for smoking cessation services. Participants were paid a maximum of \$200 for attending the screening and all four laboratory sessions (\$35 per completed laboratory session and \$5 for showing up on time to each session). Consecutive sessions were separated about one week. Participants provided informed consent to a protocol that was approved by The University of Texas MD Anderson Cancer Center's Institutional Review Board.

Of those phone screened, 59% were ineligible, 25% declined to participate, and 4% failed to return after the screening session. Among those who were ineligible, 36% met criteria for two or more exclusion criteria, 23% were menthol smokers (an exclusionary criteria initially added because the manufacturer had stopped producing menthol variants of the experimental cigarettes by the time the study started, but removed half-way through the study because it was excluding too many African-Americans), 13% did not smoke the minimum amount of cigarettes per day, 10% were taking an exclusionary medication, 4% had taken an illicit drug within the past week, 4% met criteria for a current psychiatric disorder, and 10% met criteria for one of the other reasons. Of those declining to participate, 61% were not interested after learning about the study, 17% wanted to quit smoking and were referred to ongoing clinical trials, 9% did not like the time commitment, 8% did not like the compensation scheme, and 5% reported other reasons (e.g., travel time). Four participants only completed the initial laboratory session and were removed from further analysis, leaving 51 participants who were included in the RVIP-CED analyses. For the self-assessment manikin (SAM; Lang, 1980) ratings, three participants were not collected due to technical difficulties, and one participant was excluded due to clicking too quickly (<250 ms) on the same response through the majority of ratings, leaving 47 participants whose data were included in the SAM ratings analyses.

Procedures

Telephone Pre-Screening—Participants were prescreened by telephone for eligibility, interest, and demographic information. All eligibility requirements, except for the expired CO requirement, were assessed during the telephone pre-screen. Administering the telephone assessment took 10–15 minutes. All subjects who were eligible and interested after telephone pre-screening were scheduled for a subsequent in-clinic screening/orientation session. Participants were requested to limit their intake of caffeinated beverages to no more than two cups taken before 8:00 AM on the days of their visits, and to consume no alcohol for 12 hours prior to their visits.

Screening/Orientation Session—Following an initial orientation and explanation of the study, interested participants were asked to provide informed consent and to complete additional assessments. First, participants provided an expired CO sample (Bedfont EC50

Micro III Smokerlyzer; Bedfont Scientific, Medford, NJ) to verify their eligibility. Second, participants completed a series of questionnaires to provide baseline measures of nicotine dependence, craving and withdrawal, and mood. Nicotine dependence was assessed by the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991), craving and withdrawal by the Wisconsin Smoking Withdrawal Scale (WSWS; Welsch et al., 1999), and mood by the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) and the Center for Epidemiologic Studies' Depression Scale (CES-D; Ross & Mirowsky, 1984). Third, participants were given detailed information about the RVIP-CED task and practiced it with feedback about their performance. Unlike the actual laboratory sessions, the practice RVIP-CED used pictures of geometric shapes as distracters instead of affective and smoking pictures.

At the end of the Screening/Orientation Session, we used an instrument based on the self-assessment manikin (SAM; Lang, 1980) to obtain participant ratings of each distracter picture. We administered the SAM ratings using E-Prime software (Psychology Software Tools, Pittsburgh, PA, USA), which presented each picture for 3 s, in a randomized order, followed by graphic scales on which the participant reported individual feelings of pleasure (i.e., valence) and arousal on a 9-point scale. The SAM valence scale showed a graphical representation of a figure with expressions ranging from happy (9) to unhappy (1), and the SAM arousal scale showed a figure with expressions ranging from excited (9) to calm (1). We also collected craving ratings on a 9-point scale, with 9=extreme craving and 1=no craving. Because of time constraints, each participant rated half of the 144 pictures.

Laboratory Sessions

Abstinence assessment and expectancy instruction: Prior to each of the four laboratory sessions, participants were required to abstain from smoking for 12 hours. Upon arriving at the lab, participants were seated in a small experimental chamber and compliance with nicotine deprivation instructions was assessed using expired CO, with participants required to produce CO levels below 10 ppm or 37.5% of their screening/orientation session CO value. The cutoffs were based on guidelines and findings that expired CO has a half-life of 2 to 8 hours, depending on activity level (Benowitz et al., 2002). Participants who failed biochemical verification of abstinence (which occurred on 15 occasions) were rescheduled and not reimbursed for nonabstinent sessions.

The participants next spent approximately 20 min completing questionnaires, including the PANAS and WSWS, along with items representing behavior likely to influence RT, including caffeine intake (number of cups in the past 12 h), alcohol intake (number of drinks in the past 24 h), and sleep (number of hours in the past 24 h). Following questionnaire completion, a 128-channel EEG sensor net (Geodesic Sensor Net; Electrical Geodesics Inc., Eugene, OR, USA) was applied, taking approximately 20 minutes. The participants then received expectancy instructions, informing them that they would either smoke a “regular cigarette containing nicotine” (Told-NIC) or a “placebo cigarette containing no nicotine” (Told-DENIC) following the “first half of the Numbers Task” designed to assess their “ability to pay attention.” Following the expectancy manipulation instructions, the participants completed the first block of the RVIPCED. After the first block of the RVIP-

CED task, participants smoked either a nicotine or denicotinized cigarette, followed by a second block of the RVIP-CED task, as part of a balanced placebo design manipulation the results of which will be detailed elsewhere, along with the EEG results. Here we focus on the results of the first block of trials only which were specifically designed to evaluate expectancy effects on attentional processes and reaction time. Participants received no performance-based compensation.

RVIP-CED task: In each 28-min block of the RVIP-CED, 1752 numeric digits (1–9) were presented for 800 ms, with no inter-trial interval, at the center of the computer monitor in 96-point font, interspersed with 288 slide distracters that also lasted 800 ms each (see Figure 1 for a diagram). A PC using E-prime software presented a 10 cm × 10 cm image of the digits and slides on a LCD monitor approximately 1 m from the participant's eyes. The small image size was selected to minimize scanning of the visual field. The participants were instructed to simultaneously push two buttons on a serial response box (model C-PKG-RSP-1000-01; Electrical Geodesics Inc., Eugene, OR, USA), using both index fingers, at the appearance of any third consecutive even or odd digits. Dual button presses were recorded to minimize issues of laterality, with the first button to be pressed recorded as the RT. Each block contained 192 counterbalanced target sequences (i.e., 3 consecutive even or odd digits), and 144 (75%) of the target sequences contained a slide distracter between the second and third digit, while 48 (25%) contained no distracters. Target sequences were pseudo-randomly presented such that no more than two target sequences occurred consecutively. There was a 30-s break at the midpoint of each block.

Picture Distracter Stimuli: The distracter slides were presented immediately prior to 75% of the target digits in order to evaluate their impact on smokers' attention to the RVIP task (Gilbert et al., 2005). The distracter slides were composed of four types, including smoking, pleasant, unpleasant, and neutral content. A total of 144 slides were selected for each category and were divided into four sets of 36 slides per category. Each set was randomly assigned to a session for each subject, with the within-block orders randomly selected such that no more than two consecutive slides of the same category were shown, to avoid any possibility of mood induction (Smith, Bradley, & Lang, 2005). Each of the 36 slide distracters per category were shown twice in a block, once during a target sequence and once between digits that were not part of a target sequence, for a total of 288 slide distracters per block. The pleasant, unpleasant, and neutral slides were drawn from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1999). The cigarette slides, consisting of smoking cues such as images of burning cigarettes and people smoking in a social context, were drawn from a set previously developed in our lab (Carter et al., 2006), as well as slides from the International Smoking Image Series (ISIS; Gilbert & Rabinovich, 1999). The slide sets were matched on valence and arousal ratings within each category and the pool of unpleasant and pleasant slides were matched for arousal.

Reaction Time: Mean RT to identify a target number sequence were calculated for each of the 2 (instruction) × 2 (session) × 4 (distracter slide type) conditions. Correct button presses occurring within a 150–1000 ms interval after target digit presentation were considered hits. There was no linear effect of session (time) on RT, $p > .16$. Other dependent measures

included the rates of true-positive responses (hits) and the number of false-positive responses to non-target stimuli.

We elected to use parametric measures of sensitivity and response bias because the distributions of both the d' sensitivity index (skewness = -0.09 , kurtosis = -0.39) and the c response bias index (skewness = -0.32 , kurtosis = -0.06) suggested that these measures were normally distributed. The sensitivity index was calculated as $d' = z(H) - z(FP)$, while the response bias index was calculated as $c = -0.5 (z[H] + z[FP])$, where z = z -score distribution, H = hit rate (number of hits/number of target digits), and FP = false positive rate (number of false positives/number of non-target digits and distracter pictures; Macmillan & Creelman, 2004). With the d' sensitivity index, the larger the value, the greater the hit rate and correct rejection rate. Values can potentially range from 0 to 4.65, with a d' value of 0 indicating that the participant could not discriminate true positives from false positives. Larger, more positive values on the c response bias index are indicative of a more conservative response bias (i.e., less hits and false positives) than smaller, more negative values, with values potentially ranging from -2.33 to 2.33 . Other measures we analyzed included accuracy $([H + CR] / TOT)$ and specificity $(CR / [CR + FP])$, where CR = correct rejection rate and TOT = total of all observations.

Twelve sessions with extremely low accuracy and/or high false positives, as determined by being in the lowest 5th percentile of the distribution on both the sensitivity (d') and response bias (c) indices, were removed from further statistical analyses. The sensitivity and response bias cutoffs were indicative of sessions where participant responded to targets at rates no greater than chance and with indiscriminate button pushing, respectively. One participant's initial session was removed because there were no hits on trials following distracters, suggesting a misunderstanding of the task instructions.

Statistical Analyses

Prior to analysis, the distributions of all variables were checked for skewness, outliers, and normality. We conducted repeated measures mixed models analyses on the RVIP-CED RT performance measures using SAS PROC MIXED (version 9.2; SAS Institute Inc., Cary, NC), with subject modeled as a random effect. The mixed model approach is a form of the generalized linear model (GLM) that allows for more specific estimation of the correlation structure of the residuals of the observations and will not exclude cases with missing observations, thus allowing the use of all available data (Bageilla, Sloan, & Heitjan, 2000). All descriptions of differences between means following a significant mixed model effect were the result of contrast comparisons of least-square means (LSM) and standard errors (SE) of fixed effects using tests of simple effects. For interactions involving continuous variables, we calculated slopes for average change over the continuous variable, reported as point estimates (PE) and SE (Point estimates are slopes that indicate change on a dependent measure for every 1-unit increase in the predictor, analogous to a regression beta statistic). To correct for the effects of multiple comparisons on type I error rate, the family-wise α levels ($p < .05$) of post hoc contrasts were adjusted using the Holm-Bonferroni correction (Seaman, Levin, & Serlin, 1991).

Results

Demographics

Demographics and baseline smoking behavior are displayed in Table 1. The typical participant was an African-American in his or her early 40's who smoked close to a pack a day.

Distracter Stimuli SAM and Craving Ratings

To evaluate the self-reported affect and craving evoked by the distracter pictures, we conducted separate main effects analyses of Distracter Type on the valence, arousal, and craving ratings. There was a significant main effect of Distracter Type on the valence, $F(3,138)=456.82$, $p<.0001$, arousal, $F(3,138)=1084.81$, $p<.0001$, and craving, $F(3,138)=535.85$, $p<.0001$, rating scales (see Figure 2). With the valence rating, we found the expected pattern (PLE>NEU>UNP; all pairwise $ps <.0001$). The CIG pictures were significantly less pleasant than PLE ($p=.0002$), but more pleasant than NEU ($p<.0001$). For the arousal rating, the PLE and CIG pictures did not differ from each other ($p<.61$), but both were significantly more arousing than the NEU and UNP pictures (all $ps <.0001$), which themselves differed from each other ($p<.0008$). In terms of craving rating, CIG pictures evoked the most craving, followed by PLE, UNP, and NEU (all pairwise $ps <.0001$). Overall, the craving ratings were positively correlated with the valence ($r=0.39$, $p<.0001$) and arousal ratings ($r=0.45$, $p<.0001$), and the valence ratings were positively correlated with the arousal ratings ($r=0.62$, $p<.0001$). These positive correlations remained significant even after partialing out the effects of distracter type and of the third rating not directly compared in each analysis.

Instructed Dose, Distracter Presence, and RT performance

To examine the impact of Distracter Presence (absent vs. present) and Instructed Dose (Told-DENIC vs. Told-NIC) on the RVIP-CED, we examined the impact of each of these variables, as main effects, on the RT performance measures. There were main effects of Distracter Presence on all performance measures (see Table 2), with participants producing shorter RT latency, lower sensitivity (d'), a more liberal response bias (c), greater hit rates, greater false positive rates, lower accuracy, and lower specificity to targets preceded by a distracter than to targets not preceded by a distracter picture. There were significant main effects of Instructed Dose on RT latency, response bias (c), false positive rate, and specificity, such that participants TOLD-NIC produced longer RT latency, a more conservative response bias, lower false positive rate, and greater specificity than when Told-DENIC.

Effects of Instructed Dose by Distracter Type on RT Performance

To determine whether Told-NIC reduced RT performance following cigarette compared to pleasant, unpleasant, and neutral distracters, we examined a series of Instructed Dose by Distracter Type interactions on the RVIP-CED RT performance measures. We found a main effect of Distracter Type for RT latency, $F(3,150)=2.91$, $p<.04$ (see Figure 3). Post hoc pairwise contrasts indicated that RT latency following UNP distracters were significantly

longer than RT latency following either NEU, $t(150)=2.84, p<.006$, or CIG, $t(150)=2.13, p=.04$. There were no main effects for Distracter Type on sensitivity (d'), response bias (c), hit rate, false positive rate, accuracy, or specificity. We found significant Instructed Dose by Distracter Type interactions for sensitivity (d'), $F(3,150) = 2.82, p < .04$. Post hoc pairwise contrasts indicated that sensitivity to targets following cigarette distracters was significantly lower during the Told-NIC conditions than during Told-DENIC, $t(150)=2.24, p<.03$ (see Figure 4). There were no significant Instructed Dose by Distracter Type interactions for the other RT performance measures.

Discussion

Our results support the notion that expectation of imminent nicotine use increases the attentional distraction on a vigilance task, and that this distraction is enhanced in the presence of cigarette cues. When told to expect nicotine, overnight nicotine deprived participants produced significantly longer RT latency, a more conservative response bias, a smaller false positive rate, and increased specificity than when told to expect no nicotine, suggesting that participants were more distracted by the expectation of smoking a nicotine cigarette. An alternative explanation could be that smokers expecting a nicotine cigarette were simply more motivated to engage in the task, and thus took a slower, more deliberative approach to the RVIP-CED task that resulted in greater accuracy. However, the Instructed Dose by Distracter Type interaction for sensitivity (d') suggests otherwise, as sensitivity to targets following CIG distracters was significantly lower during the Told-NIC than during Told-DENIC conditions. This suggests that overnight deprived smokers expecting to smoke a nicotine cigarette after completion of the RVIP-CED task block were more distracted by smoking-related cues than those not expecting to receive nicotine.

Our finding that expectation of imminent nicotine use increases the attentional distraction by smoking cues is consistent with several theoretical formulations that posit that perceived drug availability increases craving and attentional bias to drug cues (Baker, Morse, & Sherman, 1987; Field & Cox, 2008; Goldstein & Volkow, 2002). Our results are consistent with the finding that smoking availability increases smoking Stroop interference effects compared to those not expecting to smoke (Wertz & Sayette, 2001b). However, our findings, and those of Wertz and Sayette (2001b), that smoking availability increases attentional bias to smoking-related cues are not fully supported by Juliano and Brandon's (1998) findings. On the one hand, Juliano and Brandon found that smoking availability increased self-reported craving to smoking cues compared to unavailability. On the other hand, they found that smoking unavailability increased attentional bias on a vigilance task to smoking cues. Juliano and Brandon's findings are inconsistent with theories that postulate that drug craving and attentional bias towards substance-related cues function as a mutually excitatory positive feedback loop, meaning that conditions that increase one of these factors should result in an increase in the other (Field & Cox, 2008; Franken, 2003; Robinson & Berridge, 1993; Ryan, 2002). Juliano and Brandon's study differed from our and Wertz and Sayette's studies on three important factors. First, the cue stimulus modalities were different. Exposure to the smoking cues in our and Wertz and Sayette's studies involved representative stimuli (pictures and words, respectively), while the smoking cue exposure in the Juliano

and Brandon study involved in vivo smoking paraphernalia. Second, smoking cue proximity to the target stimuli differed. In our and Wertz and Sayette's studies, the smoking cues occurred immediately prior to or during target trials requiring button presses, but occurred before the RT vigilance task was started in Juliano and Brandon's study. Third, the abstinence durations differed. Juliano and Brandon only had participants refrain from smoking for 3 hr prior to their laboratory session, compared to 12 hr in our study and 11–13 hr in the Wertz and Sayette study. Determining how each of these factors interact with smoking availability to influence craving and attentional bias to smoking cues will require further research that directly compares cue stimulus modality, proximity to target task, and abstinence duration. Consistent with previous research involving a vigilance task (Gilbert et al., 2005; Most, Chun, Widders, & Zald, 2005), unpleasant pictures interfered with processing of target stimuli, as indicated by the increased RT latency to UNP compared to CIG, NEU, and PLE distracters (though the comparison to PLE was not statistically significant). This RT latency finding for UNP distracters is consistent with previous findings (Gilbert et al., 2005) and supports models that posit that the brain preferentially attends to unpleasant (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) and threatening (Öhman & Mineka, 2001) stimuli by interfering with the disengagement of attention (Fox, Russo, Bowles, & Dutton, 2001).

Our SAM and craving ratings data suggest that cigarette pictures were considered appetitive by smokers, as they were rated as pleasant and arousing compared to NEU, consistent with previous work by our lab (Carter et al., 2006) and others (Dempsey, Cohen, Hobson, & Randall, 2007; Muñoz et al., 2010). The positive correlations among our valence, arousal, and craving ratings were smaller than those previously reported (Muñoz et al., 2010), but in the same direction. However, two of our findings were discrepant with previous findings. First, PLE pictures generated greater craving ratings than UNP pictures. This finding is consistent with those of Muñoz and colleagues (2010) but contrary to our previous findings (Carter et al., 2006). Second, participants rated the UNP pictures as being less arousing than the PLE pictures despite our efforts to select sets of PLE and UNP pictures equivalent on IAPS arousal ratings. This is inconsistent with our previous work with both nicotine deprived and nondeprived smokers (Carter et al., 2006; Cinciripini et al., 2006), and with the IAPS literature in general (Bradley & Lang, 2007), in which pictures rated as more pleasant or unpleasant tended to be rated as more arousing. We surmise that participants may have conflated the arousal and valence ratings, based on anecdotal reports.

While previous RVIP studies used a 600 ms stimulus presentation interval (e.g., Gilbert et al., 2005), our piloting indicated that this presentation speed was too fast for our population, so we increased the interval to 800 ms. Our overall hit rate for the RT task, around 0.60, indicated that the 800 ms interval made the task neither too easy nor too difficult for our participants, thus avoiding ceiling and floor effects in RT performance. Additionally, with our RT design, we were unable to determine which aspects of attention our distracters influenced. That is, we are unable to determine whether our distracter-specific results are due to attentional orientation, engagement, or disengagement (Posner & Petersen, 1990). Our future studies will use event-related potentials (ERP) to further investigate the attentional time course of affective and cigarette-related distracters within the context of an expectancy manipulation.

Our findings have several implications. In terms of treatment implications, our findings suggest that reducing perceived opportunities to smoke may be an important component of smoking cessation counseling. Such reductions are likely to weaken the mutually excitatory positive feedback loop between attentional bias and craving (Field & Cox, 2008; Franken, 2003; Robinson & Berridge, 1993; Ryan, 2002), and hence promote abstinence. Additionally, our findings suggest that perceived smoking unavailability may even be a more important therapeutic focus than simply avoiding or removing smoking cues, particularly given the ubiquity of smoking cues in a smokers' environment. In terms of assessment implications, drug availability should be carefully considered when designing studies and interpreting results involving the measure of craving or attentional bias to drug cues. Nicotine deprived smokers who are able to smoke immediately after a laboratory session are likely to produce greater attentional bias and craving than deprived smokers who are unable or not intending to smoke after a laboratory session. In other words, perceived drug availability is likely to be confounded with drug withdrawal. Future studies should address this issue by using a balanced placebo design to separate out the effects of perceived drug availability and drug withdrawal.

In conclusion, our findings suggest that expectation of imminent nicotine use increases attentional distraction in general and attentional bias to cigarette cues in particular, at least among smokers who are nicotine deprived. Overnight nicotine deprived participants produced significantly longer RT latency, a more conservative response bias, a smaller false positive rate, and increased specificity when told to expect nicotine compared to when told to expect no nicotine, suggesting that participants were more distracted by the expectation of smoking a nicotine cigarette. Additionally, the sensitivity results suggest that this distraction was greater to smoking cues compared to affective or neutral stimuli.

Acknowledgments

This project was supported by the National Institute on Drug Abuse grant K23DA024697. The authors wish to thank Dr. Victoria L. Brown, Janeene P. Frerking, Danika D. Dirba, Silky A. Joshi, Tiffany L. Rattler, Sandra L. Stautberg, and Kevin A. Winslow for their assistance in data collection. Portions of these data were presented at the annual conference of the Society for Research on Nicotine and Tobacco-Europe on September 1, 2012, in Helsinki, Finland.

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Figure 1.
A diagram of the RVIP-CED task containing a cigarette picture distracter.

Figure 2.

Main effects of Distracter Type on the Valence (Val), Arousal (Aro), and Craving (Cra) SAM Rating scales. PLE = pleasant, CIG = cigarette, NEU = neutral, UNP = unpleasant distracter type. A score of 9 represents happy, excited, and extreme craving for the valence, arousal, and craving scales, respectively. Histograms represent least-square means, and error bars represent SE.

Figure 3.

Main effect of Distracter Type on RT. NEU = neutral, CIG = cigarette, PLE = pleasant, UNP = unpleasant distracter type. Post hoc pairwise comparisons: * = significantly different from UNP. Histograms represent least-square means and error bars represent SE.

Figure 4.

A significant Instructed Dose x Distracter Type interaction for sensitivity (d'). NEU = neutral, CIG = cigarette, PLE = pleasant, UNP = unpleasant distracter type, Told-DENIC = told cigarette contained no nicotine, Told-NIC = told cigarette contained nicotine, * = Post hoc pairwise contrast significantly different by Instructed Dose. Histograms represent least-square means and error bars represent SE.

Table 1

Demographics and baseline smoking behavior.

Variable	Mean	SD	Range
Age (years)	42.8	9.75	(21–60)
Cigarettes/day	17.8	7.53	(10–40)
Expired CO (ppm)	20.1	11.38	(8–57)
FTND	5.2	1.62	(2–8)
CES-D	9.6	8.93	(0–37)
	<u>N</u>	<u>%</u>	
Gender			
Men	29	56.9	
Women	22	43.1	
Race/Ethnicity			
African-American	28	54.9	
European-American	19	37.2	
Other	4	7.8	

Note. CO=Carbon Monoxide, FTND= Fagerström Test for Nicotine Dependence, CES-D=Center for Epidemiologic Studies' Depression Scale.

Table 2

Main effects for Distracter Presence and Instructed Dose on RVIP-CED RT performance measures (Mean [SE]).

Performance Measure	Distracter Presence		Instructed Dose					
	Absent	Present	$F_{(1,50)}$	p value	Told-DENIC	Told-NIC	$F_{(1,50)}$	p value
Reaction time, ms	520.27 (11.54)	460.29 (10.95)	229.95	.0001*	486.16 (11.12)	494.40 (11.12)	14.70	.0004*
Sensitivity d'	2.69 (0.10)	1.63 (0.10)	1027.4	.0001*	2.16 (0.10)	2.16 (0.10)	0.07	.80
Response Bias c	1.05 (0.04)	0.46 (0.04)	1419.7	.0001*	0.74 (0.04)	0.77 (0.04)	10.55	.002*
Hit Rate	0.59 (0.03)	0.63 (0.03)	13.70	.0005*	0.62 (0.03)	0.61 (0.03)	2.95	.10
False Positive Rate	0.01 (0.01)	0.05 (0.01)	69.87	.0001*	0.04 (0.01)	0.03 (0.01)	8.92	.004*
Accuracy	0.97 (.02)	0.79 (0.02)	969.06	.0001*	0.88 (0.02)	0.88 (0.02)	0.08	.78
Specificity	0.99 (0.01)	0.95 (0.01)	69.87	.0001*	0.96 (0.01)	0.97 (0.01)	8.92	.005*

Note:

Told-DENIC=participant expected a “placebo” cigarette, Told-NIC=participant expected a “regular” cigarette.

* significant after Holm-Bonferroni correction (adjusted $p < .05$).