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Ecological Momentary Assessment of Antecedents and Consequences of Smoking in Adults with Attention-Deficit/Hyperactivity Disorder

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Abstract

The current study assessed antecedents and consequences of *ad lib* cigarette smoking in smokers diagnosed with attention-deficit/hyperactivity disorder (ADHD) using ecological momentary assessment (EMA). Adult smokers with ADHD ($n = 17$) completed 870 smoking and 622 nonsmoking electronic diary entries over a seven-day observation period of their naturalistic smoking behavior. Data collection occurred from 2011 to 2012. Generalized estimating equations indicated that ADHD smokers were more likely to smoke when urge to smoke, negative affect, boredom, stress, worry, and restlessness were elevated. In addition, participants were more likely to smoke in situations that elicited higher levels of nervousness and frustration. ADHD symptoms, in general, did not differ between smoking and nonsmoking contexts, though hyperactive-impulsive ADHD symptoms were elevated prior to smoking in frustrating situations. Additional situational antecedent variables were associated with smoking, including being in the presence of others smoking, being in a bar or restaurant, while outside, and while consuming caffeinated or alcoholic beverages. Participants also reported a significant improvement in urge to smoke, negative affect, stress, hunger, and ADHD symptoms after smoking a cigarette. Findings suggest certain contextual factors that may maintain *ad lib* cigarette smoking in smokers with ADHD and identify potential treatment targets in smoking cessation interventions for this at-risk group. Clinical implications and future research directions are discussed. Funding for this study was provided by the National Institute on Drug Abuse.

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Declaration of interests

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Keywords

attention-deficit/hyperactivity disorder; nicotine dependence; cigarette smoking; affect; emotion dysregulation; ecological momentary assessment

Introduction

Cigarette smoking is common among a broad range of psychiatric disorders (Lasser et al., 2000). Compared to the general population or nondiagnosed controls, individuals diagnosed with attention-deficit hyperactivity disorder (ADHD) are more than twice as likely to smoke (Lambert & Hartsough, 1998; Milberger, Biederman, Faraone, Chen, & Jones, 1997; Molina & Pelham, 2003; Pomerleau, Downey, Stelson, & Pomerleau, 1995); initiate smoking at an earlier age and progress to regular smoking (Rohde, Kahler, Lewinsohn, & Brown, 2004); and have more difficulty quitting (Covey, Manubay, Jiang, Nortick, & Palumbo, 2008; Humfleet et al., 2005). Even after accounting for psychiatric comorbidity, ADHD is an independent risk factor for smoking (Milberger et al., 1997; Molina & Pelham, 2003). Further, subclinical ADHD symptoms confer an increased risk for lifetime smoking (Kollins, McClernon, & Fuemmeler, 2005). However, despite the robust relationship between ADHD and cigarette smoking, relatively little is known about proximal variables that influence smoking behavior in individuals diagnosed with ADHD.

The self-medication hypothesis is typically applied to ADHD to account for increased risk for smoking. This hypothesis proposes that because of the stimulating effects of nicotine and the subsequent improvement on attentional and cognitive processes that are identified as dysfunctional in individuals diagnosed with ADHD, ADHD smokers may experience an improvement in ADHD symptoms as a consequence of smoking (Gehricke et al., 2007; Glass & Flory, 2010). Similar improvements are also proposed for negative mood (Gehricke et al., 2007). Thus, ADHD symptoms and negative mood would be predicted to improve immediately after smoking a cigarette. Such consequences are proposed to maintain smoking behavior over time.

Previous studies of small groups of smoking and nonsmoking adults with ADHD demonstrate improvement in self-reported concentration, clinician ratings of overall symptom severity, and performance on computerized cognitive tasks following nicotine administration via transdermal patch (Conners et al., 1996; Levin et al., 1996; Potter & Newhouse, 2008). Other studies have also demonstrated improvement in depressed mood as well in nonsmoking adults with ADHD (Levin, Conners, Silva, Canu, & March, 2001). Overall, these findings are consistent with predictions that one function of smoking in ADHD smokers is that it improves mood and ADHD symptoms. Further, these findings also appear to translate to reports of *ad lib* smoking as well. For instance, two recent studies using retrospective self-report measures assessing *ad lib* smoking both indicate that ADHD smokers perceive smoking as providing cognitive enhancement and negative reinforcement of aversive internal states (e.g., dysphoria) than non-ADHD smokers (Mitchell, McIntyre, McClernon, & Kollins, 2014; Van Voorhees et al., 2012). In addition, smokers with ADHD report greater withdrawal symptoms (independent of ADHD symptoms), including negative

affect, while abstaining from smoking than non-ADHD smokers (McClernon et al., 2011). Though these findings are promising, ecologically valid studies of *ad lib* smoking are needed (Glass & Flory, 2010; McClernon & Kollins, 2008) as cigarette smokers are often inaccurate in retrospectively recalling details about smoking (Shiffman et al., 1997). Given that symptoms of ADHD include chronic difficulties with forgetfulness, smokers with ADHD are particularly well-suited for an assessment approach that minimizes the need for retrospective recall.

Application of ecological momentary assessment (EMA) to assess smoking behavior in-the-moment in adults diagnosed with ADHD provides preliminary support for the self-medication hypothesis and addresses concerns involving ecologically-valid assessment. In these studies, Gehricke and colleagues demonstrated that transdermal nicotine was associated with a reduction of ADHD symptoms (Gehricke, Hong, Whalen, Steinhoff, & Wigal, 2009; Gehricke, Whalen, Jamner, Wigal, & Steinhoff, 2006) and negative mood (Gehricke et al., 2009). Though these studies employed EMA with ADHD smokers, neither addressed the consequences of *ad lib* smoking in ADHD as both samples were assessed in smoking abstinent conditions. In another study on the effects of ADHD medication on cotinine levels and nicotine withdrawal symptoms in ADHD smokers (Gehricke, Hong, Wigal, Chan, & Doan, 2011), smoking urge, ADHD symptoms, and stress were assessed via EMA over two separate, two day assessment periods. Both assessment periods involving EMA entries differed based on ADHD medication status (i.e., ADHD medication or placebo). Over both assessment periods, participants completed EMA entries after smoking each cigarette and in nonsmoking situations. Although *ad lib* smoking was assessed, immediate conditions prior to smoking (i.e., pre-cigarette entries) were not measured to serve as a baseline to assess changes in ADHD symptoms after smoking. Further, ADHD medications reduce ADHD symptoms in smokers diagnosed with ADHD (Kollins et al., 2012; Winhusen et al., 2010) and participants were administered an ADHD medication during one of the two assessment periods. Therefore, the study design does not allow for assessment of the consequences of *ad lib* smoking on ADHD symptoms.

In addition to emphasizing the consequences of smoking, the self-medication hypothesis also suggests that certain situational cues may prompt smoking in individuals with ADHD. For instance, poor concentration may cue tobacco use among ADHD smokers given the effect of nicotine on cognition. Although no studies have assessed antecedents to *ad lib* smoking in an ADHD sample naturalistically, EMA studies in nonclinical samples indicate that urge to smoke or craving, consumption of coffee and food, and the presence of other smokers are predictive of smoking (Carter et al., 2008; Shiffman et al., 2002; Shiffman & Paty, 2006; Shiffman, Paty, Gwaltney, & Dang, 2004). Negative mood states have been predictive of smoking behavior in some EMA studies including nonclinical smokers (Carter et al., 2008; Delfino, Jamner, & Whalen, 2001), but not others (Shiffman et al., 2002; Shiffman et al., 2004).

The overall goal of this study was to examine the impact of smoking antecedents and consequences of smoking on ADHD symptoms and affect among cigarette smokers with ADHD by utilizing EMA. Within a sample of adult ADHD cigarette smokers, ADHD symptoms and affect were assessed immediately prior to and following smoking episodes. In

addition, ADHD symptoms and affect were assessed in nonsmoking contexts as well. To date, no studies have considered naturalistic *ad lib* smoking behavior using EMA among adult ADHD smokers to assess the antecedents and consequences of smoking. Further, no studies have assessed *ad lib* smoking using EMA in adult ADHD smokers for more than two consecutive days—we proposed to extend this period to seven days. This assessment period is consistent with other studies examining *ad lib* smoking behavior using EMA in other comorbid psychiatric samples (e.g., Beckham et al., 2008). A longer observation period over the course of seven days also allows for more assessments, which is thought to provide a greater sampling of participant smoking experiences and to improve reliability.

A within subject design in a sample of regular cigarette smokers diagnosed with ADHD was adopted. We hypothesized that smokers with ADHD would be more likely to smoke in situations in which ADHD symptoms and negative affect were elevated; similarly, smokers with ADHD would also be more likely to smoke in situations eliciting the need for greater cognitive control and eliciting higher negative affect. We further predicted that smokers with ADHD would report a significant reduction in ADHD symptoms and negative affect after smoking. Variables such as location, social setting, activity status, and consumption (e.g., food, caffeine, alcohol) were also measured to assess whether additional situations predispose individuals with ADHD to smoke.

Methods

Participants

A total of 19 adult smokers diagnosed with ADHD were initially enrolled. Electronic diary data from two participants was excluded due to excessive noncompliance, resulting in 17 smokers with at least seven days of electronic diary entries for analysis as the final sample (Table 1). Based on previous studies demonstrating that (a) EMA results in decreased error variance, thereby increasing statistical power and allowing for smaller sample sizes relative to non-EMA approaches (McKenzie, 2004), and (b) small sample sizes (e.g., $n = 17$) yield largely identical results to larger samples when assessing antecedents to smoking in EMA research (Shiffman et al., 2004), we chose a sample size of approximately 20 adult smokers diagnosed with ADHD.

Participants were recruited from the community via advertisements, word of mouth, and referrals from local clinics. Inclusion criteria included age 18–50 years; met DSM-IV criteria for ADHD; smoked 10 cigarettes per day of a brand delivering at least 0.5mg nicotine; provided expired CO concentrations 10ppm; intellectual functioning 80 as assessed by an IQ screener; and were generally healthy (i.e., no major medical problems). Exclusion criteria included: met criteria for *DSM-IV* Axis I disorders other than ADHD or nicotine dependence; illicit substance use; unable to attend all required experimental sessions; were pharmacologically treated in the past month; and, if they were female, were pregnant or planned on becoming pregnant. This study was approved by the local Institutional Review Board.

Forty potential participants completed a telephone prescreen, and 36 were invited for an in-person screening visit. Among the reasons for being excluded following the telephone

prescreening included: scheduling difficulty ($n = 1$), smoking too few cigarettes ($n = 1$), ongoing marijuana use ($n = 1$), and currently taking psychoactive medications ($n = 1$). Among the 36 invited for the in-person screening, five had repeated scheduling difficulties, five repeatedly missed the in-person appointment, and seven failed the in-person screening for various reasons ($n = 2$ failed a urine drug test, $n = 1$ scored below the IQ cut-off, $n = 1$ did not meet diagnostic criteria for ADHD, $n = 2$ met criteria for a comorbid disorder, and $n = 1$ was already receiving ongoing psychoactive medication treatment).

Measures

Screening Measures—Following informed consent, demographic information and medical, psychiatric, smoking, and substance use histories were collected. Baseline nicotine dependence was assessed with the Fagerström Test for Nicotine Dependence (FTND) (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991), smoking status was verified by expired CO concentrations, and IQ was assessed by the Kaufman Brief Intelligence Test, Second Edition (Kaufman & Kaufman, 2004). The Conners Adult ADHD Rating Scale (CAARS)-Self-Report (Conners, Erhardt, & Sparrow, 1999), followed by the Conners Adult Diagnostic Interview for *DSM-IV* (CAADID) (Epstein, Johnson, & Conners, 2000) to assess full ADHD diagnostic criteria, and the computerized Structured Clinical Interview for the *DSM-IV* (SCID) (First, Spitzer, Williams, & Gibbon, 2002) with follow-up clinical interviewing to assess Axis I disorders by a PhD-level clinical psychologist.

EMA Measures—Current craving for a cigarette, situational variables, affect, and ADHD symptoms were assessed via electronic diary (Table 2). Craving was assessed by one item and situational variables were assessed by 10 items (all items listed in Table 2). Affect was assessed by 20 items from the PANAS (Watson, Clark, & Tellegen, 1988) and six additional affect items associated with smoking (Beckham et al., 2005). All 18 *DSM-IV-TR* inattentive and hyperactive-impulsive ADHD symptoms were assessed as well (APA, 2000). All items were administered for full assessments for nonsmoking entries and full assessments for the pre-cigarette portion of smoking entries. For the post-cigarette portion of smoking entries, all but the situational items were administered.

Procedures

Following the in-person screening, participants eligible to enroll in the study were scheduled for an appointment to start a one-day practice using the electronic diary and then to begin a seven-day electronic diary assessment period.

One-day diary training—Participants received individual electronic diary training. Assessment questionnaire and a random alarm mechanism were designed with Entryware Designer software version 6.3 developed by Technos Systems, Inc. The electronic diaries were administered on Treo 755P handheld computers. Following one day of practice entries, questions were addressed and participants were provided feedback on their compliance with the electronic diary.

Seven-day observation period—After completing training in the use of the handheld electronic diaries, participants began a seven-day sampling period. During this period,

participants provided two types of ratings: (a) nonsmoking alarm entries and (b) self-initiated smoking entries for each cigarette smoked.

Nonsmoking alarm entries took approximately 2–4 minutes. These entries included questions about the participant's situation, affect, and ADHD symptoms. Nonsmoking alarm entries were initiated by an audible alarm approximately every 2.5 hours during waking hours to result in approximately five to six alarms per day. If participants did not respond within two minutes after the alarm sounded (six audible beeps), the electronic diary would not allow the participant to respond to that alarm, a missed alarm was recorded, and the alarm would reset to go off approximately 30–40 minutes later. If participants did respond within two minutes to an alarm, they were provided the option to choose “snooze” (the alarm would sound five minutes later), “skip” (the alarm would be delayed and sound 30–40 minutes later) or “answer.” Participants were instructed on how to turn off the audible alarm while they slept, and for short periods during the day when it may be dangerous (e.g., driving) or inappropriate (e.g., showering) to respond. Participants were allowed to choose how long to temporarily turn off the audible alarm, though the alarm did not require any reactivation by the participant as it was programmed to automatically resume following the period it was turned off by the participant. For all alarm entries, participants were asked if they were in the middle of smoking or had smoked within five minutes. If so, the reading was terminated and thus ensured that the nonsmoking alarm entries were not completed during or immediately following smoking occasions. No other alarm entries were abbreviated.

Participants were also requested to initiate electronic diary readings immediately prior to and following each cigarette. Full assessment entries took approximately 2–4 minutes. Initiated entries included questions about the current situation participants were in (only for the pre-cigarette portion of the entry), affect (for pre-and post-cigarette), and ADHD symptoms (for pre- and post-cigarette). To reduce participant burden, electronic diaries were programmed to present full assessments for self-initiated entries approximately five times per day and allow the remaining assessments to be abbreviated consistent with our previous applications of EMA (Beckham et al., 2008). Abbreviated entries assessed craving for a cigarette prior to smoking, then instructed participants that they completed the entry.

Participants were compensated up to US\$385, which included \$300 for study completion, \$40 for not missing more than three alarms per day, \$30 for returning electronic diary equipment at the end of the study, and an additional \$15 for returning to the laboratory for any electronic diary technical difficulties. Regarding the latter, a total of two such visits were required across all participants.

Data Reduction and Analysis

Electronic diary data reduction—Electronic diary data was assessed for both types of entries: nonsmoking alarm and self-initiated smoking entries.

The minimal time limit for nonsmoking alarm entries was < 60s. The maximum amount of time allowable for a nonsmoking alarm entry was 20min.

Self-initiated smoking entries were subdivided into three individually timed parts (i.e., time allotted to: pre-cigarette questions, smoke a cigarette, and post-cigarette questions). A minimum time was established as insufficient to have read and responded to pre-cigarette (60s) and post-cigarette (60s) entries. A minimum was also set for length of time for a participant to smoke a cigarette (30s) to confirm that participants did not immediately continue from pre-cigarette questions to post-cigarette questions. Similarly, a maximum time limit was established for pre-cigarette questions, time allotted to smoke, and post-cigarette questions. These time limits were established to remove entries in which participants took longer than reasonable. A maximum time was established for pre-cigarette (20min) and post-cigarette (20min) entries, in addition to time allotted to smoking (35min). Entries that fell outside of established time limits were discarded. As in similarly designed studies (Beckham et al., 2008), if post-cigarette questions were determined noncompliant they were therefore deleted, while pre-cigarette responses were retained.

Across both types of readings (i.e., self-initiated smoking and nonsmoking alarm entries), these time constraints resulted in 59 deleted noncompliant readings of the 1,913 total readings (3%).

Responsiveness to alarms was also considered. Since participants were allowed up to three missed or skipped alarms per day, compliance with alarms was defined by the frequency with which a participant missed an alarm or skipped an alarm after they had surpassed the allowable limit of three. The final sample was compliant 94% of the time.

Data analysis—The final sample consisted of 870 self-initiated smoking entries, with the exception of craving for a cigarette prior to smoking since this question was included in abbreviated entries (see above). The latter item was included in 1,232 self-initiated smoking entries. There were 622 nonsmoking alarm entries, which resulted in approximately four to six nonsmoking alarm entries per day.

Analyses were conducted with PC SAS version 9.2 (SAS Inc., 2008). A within subjects design was adopted to address our primary aims to assess whether antecedent conditions vary for smoking within adult ADHD smokers and what are the consequences of smoking within this group. In the antecedent analysis, individual observations were the unit of analysis. Self-initiated participant EMA entries prior to smoking a cigarette and nonsmoking alarm entries were analyzed. To account for the nesting of multiple observations within subjects, data were analyzed using logistic generalized estimating equations (GEE) (Zeger, Liang, & Albert, 1988). An autoregressive correlation structure was considered. This analysis, essentially logistic regression, considered each EMA entry occasion (i.e., smoking vs. nonsmoking) as a categorical dependent variable modeled as a function of a situational variable (e.g., affect). To offset issues of collinearity and to preserve power, separate models were run for each independent variable. Odds ratios and confidence intervals (95%) are reported.

An analysis of the consequences of smoking was also conducted. Following a repeated-measures MANOVA, within-group paired-samples *t*-tests were conducted to analyze changes in dependent variable scores (e.g., negative affect) prior to and following smoking a

cigarette. This analysis is modeled after previous studies considering the consequences of smoking in psychiatric samples using EMA (Beckham et al., 2008).

Results

Smoking Antecedent Analysis

GEE analyses comparing situations prior to a smoking episode and a nonsmoking period indicated that ADHD smokers were more likely to smoke when the following were elevated: urge to smoke ($p < .0001$), negative affect ($p = .0009$), boredom ($p = .004$), stress ($p = .002$), worry ($p = .008$), and restlessness ($p = .0002$). In addition, they were more likely to smoke in situations that made them feel frustrated ($p = .03$) and nervous ($p = .003$). ADHD symptoms were not elevated prior to a smoking episode (see Table 3). Given that participants were more likely to smoke in situations that elicited more nervousness and frustration, we conducted a post-hoc analysis to assess if ADHD symptoms were more likely to precede a smoking occasion in those situations (i.e., when participants provided a rating response 2 for either respective item). Accordingly, hyperactive-impulsive ADHD symptoms were more likely to be elevated and precede a smoking episode in situations that were perceived as frustrating ($p = .01$).

Regarding situational antecedents, ADHD smokers were more likely to smoke in the presence of other smokers ($p < .0001$), in a bar or restaurant ($p = .01$), while outside ($p < .0001$), and while consuming a caffeinated beverage ($p < .0001$) or alcohol ($p = .04$). Smokers with ADHD were less likely to smoke, however, while eating ($p = .003$). No other situational antecedents were statistically significant (Table 3).

Smoking Consequence Analysis

Pre-smoking and post-smoking ratings were also compared across participants to assess the consequences of smoking. A repeated-measures MANOVA indicated a statistically significant difference in pre and post scores (Wilks' $\lambda = 22.50$, $p < .001$). Participants reported a statistically significant reduction in urge to smoke ($p < .001$), negative affect ($p = .027$), stress ($p = .002$), hunger ($p = .021$), total ADHD symptoms ($p = .008$), inattentive ADHD symptoms ($p = .022$), and hyperactive-impulsive ADHD symptoms ($p = .004$) (Table 4).

Discussion

The present study assessed the antecedents and consequences of smoking using EMA among smokers with ADHD over a seven day assessment period, which is the longest period of EMA assessment of *ad lib* smoking in an adult ADHD sample to date. In addition, this is the first study to observe naturalistic *ad lib* smoking behavior using EMA among adult ADHD smokers to assess both the antecedents and consequences of smoking, which allows for a more ecologically-valid assessment of the self-medication hypothesis. Among the antecedent findings, higher urge to smoke and negative affect ratings (i.e., negative affect total score, boredom, stress, worry, and restlessness) increased the odds of smoking. Relatedly, situations that elicited frustration and nervousness were also associated with greater likelihood of smoking. Counter to our predictions, higher levels of ADHD

symptoms, situations demanding attentional control, and situations demanding behavioral control failed to be associated with smoking. However, a relationship between hyperactive-impulsive ADHD symptoms and smoking did emerge in the context of situations that were perceived as frustrating. Situational antecedents were also associated with smoking in adults with ADHD, including consumption of caffeinated and alcoholic beverages, the presence of others who are smoking, being at a bar or restaurant, and being outside. Participants were less likely to smoke when they were eating. When pre-cigarette and post-cigarette ratings were considered, urge to smoke, negative affect (i.e., negative affect total score and stress), hunger, and ADHD symptoms (i.e., inattention and hyperactivity-impulsivity) improved after smoking.

These findings provide some support for the self-medication hypothesis, though not necessarily in a straightforward way. Specifically, the probability of smoking increased in ADHD smokers in situations involving negative emotional states. Across both antecedent and consequence analyses, negatively-valenced mood consistently emerged as a significant variable. ADHD symptoms also improved following smoking episodes. While ADHD symptoms do appear to play a role as an antecedent to smoking, it is only in the context of experiencing negative mood (i.e., frustration). These findings add to the growing literature on the role of emotion dysregulation in ADHD and suggest that smoking may be an emotion regulation strategy. That is, emotion dysregulation is increasingly recognized as an important feature in ADHD (Barkley, 2010; Martel, 2009; Skirrow, McLoughlin, Kuntsi, & Asherson, 2009). Those with the disorder are hypothesized to be less likely to inhibit their emotions, particularly those pertaining to frustration, impatience, and anger, as a result of deficient cognitive control (Barkley, 2010). In the context of smoking, those with ADHD may engage in smoking episodes to improve the regulation of negative emotional states.

Overall, findings from the current study support that ADHD individuals smoke to alleviate negative mood and, to a relatively lesser extent, ADHD symptoms. These features may be negatively reinforced when smoking episodes occur, and serve to maintain smoking behavior in adults with ADHD. One possible explanation for the relatively less robust role of ADHD symptoms, in comparison to negative affect, may involve the use of core ADHD symptoms in the current study. That is, core symptoms of ADHD listed in the *DSM-IV-TR*, which are unchanged in the *DSM 5*, have been criticized for being developmentally inappropriate for adults (McGough & Barkley, 2004). Further, executive functioning symptoms, which are more consistent and discriminating predictors of ADHD in adulthood than inattentive and hyperactive-impulsive symptoms, are not included among *DSM* symptoms (Kessler et al., 2010). Future studies should consider additional age-appropriate and executive functioning symptoms of ADHD to more thoroughly assess the self-medication hypothesis in ADHD smokers.

An additional explanation involves clarification of the self-medication hypothesis. In most models, substance use is the result of negative reinforcement of symptoms and moods, which does not necessarily imply an increase in symptoms prior to substance use. In the current study, participants may have engaged in smoking in anticipation of worsening of ADHD symptoms (e.g., prior to a boring situation), which would therefore not result in an actual increase in ADHD symptoms prior to smoking.

To the extent that specific smoking antecedents and consequences are associated with ADHD, they may be appropriate targets for behavioral and pharmacological interventions during smoking cessation attempts among ADHD adults. For example, acceptance-based approaches for coping with negative mood during quit attempts (e.g., Brown et al., 2008) may assist ADHD smokers in coping with elevations of negative affect and how they respond to it. Use of EMA as both assessment and intervention tools during smoking cessation attempts may be beneficial as well. In particular, increases in negative mood may predict a smoking episode. It may be beneficial for clinicians to use EMA to assist patients in identifying times at which negative mood increases and use techniques to regulate their negative mood at those times. Future treatment efforts may also be improved by incorporating additional contextual variables not examined in the current study but are easily attainable in combination with EMA, such as geographic information attained by global positioning system (GPS) data (Mitchell et al., 2014; Watkins et al., 2014).

Limitations of findings from the current study should be considered. First, no comparison groups of nonpsychiatric or psychiatric nicotine dependent adults were involved. Although a comparison group was not necessary given that the aim of this study was to assess changes in mood and ADHD symptoms within an adult ADHD sample as a function of *ad lib* smoking, future studies should include comparison groups to address the specificity of these findings to ADHD. Second, the sample size for the current study was small and may have therefore limited statistical power. Associated with this limitation, although outside the scope of this study, the moderating role of gender or ADHD subtypes were not considered. Third, the role of comorbidity was not assessed and may limit generalizability. Although comorbidity outside of ADHD and nicotine dependence was exclusionary since adults with ADHD are at increased risk for a range of other psychiatric disorders (Kessler et al., 2006), and increased negative affect within the ADHD smoking group may be an artifact of comorbid depression, future studies should build on the current findings and address the role of comorbid disorders. Another potential limitation of the current study design involves overlapping symptom profiles between ADHD and nicotine withdrawal such that it is difficult to clearly distinguish between them. For example, in the current study, “restlessness” was assessed as both a withdrawal symptom and ADHD symptom. However, previous studies of adult ADHD smokers demonstrate that withdrawal symptoms are either unrelated to changes in ADHD symptoms in a non-treatment seeking sample (McClernon et al., 2011) or only modestly related to ADHD symptoms prior to a quit attempt in a treatment-seeking sample (Berlin, Hu, Covey, & Winhusen, 2012). Although these variables demonstrate a stronger relationship during smoking abstinence in treatment-seeking smokers with ADHD (Berlin et al., 2012), this is less concerning in the current study given that the sample was non-treatment-seeking and did not undergo smoking abstinence. Any future studies using EMA to assess these variables during a quit attempt should consider withdrawal measures not confounded by ADHD symptoms.

The current study overcomes past methodological limitations utilizing retrospective self-report measures to assess smoking behavior in adults with ADHD and is the first to assess *ad lib* smoking in adults diagnosed with ADHD using EMA to address its antecedents and consequences. Further, the seven day period of assessment of *ad lib* smoking in ADHD

smokers is the longest period of assessment using EMA in this population to our knowledge. Our findings provide improved ecological validity supporting the self-medication hypothesis, particularly for the role of negative affect. Findings also indicated that smokers with ADHD smoke to regulate ADHD symptoms as well, though these symptoms were not associated with an increased likelihood of smoking. Future studies should consider these variables as targets for intervention efforts for this at-risk population.

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Table 1

Participant baseline characteristics

	ADHD (<i>n</i> = 17)	
	<i>M (SD)</i>	Frequency (%)
Age	32.29 (9.66)	
KBIT	107.88 (16.07)	
ADHD Subtype		
Combined		8 (47.1%)
Inattentive		9 (52.9%)
Gender		
Female		8 (47.1%)
Male		9 (52.9%)
Race		
Caucasian		10 (58.8%)
African American		6 (35.3%)
Native American		1 (5.9%)
Hispanic		0 (0%)
Marital Status		
Married		2 (11.8%)
Single		15 (88.2%)
Education		
< 7 th grade		1 (5.9%)
High School		2 (11.8%)
Partial College		10 (58.8%)
College		2 (11.8%)
Post-Graduate Studies		2 (11.8%)
Employment Status		
Full-Time		7 (41.2%)
Part-Time		7 (41.2%)
Assistance		1 (5.9%)
Unemployed		2 (11.8%)
Salary Range		
\$ 0		1 (5.9%)
\$0–\$10,000		6 (35.3%)
\$10,000–\$25,000		5 (29.4%)
\$25,000–\$50,000		4 (23.5%)
>\$50,000		1 (5.9%)
CO reading (ppm)	17.47 (9.27)	
Cigarettes per day	14.18 (3.76)	
Duration of Current Smoking (years)	8.63 (8.60)	
Smoking Onset (age)	16.71 (2.87)	
# of Quit Attempts	3.59 (3.92)	

ADHD (<i>n</i> = 17)	
	<i>M</i> (<i>SD</i>) Frequency (%)
FTND	4.88 (1.79)

Note. KBIT = Kaufman Brief Intelligence Test, Second Edition, FTND = Fagerström Test for Nicotine Dependence

Table 2

Variables assessed for electronic diary entries

	No. of Questions	Sample Question(s)	Response Options
Craving	1	How strong is your urge for a cigarette right now?	1 (not at all) to 5 (extremely)
Situation	10		
Location		Where are you?	Home, Home of Friend/Family, Work, Car/Bus, Bar/Restaurant, Outside, Other location
Social Situation		Who are you with?	Significant other, Family, Friends, Co-workers, Strangers, Nobody
Activity		What are you doing?	Working, Leisure Activity, Interacting with Others, Talking on the Phone, Eating, Reading, Doing Nothing/Inactive, Other/None of the Above
Other Smokers		Right now is there anyone around you who is smoking?	Yes or No
Consumption		During the last 30 minutes have you had any of the following?	Coffee [caffeinated], Soda [caffeinated], Tea [caffeinated], Non-Caffeinated Coffee/Soda/Tea, Food, Alcohol
Demanding Attentional Control		To what extent are you in a situation in which you need to pay attention or stay focused?	1 (not at all) to 5 (extremely)
Demanding Behavioral Regulation		To what extent are you in a situation in which you need to be patient or wait?	1 (not at all) to 5 (extremely)
Eliciting Negative Affect		To what extent are you in a situation that is upsetting? To what extent are you in a situation that is frustrating? To what extent are you in a situation that is making you feel nervous?	1 (not at all) to 5 (extremely)
Affect	26		
PANAS items (20 items)		Indicate to what extent you feel this way right now: upset	1 (very slightly/not at all) to 5 (extremely)
Additional affect items (6 items)		Indicate to what extent you feel this way right now: bored	1 (very slightly/not at all) to 5 (extremely)
ADHD Symptoms	18		
Inattention (9 items)		To what extent are you currently having difficulty being easily distracted by things going on around you?	1 (not at all) to 5 (extremely)
Hyperactivity-Impulsivity (9 items)		To what extent are you currently having difficulty talking too much?	1 (not at all) to 5 (extremely)

Note. PANAS = Positive and Negative Affect Scale (Watson, Clark, & Tellegen, 1988). Six additional affect levels associated with smoking (Beckham et al., 2005), boredom, anxiety, stress, hunger, worry, and restlessness, were also administered with the PANAS. Situational items were not included in post-cigarette entries since they were included prior to smoking entries.

Table 3

Antecedent context prior to smoking and nonsmoking episodes

	Smoking Occasions (<i>n</i> = 870) ^a <i>M</i> (<i>SD</i>) ^b	Nonsmoking Occasions (<i>n</i> = 622) <i>M</i> (<i>SD</i>) ^b	Odds Ratio: Smoking vs. Nonsmoking (95% CI)
Urge to smoke	3.63 (0.53)	2.89 (0.71)	2.04 (1.85–2.25) ****
ADHD Symptoms			
Total ADHD Symptoms	32.59 (9.49)	32.54 (8.88)	1.01 (1.00–1.01)
Inattentive Symptoms	17.24 (4.81)	17.19 (4.42)	1.01 (0.99–1.02)
Hyp-Imp Symptoms	15.35 (5.07)	15.35 (4.87)	1.01 (1.00–1.03)
Mood			
Positive Affect	22.69 (6.66)	23.17 (7.04)	1.00 (0.99–1.01)
Negative Affect	12.84 (1.48)	12.26 (1.12)	1.05 (1.02–1.09) ***
Boredom	1.69 (0.63)	1.57 (0.50)	1.17 (1.05–1.30) **
Anxiety	1.73 (0.38)	1.73 (0.59)	1.11 (1.00–1.23)
Stress	1.50 (0.38)	1.40 (0.27)	1.23 (1.08–1.40) **
Hunger	1.74 (0.51)	1.91 (0.63)	0.96 (0.88–1.04)
Worry	1.26 (0.29)	1.17 (0.17)	1.26 (1.06–1.50) **
Restlessness	1.75 (0.65)	1.62 (0.49)	1.23 (1.10–1.37) ***
Situational Context			
Attentional Control	2.28 (0.44)	2.36 (0.40)	0.95 (0.87–1.04)
Waiting	2.09 (0.51)	2.10 (0.46)	1.03 (0.94–1.12)
Upset	1.30 (0.25)	1.33 (0.34)	1.12 (0.97–1.31)
Frustrate	1.38 (0.28)	1.33 (0.17)	1.17 (1.02–1.34) *
Nervous	1.30 (0.28)	1.27 (0.24)	1.28 (1.09–1.51) **
Activity			
Working	14	16	0.88 (0.68–1.14)
Leisure activity	32	30	1.07 (0.88–1.31)
Interacting with others	14	13	1.10 (0.84–1.45)
Telephone	3	2	1.89 (0.96–3.72)
Eating	4	8	0.53 (0.35–0.80) **
Inactive	13	10	1.31 (0.97–1.78)
Car	7	7	1.01 (0.70–1.46)
Reading	1	3	0.59 (0.30–1.15)
Other	14	13	0.92 (0.68–1.24)
Consumption (within last 30 mins)			
Caffeinated beverage	35	24	1.62 (1.32–1.99) ****
Food	25	24	1.03 (0.82–1.28)
Alcohol	6	3	1.59 (1.02–2.50) *
Social situation			

	Smoking Occasions (<i>n</i> = 870) ^a <i>M</i> (<i>SD</i>) ^b	Nonsmoking Occasions (<i>n</i> = 622) <i>M</i> (<i>SD</i>) ^b	Odds Ratio: Smoking vs. Nonsmoking (95% CI)
With significant other	29	32	0.88 (0.72–1.06)
With family	26	24	1.09 (0.88–1.34)
With friends	17	14	1.19 (0.92–1.54)
With co-workers	12	13	0.91 (0.70–1.19)
With strangers	7	5	1.35 (0.90–2.02)
Alone	27	28	1.01 (0.83–1.24)
Location			
Home	51	52	0.94 (0.79–1.12)
Home of friend/family	17	17	0.99 (0.78–1.25)
Work	11	12	0.91 (0.68–1.20)
Car/bus	11	10	1.13 (0.84–1.54)
Bar/restaurant	5	2	2.07 (1.19–3.60) **
Outside	11	5	2.22 (1.52–3.24) ****
Other location	4	6	0.70 (0.45–1.08)
Around someone who is smoking	18	8	2.17 (1.61–2.93) ****

Note. Situational context refers to situations requiring attentional control or behavioral regulation, and eliciting negative affect. Means were calculated from one question presented in the electronic diary for all variables (response options ranging from 1 to 5) except Total ADHD Symptoms (18 items), Inattentive ADHD Symptoms (9 items), Hyperactive-Impulsive ADHD Symptoms (9 items), Positive Affect (10 items), and Negative Affect (10 items). Means represent summed scale scores for these latter variables.

*
 $p < .05$,

**
 $p < .01$,

 $p < .001$,

 $p < .0001$

^aThere was a total of 870 smoking entries for all variables with the exception of urge to smoke. Abbreviated smoking entries only assessed craving for a cigarette prior to smoking, then instructed participants that they completed the entry. Therefore, there are more urge to smoke readings than other variables (1,232 urge to smoke entries).

^bActivity, Consumption, Social Situation, and Location values are listed as percentages.

Table 4Comparing pre-smoking and post-smoking ratings ($n = 17$)

	Pre	Post			
	<i>M (SD)</i>	<i>M (SD)</i>	Difference	<i>t</i>	<i>p value</i>
Urge to smoke	3.63 (.53)	1.83 (.73)	1.80	8.89	< .001
ADHD Symptoms					
Total ADHD Symptoms	32.59 (9.49)	30.58 (8.61)	2.01	3.02	.008
Inattentive Symptoms	17.24 (4.81)	16.29 (4.28)	.95	2.53	.022
Hyperactive-Impulsive Symptoms	15.35 (5.07)	14.29 (4.64)	1.06	3.39	.004
Mood					
Positive Affect	22.69 (6.66)	22.87 (6.40)	-.17	-.68	.504
Negative Affect	12.84 (1.48)	12.47 (1.80)	.37	2.43	.027
Boredom	1.69 (.63)	1.64 (.65)	.06	1.54	.144
Anxiety	1.73 (.38)	1.65 (.50)	.08	1.82	.087
Stress	1.50 (.38)	1.39 (.37)	.11	3.62	.002
Hunger	1.74 (.51)	1.62 (.44)	.11	2.57	.021
Worry	1.26 (.29)	1.28 (.35)	-.03	-1.11	.283
Restlessness	1.75 (.65)	1.68 (.68)	.08	1.53	.146

Note. Means were calculated from one question presented in the electronic diary for all variables (response options ranging from 1 to 5) except Total ADHD Symptoms (18 items), Inattentive ADHD Symptoms (9 items), Hyperactive-Impulsive ADHD Symptoms (9 items), Positive Affect (10 items), and Negative Affect (10 items). Means represent summed scale scores for these latter variables.