Cognition and Craving During Smoking Cessation: An Ecological Momentary Assessment Study

Andrew J. Waters PhD1, Edwin H. Szeto BS1, David W. Wetter PhD2, Paul M. Cinciripini PhD3, Jason D. Robinson PhD3, Yisheng Li PhD4

1Department of Medical and Clinical Psychology, Uniformed Services University of the Health Sciences, Bethesda, MD; 2Department of Health Disparities Research, University of Texas MD Anderson Cancer Center, Houston, TX; 3Department of Behavioral Science, University of Texas MD Anderson Cancer Center, Houston, TX; 4Department of Biostatistics, University of Texas MD Anderson Cancer Center, Houston, TX

Corresponding Author: Andrew J. Waters, PhD, Department of Medical and Clinical Psychology, Uniformed Services University of the Health Sciences, 4301 Jones Bridge Road, Bethesda, MD 20814, USA. Telephone: 301-295-9675; Fax: 301-295-3034; E-mail: andrew.waters@usuhs.edu

Received February 4, 2013; accepted June 20, 2013

ABSTRACT

Introduction: Some studies using ecological momentary assessment (EMA) have revealed an association between craving for cigarettes and relapse. It is therefore important to understand the correlates of craving during smoking cessation. Attentional bias to smoking cues is a potential correlate of craving, but it has not previously been assessed using EMA during smoking cessation.

Methods: Smokers enrolled in a research smoking cessation study were offered the opportunity to take part in an EMA study. Volunteers carried around a personal digital assistant (PDA) for the first week of their quit attempt. They completed up to 4 random assessments (RAs) per day as well as assessments when they experienced a temptation to smoke and when they relapsed. Craving for cigarettes was assessed with a single item (1–7 scale). Attentional bias was assessed with a smoking Stroop task (a reaction time task) at every other assessment, as was self-reported attention to cigarettes.

Results: Data were available from 119 participants. Across 882 assessments, participants exhibited a significant smoking Stroop effect. Linear mixed models revealed a significant between-subject association between craving and the smoking Stroop effect. Individuals with higher levels of craving exhibited greater attentional bias. The within-subject association was not significant. Similar results were obtained for the relationship between self-reported attention to cigarettes and attentional bias.

Conclusions: Attentional bias can be assessed in the natural environment using EMA during smoking cessation, and attentional bias is a correlate of craving during the early stages of a quit attempt.

INTRODUCTION

Relapse is a central problem in smoking cessation treatment. When attempting to quit smoking, smokers report cravings for cigarettes, and some studies have reported that craving is associated with relapse (Shiffman et al., 1997; Wray, Gass, & Tiffany, 2013). Understanding the correlates of craving during smoking cessation may assist the development of new smoking cessation interventions.

Much recent research has focused on cognitive processes associated with craving and relapse (Wiers & Stacy, 2006). A number of researchers have highlighted the role of automatic (or implicit) cognitive processes (Baker, Piper, McCarthy, Majeskie, & Fiore 2004; Robinson & Berridge, 1993; Rooke, Hine, & Thorsteinsson, 2008; Tiffany, 1990; Wiers & Stacy, 2006). Automatic/implicit processes are fast, parallel, effortless, and may not engage conscious awareness. One widely studied automatic process in addiction is “attentional bias” to drug cues (Cox, Fadardi, & Pothos, 2006). Attentional bias refers to the tendency to automatically attend to drug cues and to maintain attention on those cues. It is often assessed using the drug Stroop task. In this task, participants are required to classify the colors of drug-related and neutral words (Cox et al., 2006). Slower responses on drug-related words are interpreted as an attentional bias to drug-related cues. Drug addicts generally exhibit an attentional bias to drug-related cues, whereas controls do not (Cox et al., 2006). In addition, studies have reported that attentional bias is prospectively associated with addiction outcomes (Carpenter, Schreiber, Church, & McDowell, 2006; Cox, Hogan, Kristian, & Race, 2002; Cox, Pothos, & Hosier, 2007; Janes et al., 2010; Marissen et al., 2006; Powell, Dawkins, West, & Pickering, 2010; Waters et al., 2003).

Cognition and craving during smoking cessation

Most pertinent to this article, Franken’s (2003) model assumes that attentional bias can cause or increase craving (see also Field & Cox, 2008). Individuals who exhibit greater attentional bias will be exposed to a greater number of smoking cues. Given that exposure to smoking cues increases craving (Warthen & Tiffany, 2009), this is one mechanism by which attentional bias can cause craving. Franken’s model also assumes that craving can cause attentional bias. A meta-analysis has confirmed that attentional bias is associated with craving (Field, Munafo, & Franken, 2009). However, the association is small to moderate in magnitude. In addition, the association is more robust for illicit drugs than for tobacco/alcohol (Field, Munafo et al., 2009).

Recently, craving and relapse to smoking have been rigorously examined using ecological momentary assessment (EMA). During EMA, assessments occur in the natural environment and can be scheduled at random times (“random assessments”; RAs), and/or when participants experience heightened motivational states (e.g., temptations) or complete certain behaviors (e.g., relapse). Numerous EMA studies have examined craving and smoking/relapse (Shiffman et al., 1997, 2002). It is also feasible to administer reaction time tasks to mobile devices in EMA studies (Shiffman, Paty, Gnys, Kassel, & Elash, 1995), including drug Stroop tasks (Waters, Marhe, & Franken, 2012).

In this study, we investigated the associations between craving and attentional bias in a naturalistic setting as smokers were attempting to quit. This study can reveal whether the laboratory findings generalize from that setting to the natural environment. In addition, each participant completed many assessments during EMA. Therefore, it is possible not only to examine between-subject associations (Do individuals who report higher craving exhibit greater attentional bias?) but also within-subject associations (Within individuals, is attentional bias greater at those assessments when they report higher craving?).

In this study, we also administered a self-report measure of attentional bias. Although the processes that give rise to attentional bias to drug cues operate largely automatically, there may be a conscious end product. A smoker trying to abstain may find him or herself staring at another smoker although he or she would have no insight into the automatic cognitive processes that caused the shift of attention. Although self-reported attentional bias is doubtless a crude outcome measure of the underlying automatic processes, a relationship between the smoking Stroop effect and self-reported attentional bias might be expected. Analogously, automatic/implicit attitudes assessed with the Implicit Association Test (IAT) are often correlated with self-reported attitudes, a finding that has been used to validate the IAT (Greenwald, Nosek, & Banaji, 2003).

In sum, we assessed craving and attentional bias in a naturalistic context using EMA. Participants were cigarette smokers who were attempting to quit smoking. We examined whether attentional bias was present in this context, and whether attentional bias was associated with craving and self-reported attentional bias.

METHODS

Participants

Participants were 119 adult cigarette smokers recruited from the Houston, TX (n = 57) and Washington, DC, metropolitan areas (n = 62) who volunteered to participate in an EMA study during the first week of a smoking cessation attempt. Participants were a subset of 268 participants who enrolled in the parent smoking cessation study. Of the 268 participants, the final 221 participants were offered the opportunity to enroll in the EMA study, and, of those, 129 volunteered to enroll, and 119 contributed data. The study was approved by the Institutional Review Boards of the University of Texas M. D. Anderson Cancer Center and the Uniformed Services University of the Health Sciences.

The inclusion criteria were as follows: aged 18–65; report smoking at least 10 cigarettes/day for the last year; be motivated to quit smoking within the next 4 weeks; have a home address and a functioning home telephone number; be able to speak, read, and write in English at an eighth-grade literacy level; and report that English is the first language. Exclusion criteria were as follows: active substance abuse or dependence; regular use of tobacco products other than cigarettes (e.g., cigars, pipes, smokeless tobacco); use of nicotine replacement products or other smoking cessation medications (e.g., varenicline, bupropion); another household member enrolled in the study; self-reported color-blindness; expired breath carbon monoxide (CO) < 10 ppm; pregnant or breast feeding; and indication of current suicidal ideation or depression.

The 119 participants (43% female) were on average 43.3-years-old (SD = 11.1), and they reported smoking 19.1 (SD = 7.9) cigarettes/day. On a race question, 52.9% of participants self-identified as White, 39.5% self-identified as Black, and 7.6% self-identified another category. The average score on the Fagerstrom Test of Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) was 5.11 (SD = 2.07), the average expired level of CO in breath at orientation was 20.1 ppm (SD = 8.66), and the average level of cotinine (a nicotine metabolite) in saliva was 405.1 ng/ml (SD = 242.0).

For the parent study, participants received $25 for an orientation session, and $50 for each of five laboratory sessions. Participants also received $2.50 for each RA that they completed during EMA.

Procedure

Participants for the parent study were first screened by a telephone interview during which tobacco history and demographic information were obtained. Eligible participants were invited to attend an orientation session, during which expired breath CO was assessed. Participants also completed the following assessments: the Rapid Estimate of Adult Literacy in Medicine (REALM; Davis et al., 1991), the Patient Health Questionnaire (PHQ; Spitzer, Kroenke, & Williams, 1999), Section K (nonalcohol psychoactive substance use disorders) of the Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998), and the Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 2006).

Eligible participants attended up to five additional laboratory visits. There were two prequit laboratory visits, a quit day visit (Week 0), a visit 1 week postquit day (Week +1), and a visit at end of treatment (4 weeks after Week 0). Participants were given a smoking diary to complete each day (see measures). At Week 0, participants could volunteer to take part in the 1 week EMA study. If they volunteered, participants were
trained how to use the PDA. They completed an assessment (which included the smoking Stroop task) on the PDA in the laboratory (included in analyses). They took the PDA away with them and completed up to four RAs daily on the PDA. Participants also completed participant-initiated assessments. They completed an assessment any time they experienced a temptation to smoke, defined as an occasion when they “felt an acute increase in the desire to smoke, or an occasion when they felt they came to the brink of smoking without actually smoking” by pressing a button labelled “temptation or lapse assessment.” If they lapsed, they were instructed to press this button, and they completed an assessment. Participants returned the PDA at Week +1.

**Treatment**

Participants received a standardized self-help manual that used a standard relapse prevention/cop ing skills approach. Participants also received individualized smoking cessation counseling from a licensed counselor that was based on standard and recommended smoking cessation/relapse prevention procedures as described in *Tobacco Use and Dependence Clinical Practice Guideline* (Fiore et al., 2008). Counseling sessions lasted approximately 15–20 min during each laboratory visit.

**Measures**

*Subjective Measures*

On PDA assessments (RAs and participant initiated), craving for cigarettes (“Right now”; “I am craving a cigarette”; 1 = strongly disagree to 7 = strongly agree) was assessed at every assessment. Self-reported attentional bias (“My attention is often drawn to cigarettes”; 1 = strongly disagree to 7 = strongly agree) was assessed at each assessment on which the smoking Stroop task was administered. Additional items, not reported here, assessed affect, contextual variables, and pharmacological variables.

*Smoking Stroop Task*

The smoking Stroop task described in Waters and Li (2008) was administered at every other assessment. Briefly, participants were informed that words written in red, green, or blue would be presented on the PDA screen, one after the other, and that their task was to indicate as rapidly and as accurately as possible which color the word was written in. They made a response by pressing one of three response buttons on the PDA using a stylus. Participants were instructed that they could ignore the meaning of the word itself, and that they just needed to respond to the color. At each assessment, participants completed a practice sequence of letter strings (e.g., HHHHH) (33 trials), followed by two test blocks of 33 trials each (separated by 5 s). One test block consisted of neutral words and other of smoking words. Each word was presented in capital letters, and remained on the screen until the participant responded or for 3 s if the participant did not respond.

*Materials.* There were 24 sequences of words (“lists”). Each list contained 11 smoking words and 11 neutral words drawn from the category “household objects” of comparable length and frequency (Waters & Li, 2008). A list was selected randomly (without replacement) at each assessment. Order of presentation of neutral and smoking words was counterbalanced over lists. A random sequence determined the order of presentation of words within each list.

*Scoring.* Reaction times (RTs) from incorrect responses were discarded, as were RTs <100 ms. To reduce the influence of RT outliers, we computed median RTs on smoking words and neutral words. The smoking Stroop effect for each assessment was computed as the median RT on smoking words minus median RT on neutral words.

**Task Interruption**

After the task, an item asked participants to report the number of occasions they were interrupted during the task (e.g., by the telephone ringing or by somebody trying to talk to them; response options: No times, 1 time, 2 times, 3 times, 4+ times).

*Smoking*

To assess number of cigarettes smoked each day, participants were required to make an entry in a smoking diary before they went to bed every day. To verify reports of abstinence, two biological measures of smoking were used: Cotinine levels in saliva and CO levels in exhaled breath (using a CO monitor, Vitalograph; SRNT Subcommittee for Biochemical Verification, 2002). On the PDA, an item assessed smoking so far that day (response options: Had not smoked that day; Had smoked that day).

*Relapse Status*

Relapse status at each assessment was coded as “abstinent,” “after relapse,” or “unknown.” The following were required for a designation of “abstinent”: (a) no reported smoking on the PDA or on the smoking diary, (b) breath CO level <13 ppm at Week 0 and <10 ppm at Week +1, and (c) level of cotinine in saliva < 15 ng/ml at Week +1. Assessments occurring after reported smoking on the PDA or diary were coded as “after relapse.” “Unknown” cases occurred when a participant did not report any smoking (PDA or diary), but his or her CO or cotinine levels in saliva at the Week +1 visit indicated smoking, meaning that the timing of relapse was unknown.

**PDA Hardware and Software**

A HP iPAQ Pocket PC was used. Participants could prevent the PDA from presenting RAs for up to 2 hr (“suspend” function), and could delay RAs by 5 min (up to 3 times per RA).

**Data Analysis**

Of the 129 participants who volunteered for the EMA study, 119 contributed data. Two PDAs were reportedly stolen, and data from eight participants were lost due to participant error (failure to charge the PDA) or researcher error. The 119 participants completed 2,441 assessments. Data from the Stroop task were available from 1,322 assessments. On this task, number of reported interruptions during task performance was associated with slower overall RTs on the task (mean of RTs on neutral and smoking words; $p < .0001$), greater number of errors ($p < .0001$), and greater RT variability ($p < .0001$), but was not associated with the smoking Stroop effect ($p > .1$). The primary analyses were conducted on assessments with
Cognition and craving during smoking cessation

no reported interruptions (68.3% of assessments). On the 903 interruption-free assessments, the error rate was 2.97% (SD = 6.20). Assessments on which there were 17 or more errors (>25% errors) were excluded from analysis (17 assessments, 1.88% of assessments), as were assessments on which the smoking Stroop effect was greater than or less than 4 SDs from the grand mean (4 assessments, 0.45% of assessments), leaving 882 assessments (678 RAs, 204 participant initiated) for primary analyses. Self-reported attentional bias was introduced midstream, and data were available from 793 assessments (108 participants).

Linear mixed models (LMM) were used for the primary analyses using SAS PROC MIXED. LMM analyses take into account the dependence between observations due to clustering of the data by participants, and allow for different numbers of observations across participants. For all models, we used a random (subject-specific) intercept and an autoregressive model of Order 1 for the residuals within subjects. Parameter estimates were reported as a (unstandardized) measure of effect size (Wilkinson, 1999).

The dependent variable was the smoking Stroop effect. The primary independent variables, which were assessed before the smoking Stroop task during a PDA assessment, were craving for cigarettes and self-reported attentional bias (tested in separate models). To account for the effect of time, day in study was entered as a continuous variable, as was assessment number during the day. Assessment type (RA vs. participant initiated), location of assessment (lab vs. field), and relapse status at the time of assessment (three levels) were included as class variables. The coefficients of the assessment-level primary independent variables, craving for cigarettes and self-reported attentional bias, were treated as fixed effects in the LMMs because the p value for the likelihood ratio test (testing the need for random slopes for the primary independent variable) was greater than .1 (Fitzmaurice, Laird, & Ware, 2011; Verbeke & Molenberghs, 2000). If these coefficients were treated as random effects (which allows the relationship between the independent variable and the dependent variable to differ across subjects), the results (data not shown) were similar and this did not change any of the conclusions. The same was true for day in study and other assessment-level variables.

A significant parameter estimate for craving would indicate a significant relationship between craving and attentional bias, but it would not reveal the source of the relationship. The association could be a between-subject effect and/or a within-subject effect (Preacher, Zyphur, & Zhang, 2010). We, therefore, ran an additional model that included subjects’ mean craving (a subject-level variable) as well as a difference score (an assessment-level variable) between the observed craving at each assessment and the mean craving (Hedeker, Mermelstein, Berbaum, & Campbell, 2009), as well as the covariates listed above. A significant effect for mean craving would indicate a between-subject effect. That is, individuals who report generally higher levels of craving exhibit generally greater smoking Stroop effects. A significant effect for the difference score would reveal a within-subject effect. That is, within individuals, assessments with a higher craving score are associated with a greater smoking Stroop effect. The same procedure was used to analyze the association between self-reported attentional bias to smoking and the smoking Stroop effect.

RESULTS

Aggregated over participants (N = 119), the mean craving rating was 3.66 (SD = 1.58), and the mean self-reported attentional bias rating was 3.63 (SD = 1.50). The mean RT on neutral words was 808.3 ms (SD = 162.8), and the mean RT on smoking words was 826.3 ms (SD = 170.1). The mean smoking Stroop effect was 17.9 ms (SD = 46.6), which was significantly different from zero, t(118) = 4.19, p < .0001, Cohen’s d = 0.38.

Association Between Craving and Smoking Stroop

The relationship between craving and the smoking Stroop effect across assessments (n = 882) is shown in Figure 1. Using LMM, craving was positively associated with the smoking Stroop effect (Table 1, Model A). On assessments with no reported craving (craving = 1), there was no attentional bias, M = -4.00 ms, SE = 7.78, t = -0.51, p > .1. On assessments with at least minimal levels of craving (craving = 2 or more), there was significant attentional bias, M = 18.6 ms, SE = 3.98, t = 4.67, p < .0001.

To examine the source of this association, mean craving was entered as a subject-level variable, and difference in craving was entered as an assessment-level variable. Mean craving was significantly associated with the smoking Stroop effect (Table 1, Model B). The association persisted when FTND scores were included in the model, PE = 6.01, SE = 2.36, p = .01. The association between the difference score and the smoking Stroop effect was not significant (Table 1, Model B). To illustrate the significant between-subject association, we computed mean craving and mean smoking Stroop scores for all individuals, and correlated the two mean scores, Pearson’s r (117) = .28, p < .01 (Figure 2).

In a secondary sensitivity analysis, we recomputed LMMs including assessments that involved at least one interruption. This analysis (n = 1,288) revealed similar findings to the primary analysis: a significant effect of mean craving (p < .05) but no effect for difference in craving (p > .1).

Association Between Self-Reported Attentional Bias and Smoking Stroop

Using LMM, self-reported attentional bias was marginally positively associated with the smoking Stroop effect (Table 1.

![Figure 1. Relationship between attentional bias (ms) (smoking Stroop effect) and craving over assessments (n = 882). Error bars are ±1SE.](image-url)
Table 1. Results of Linear Mixed Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictor variables</th>
<th>n₁</th>
<th>n₂</th>
<th>F</th>
<th>df</th>
<th>PE</th>
<th>SE</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Craving</td>
<td>882</td>
<td>119</td>
<td>7.43</td>
<td>1,757</td>
<td>4.50</td>
<td>1.65</td>
<td>.007</td>
</tr>
<tr>
<td>B</td>
<td>Mean craving</td>
<td>882</td>
<td>119</td>
<td>6.19</td>
<td>1,756</td>
<td>5.84</td>
<td>2.35</td>
<td>.013</td>
</tr>
<tr>
<td>C</td>
<td>Difference from mean</td>
<td>882</td>
<td>119</td>
<td>1.71</td>
<td>1,756</td>
<td>3.12</td>
<td>2.39</td>
<td>.19</td>
</tr>
<tr>
<td>D</td>
<td>Mean attention</td>
<td>793</td>
<td>108</td>
<td>3.57</td>
<td>1,679</td>
<td>3.58</td>
<td>1.90</td>
<td>.059</td>
</tr>
<tr>
<td></td>
<td>Difference from mean</td>
<td>793</td>
<td>108</td>
<td>0.09</td>
<td>1,679</td>
<td>0.95</td>
<td>3.11</td>
<td>.76</td>
</tr>
</tbody>
</table>

Note. n₁ = number of assessments; n₂ = number of subjects; F = F value from linear mixed model; PE = parameter estimate; SE = standard error.

For each model, the dependent variable was the smoking Stroop effect. In Model A, craving was the primary predictor variable. In Model B, subjects’ mean craving (subject-level variable) and difference from mean (assessment-level variable) were the two primary predictor variables (entered together). In Model C, self-reported attention was the primary predictor variable. In Model D, subjects’ mean attention (subject-level variable) and difference from mean (assessment-level variable) were the two primary predictor variables (entered together). All models included the following covariates: day in study, number during day, assessment type, smoking status at assessment, and location of assessment (see text for details).

DISCUSSION

The main findings were as follows. First, participants exhibited significant attentional bias, as assessed by the smoking Stroop task on a PDA, during the first week of a smoking cessation attempt. Second, in a between-subject analysis, craving was associated with attentional bias. Individuals who reported higher craving during the week exhibited greater attentional bias. Third, in a between-subject analysis, self-reported attentional bias was associated with attentional bias measured by the smoking Stroop task. Again, individuals with higher self-reported attentional bias during the week exhibited greater measured attentional bias. Last, there was little evidence of a within-subject association for the relationship between craving and attentional bias or for the relationship between self-reported attentional bias and attentional bias measured by the smoking Stroop task.

Over all individuals, the mean smoking Stroop effect was 17.9 ms, with a small to moderate effect size (d = 0.38). In a comparable study of heroin/cocaine addicts undergoing the first week of detoxification (Waters et al., 2012), the mean drug Stroop effect (aggregated over heroin and cocaine Stroop tasks) was 40.7 ms (SD = 57.8 ms), a larger effect size (d = 0.70). Attentional bias in smokers attempting to achieve abstinence may be of smaller magnitude than attentional bias in heroin/cocaine addicts attempting to achieve abstinence. This difference, if real, may be due to between-drug differences in the incentive salience of cues. Alternatively, differences in executive function between the two populations may account for the smaller effect size in smokers (Field & Cox, 2008).

The observed between-subject association between craving and attentional bias was of modest magnitude. Laboratory studies have also reported between-subject associations (between craving and attentional bias) of small to moderate magnitude (Field, Munafo et al., 2009), particularly for smokers. Moreover, the causal relationships between attentional bias and craving remain unclear. Attentional bias may cause craving, craving may cause attentional bias, or a third variable may underlie the association. In this study, the between-subject association persisted when controlling for nicotine dependence. Several researchers have manipulated attentional bias as an independent variable and examined the effect of this manipulation on craving. These studies have not yielded definitive

Figure 2. Relationship between mean attentional bias (ms) (smoking Stroop effect) and mean craving over subjects (n = 119). Dots are data from individual participants.

Model C). To examine the source of this association, mean self-reported attentional bias was entered as a subject-level variable and difference in self-reported attentional bias was entered as an assessment-level variable. Mean self-reported attentional bias was significantly associated with the smoking Stroop effect (Table 1, Model D). The association persisted when FTND scores were included in the model, PE = 5.04, SE = 2.37, p = .03. The association between the difference score and the smoking Stroop effect was not significant (Table 1, Model D). The association persisted when PEFTND scores were included in the model, PE = 5.04, df = 2.37, p < .01.

In a secondary sensitivity analysis, we recomputed LMMs including assessments that involved at least one interruption. This secondary analysis (n = 1,162) revealed a marginally significant effect of mean self-reported attentional bias (p = .07) and no effect for difference in self-reported attentional bias (p > .1).

Moderators of Associations

In secondary analyses, we examined whether the magnitude of the associations differed (a) over days in the study or (b) as a function of abstinence. None of the pertinent interaction terms was significant (all ps > .10).
conclusions, with some studies reporting an effect of attentional retraining on craving (Attwood, O’Sullivan, Leonards, Mackintosh, & Munafo, 2008; Field & Eastwood, 2005, males only), and others reporting no effect (Field, Duka, Tyler, & Schoenmakers, 2009; Schoenmakers, Wiers, Jones, Bruce, & Jansen, 2007).

The within-person association between attentional bias and craving was not statistically significant. The meaning of this null effect is not clear. Theoretical models assume a tight coupling between attentional bias and craving (Franken, 2003; Field & Cox, 2008), and there is little theoretical reason to believe that an association between attentional bias and craving should be limited to a between-subject association. Taken at face value, the data suggest that individuals who generally exhibit higher attentional bias generally experience more craving, but when an individual exhibits higher attentional bias (relative to their mean) they do not experience higher craving (relative to their mean). Clinically, this suggests that smokers who generally exhibit high attentional bias when abstinent may benefit from treatment that reduces attentional bias (or craving), but a particularly elevated attentional bias may not be an acute precipitant of craving (or vice versa). However, this conclusion is stated with caution given that a within-subject association is expected from theory, and given that, as noted below, a within-subject association may have been more difficult to detect than a between-subject association in this study.

Related to previous points, perhaps the overarching conclusions of this study are that attentional bias in smokers, assessed using the smoking Stroop task, is of modest magnitude, even when smokers are attempting to quit, and that the same is true for the association between attentional bias and craving (see also Waters & Li, 2008). Further research is required to disambiguate whether (a) the “true” association between attentional bias and craving is indeed modest, as suggested by this study and the findings of Field, Munafo et al. (2009), or (b) the “true” association is strong, as suggested by theory (Field & Cox, 2008; Franken, 2003), but its detection has been obscured by methodological problems (see Waters & Leventhal, 2006). For example, measurement error in the assessment of attentional bias will attenuate the magnitude of associations with craving. For example, inaccuracies in the measurement of reaction times on the PDA platform will decrease the reliability of the attentional bias measure, and this may be particularly important for the within-subject analyses which aggregate over fewer events. Similarly, craving was assessed using a single item, and multiitem measures of craving may fare better. Finally, smokers may be able to recruit strategic processes to counteract the effect of the distracting smoking words, and these strategic processes may diminish the magnitude of the observed attentional bias as well as the association with craving.

The study had several limitations. First, the self-reported attentional bias measure and the craving measure were both single items. Future research should administer multiitem assessments. Second, participants were monitored for 1 week. A longer period of monitoring and/or more aggressive monitoring would permit collection of larger datasets that may facilitate the detection of within-subject associations between attentional bias and craving. Third, we did not examine the influence of assessment type (e.g., RAs vs. temptations vs. lapses) and relapse on craving and attentional bias. Fourth, there are limitations with the modified Stroop task, an “indirect” measure of attentional bias, which is derived from reaction time data as described earlier (Field et al., 2009). For example, some data suggest that “direct” measures of attentional bias (including measures of eye gaze) exhibit a stronger correlation with craving than “indirect” measures based on reaction times (Field et al., 2009). Fifth, analyses were restricted to those participants who volunteered for the study and who provided data. The generalizability of the findings to the sampled population or the broader smoking cessation population is unknown. Last, the reported analyses did not reveal information on the causal relationships between craving and attentional bias.

The study also had strengths. In particular, this was the first study to examine the association between craving and attentional bias in smokers attempting to quit in a naturalistic setting. The study design also allowed us to examine both the between-subject and within-subject associations between attentional bias and craving, a novel approach in this literature.

In sum, this study revealed that smokers who exhibit greater attentional bias in the natural environment during the first week of a quit attempt report more craving. EMA could plausibly be used to track both attentional bias and craving during the early stages of smoking cessation, when the risk of relapse is high. These data may ultimately help to identify those individuals at risk of early relapse.

FUNDING
This study was funded by National Institutes of Health (R01 DA020436 to AJW).

DECLARATION OF INTERESTS
None declared.

ACKNOWLEDGMENTS
The authors thank Elizabeth Miller, Angela Burgess, Kyle Noll, Sunetra Martinez, Don Wiley, Evan Odenksy, William Kerst, Jessica Forde, Brigid Rowell, and Marilyn Ritzau for assistance with data collection and/or administering therapy.

REFERENCES


Cognition and craving during smoking cessation


