ORIGINAL INVESTIGATION

Anxiety Sensitivity as a Predictor of Acute Subjective Effects of Smoking

Matthew Wong[1], **Andrea Krajisnik**[2], **Lauren Truong**[1], **Nadra E. Lisha** PhD[3], **Michael Trujillo** BA[2], **Jodie B. Greenberg** MA[2], **Christopher W. Kahler** PhD[4], **Michael J. Zvolensky** PhD[5], **Adam M. Leventhal** PhD[1,2]

[1]*Department of Psychology, University of Southern California, Los Angeles, CA;* [2]*Department of Preventive Medicine, University of Southern California Keck School of Medicine, Los Angeles, CA;* [3]*Department of Psychiatry, University of California San Francisco, San Francisco, CA;* [4]*Department of Behavioral and Social Sciences and the Center for Alcohol and Addiction Studies, Brown University, Providence, RI;* [5]*Department of Psychology, University of Houston, Houston, TX*

Corresponding Author: Adam M. Leventhal, Ph.D., University of Southern California Keck School of Medicine, 2250 Alcazar Street, CSC 240, Los Angeles, CA 90033, USA. Telephone: (323) 442-2732; Fax: (323) 442-2359; E-mail: adam.leventhal@usc.edu

Received June 4, 2012; accepted August 11, 2012

ABSTRACT

Introduction: Anxiety sensitivity (i.e., AS; the degree to which one believes that anxiety and its related sensations are harmful) is a stable trait that is associated with habitual smoking. Yet, the mechanisms linking AS and smoking are unclear. A promising hypothesis is that high-AS individuals are more sensitive to the acute subjective reinforcing effects of smoking and are, therefore, more prone to tobacco dependence. This study examined trait AS as a predictor of several subjective effects of cigarette smoking.

Methods: Adult non-treatment-seeking smokers (N = 87; 10+ cigarettes/day) completed a measure of AS during a baseline session. Prior to a subsequent experimental session, participants were asked to smoke normally before their appointment. At the outset of that visit, each participant smoked a single cigarette of their preferred brand in the laboratory. Self-report measures of affect and cigarette craving were completed before and after smoking, and post-cigarette subjective effect ratings were provided.

Results: AS predicted greater increases in positive affect from pre- to post-cigarette (β = .30, p = .006) as well as greater smoking satisfaction and psychological reward (β = .23 to .48, ps < .03). Each of these effects remained statistically significant after adjusting for anxiety symptom severity. AS did not predict the degree of negative affect and craving suppression or post-cigarette aversive effects.

Conclusions: These findings suggest that positive reinforcement mechanisms may be particularly salient etiological processes that maintain smoking in high-AS individuals.

INTRODUCTION

Anxiety disorders are particularly prevalent in smokers and are believed to play an etiological role in smoking behavior (Morissette, Tull, Gulliver, Kamholz, & Zimering, 2007). One means of elucidating the role of anxiety in tobacco dependence is to investigate the influence of psychological vulnerability factors that underlie anxiety-related conditions (rather than anxiety disorders per se) on smoking (e.g., Brown, Lejuez, Kahler, Strong, & Zvolensky, 2005; McLeish, Zvolensky, & Bucossi, 2007).

Anxiety sensitivity (AS) is one such vulnerability factor consistently linked with smoking. AS—the extent to which an individual believes that anxiety and anxiety-related sensations have harmful consequences—is a relatively stable, yet malleable, cognitive characteristic that predisposes an individual to the development and maintenance of anxiety psychopathology (Reiss, Peterson, Gursky, & McNally, 1986). AS is associated with a number of characteristics indicative of more severe tobacco dependence, such as early lapse and relapse (e.g., Brown, Kahler, Zvolensky, Lejuez, & Ramsey, 2001; Zvolensky, Bernstein, et al., 2007; Zvolensky, Stewart, Vujanovic, Gavric, & Steeves, 2009). Many relations between AS and smoking variables remain, even after statistically controlling for anxiety symptoms (Zvolensky et al., 2009; Zvolensky, Vujanovic, et al., 2007), which suggests that AS may play a unique role in smoking behavior.

AS is associated with higher accuracy in estimating changes in physiological reactivity. (Stewart, Buffett-Jerrott, & Kokaram, 2001). Accurate interoception may enhance subjective response to physiologically aversive stimuli (e.g., stress), which could generate more anxiety in high-AS individuals. Accurate interoception could also enhance subjective responses to physiologically rewarding stimuli, such as smoking. Given that smoking has a wide variety of reinforcing effects, greater sensitivity to the subjective effects of smoking in high-AS smokers could promote more frequent smoking.

To our knowledge, only two studies have examined the effect of AS on the subjective effects of smoking. Evatt and Kassel

doi:10.1093/ntr/nts208
Advance Access publication November 9, 2012

(2010) examined baseline AS as a moderator of the effect of smoking on subjective stress and state anxiety. They found that smoking reduced anxiety in high-AS individuals during an induced stressful situation (speech preparation), but not in a non-stress situation. Low-AS smokers reported smoking-induced anxiety reductions in both conditions (Evatt & Kassel, 2010). In a separate study, Perkins, Karelitz, Giedgowd, Conklin, and Sayette (2010) reported that AS predicted increased smoking-induced changes in some measures of state positive and negative affect and an item measuring cigarette reward ("How much do you like this cigarette?") under certain conditions of stress or smoking abstinence (Perkins et al., 2010).

The findings of Evatt and Kassel (2010) and Perkins et al. (2010) indicate that AS may moderate some reactions to smoking, particularly during stressful situations. However, several aspects of the relation between AS and the subjective effects of smoking are still unclear. First, these two studies did not account for the effect of baseline anxiety symptoms. Given that AS and anxiety symptoms are correlated (Johnson, Stewart, Rosenfield, Steeves, & Zvolensky, 2011; Zvolensky et al., 2009), AS may simply be a proxy for anxiety symptoms, which could account for AS-related variability in smoking effects. Thus, it is important to explore whether AS predicts degree of subjective effects of smoking after statistically covarying for the effect of baseline anxiety symptoms. In addition, the assessment of smoking effects in Evatt and Kassel (2010) and Perkins et al. (2010) were restricted to a battery of subjective measures mainly focused on state affect and brief single-item measures of subjective smoking reward. It would be useful to explore AS as a predictor of a wider variety of subjective reinforcing effects that could maintain smoking behavior such as cigarette craving suppression, enjoyment of respiratory tract sensations, and broad indices of psychological reward (e.g., irritability reduction, increase in wakefulness, concentration enhancement, hunger satiation) (Cappelleri et al., 2007). Similarly, it would be beneficial to assess whether AS is associated with degree of aversive effects of smoking (e.g., dizziness, nausea), which may serve to reduce risk of dependence (Cappelleri et al., 2007).

In this study, we examined trait AS as a predictor of several subjective effects of cigarette smoking in non-treatment-seeking smokers following a period of normal smoking. This paradigm is useful for identifying stable individual differences in smoking reinforcement and reward that may serve to maintain smoking behavior under typical conditions (Perkins, Karelitz, Giedgowd, & Conklin, 2012). Given prior empirical reports and theory indicating that AS is associated with greater interoceptive abilities (Evatt & Kassel, 2010; Leyro, Zvolensky, Vujanovic, & Bernstein, 2008; Perkins et al., 2010), we hypothesized that AS would predict greater negative affect reduction, positive affect enhancement, and psychological reward from smoking after statistically controlling for covariance with anxiety symptoms. Due to the paucity of prior research and theory on AS and aversive effects, respiratory tract sensations, and craving suppression, we did not articulate any hypotheses regarding these relations.

METHODS

Participants and Procedure

Recruitment and Sample Demographics

Participants were recruited from the community via newspaper and online advertisements to take part in a study on individual differences in tobacco deprivation effects (data collection 2009–2012). This report is a secondary analysis focusing on data collected as part of a cigarette administration procedure that took place during a particular portion of the study protocol (see Procedure section). Inclusion criteria were: (a) >18 years old; (b) regular cigarette smoking for 2+ years; (c) currently smoking 10+ cigarettes/day; (d) normal or corrected-to-normal vision; and (e) fluent in English. Exclusion criteria were: (a) current *DSM-IV* substance dependence other than nicotine dependence; (b) current *DSM-IV* mood disorder or psychotic symptoms; (c) breath carbon monoxide (CO) levels <10 ppm at intake (used as a biochemical verification of smoking level to prevent the entry of individuals who may overreport their level of smoking in order to participate in the study); (d) use of non-cigarette forms of tobacco or nicotine products; (e) use of psychiatric medications; and (f) currently pregnant. Of the 141 participants who enrolled in the study, 38 were ineligible and 16 dropped out following the baseline session, leaving a final sample of 87 for analyses. Participants were compensated $200 for completing the study. The University of Southern California Internal Review Board approved the protocol.

Procedure

Overview

Following a telephone screen, participants attended a baseline session involving informed consent, breath CO analysis, psychiatric interview, and measures of demographics, smoking characteristics, and affective characteristics. Participants then attended two counterbalanced (deprived and non-deprived) experimental sessions. Procedures were identical for both session types except for the inclusion of a cigarette administration procedure at the outset of the non-deprived session. Participants were also instructed to smoke normally prior to arriving to the laboratory for the non-deprived session. The current report references only the cigarette administration procedure during participants' non-deprived sessions as they did not complete a cigarette administration procedure during deprived sessions.

Cigarette Administration Procedure

This procedure was performed at the outset of the non-deprived session in a laboratory facility with a ventilation system to clear smoke. Following an alcohol breath test (participants with breath alcohol content > 0.00 were rescheduled), participants completed pre-cigarette assessments (i.e., CO, Positive and Negative Affect Schedule [PNAS], Tobacco Craving Questionnaire [TCQ]). They were then instructed to smoke a cigarette of their preferred brand inside the laboratory. In order to approximate typical smoking conditions, participants were not given additional instructions regarding the timing or frequency of puffing. Experimenters observed participants while they smoked to ensure that all individuals complied with the instructions. Smoking topography data were not collected. Immediately after participants extinguished the cigarette, they completed post-cigarette assessments identical to the pre-cigarette assessments except for the inclusion of an additional Cigarette Evaluation Questionnaire (CEQ; see Experimental Session Measures section). As previously reported, subjective measures during the ad lib smoking of a single cigarette following normal smoking have high reliability (Perkins et al., 2012).

Baseline Session Measures

Structured Clinical Interview for DSM-IV Non-Patient Edition
The Structured Clinical Interview for *DSM-IV* was used to assess psychiatric diagnoses for eligibility purposes (First, Spitzer, Gibbon, & Williams, 2002).

Fagerström Test of Nicotine Dependence
The Fagerström Test of Nicotine Dependence (FTND) is a well-validated six-item measure of nicotine-dependence severity (Heatherton, Kozlowski, Frecker, & Fagerström, 1991).

Smoking History Questionnaire
An author-constructed smoking history questionnaire was used to assess basic information including number of cigarettes smoked per day, age of smoking onset, and other relevant smoking characteristics.

The Anxiety Sensitivity Index
The Anxiety Sensitivity Index (ASI; Reiss et al., 1986) is a 16-item questionnaire measuring the extent to which one fears the potential negative consequences of anxiety-related symptoms and sensations (e.g., "It scares me when I feel shaky"). Items were rated on a 5-point Likert scale ranging from 0 (very little) to 4 (very much), and a total score was computed. The ASI has three lower order factors (physical, psychological, and social concerns) that all load on a single common global factor (Zinbarg, Barlow, & Brown, 1997). Here, we utilized the total ASI score because: (a) it represents the global AS factor and thus incorporates general sensitivity to a variety of anxiety-causing situations that may each influence smoking; and (b) we wished to reduce the number of statistical tests performed and corresponding type-I error rates. The ASI total scale has been shown to possess good psychometric properties and exhibits excellent discriminant validity from trait anxiety and other constructs (McNally, 2002; Peterson & Heilbronner, 1987; Zvolensky, Kotov, Antipova, & Schmidt, 2005). The internal consistency of the ASI in this sample was good (Cronbach's $\alpha = .85$).

The Mood and Anxiety Symptom Questionnaire—Short Form Anxious Arousal Subscale
The Mood and Anxiety Symptom Questionnaire (MASQ; Watson et al., 1995) is a self-report measure of affective symptoms in the past week. Participants indicate how much they have experienced each symptom on a 5-point Likert-type scale (1 = not at all to 5 = extremely). Only the 17-item Anxious Arousal subscale (MASQ-AA) was used in this report as it addresses symptoms of somatic tension and arousal (e.g., felt dizzy) specific to anxiety that are psychometrically distinct from other forms of emotional distress (e.g., depression) (Watson et al., 1995). The Cronbach's α in this sample was .83.

The Center for Epidemiologic Studies Depression Scale
The Center for Epidemiologic Studies Depression Scale (CESD) is a 20-item self-report scale that measures past-week depressive symptomatology for general population samples and has shown good psychometric properties (Radloff, 1977; Shafer, 2006).

Experimental Session Measures

Positive and Negative Affect Schedule
The PANAS (Watson, Clark, & Tellegen, 1988) assesses positive affect (10 items, e.g., enthusiastic, strong; Cronbach's α for change [post-cigarette – pre-cigarette] = .62) and negative affect (10 items, e.g., distressed, upset; α change = .66). Participants were instructed to respond based on how they feel "right now" on a scale ranging from 1 (not at all) to 5 (extremely).

Tobacco Craving Questionnaire–Short Form
The TCQ is a 12-item questionnaire that measures tobacco craving via four subscales: (a) emotionality—smoking to avoid negative affect (α change = .77); (b) expectancy—smoking in anticipation of positive affect (α change = .89); (c) compulsivity—inability to regulate tobacco intake (α change = .63); (d) purposefulness—motivated decisiveness to smoke for positive effects (α change = .54; Heishman, Singleton, & Pickworth, 2008). Participants were instructed to respond based on how they feel "right now" on a Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). The TCQ's internal consistency, criterion validity, and factorial validity have been supported in prior work (Heishman et al., 2008).

Cigarette Evaluation Questionnaire
The CEQ is a self-report measure of the acute effects of smoking that includes five subscales: smoking satisfaction (two items: "Was it satisfying?" "Did it taste good?"; $\alpha = .86$); psychological reward (five items: "Did it calm you down?" "Help you concentrate?" "Make you feel more awake?" "Reduce hunger?" "Make you feel less irritable?"; $\alpha = .88$); aversion (two items: "Make you nauseated?" "Make you dizzy?"; $\alpha = .53$); enjoyment of sensations in the respiratory tract (one item), and craving reduction (one item; Westman, Levin, & Rose, 1992). Responses were provided on a visual analog 100-mm scale, and participants were instructed to rate effects from the cigarette they just smoked. Psychometric properties of the CEQ including the factorial validity of its subscales have been previously established (Cappelleri et al., 2007).

Statistical Analysis

Following calculation of descriptive statistics, all variables were checked for normality, and transformations to approximate normality were applied when appropriate. Then, Pearson or point-biserial correlation coefficients were calculated to examine the relation of ASI scores to baseline session variables (demographic characteristics, MASQ-AA, CESD, FTND), pre-cigarette measures (CO, PANAS, and TCQ), and nicotine and tar yields for participants' brand of cigarettes they smoked during the cigarette administration procedure based on publically available data (FTC, 2008). Because there were no significant correlations between ASI scores and baseline variables other than the MASQ-AA scale (see Results section), these variables were not included as covariates in the primary analyses. CO levels, PANAS, and TCQ scores were compared from pre- to post-cigarette assessments using paired-samples *t* tests to examine smoking effects in the overall sample.

To address the study's primary aim, linear regression models were generated that included anxiety measure(s) as the primary predictor(s) and a smoking effect variable as the outcome. Separate models were calculated for each outcome. For

each outcome, we tested three separate models that included: (a) ASI as the primary predictor; (b) MASQ-AA as the sole predictor to compare the effects of ASI to a general measure of anxiety symptoms; and (c) ASI and MASQ-AA scores as simultaneous predictors to examine whether the predictive validity of AS for predicting smoking effects is incremental to shared variance with anxiety symptoms. For CO, PANAS, and TCQ variables, models included the change score (post-cigarette rating minus pre-cigarette rating) as the outcome and respective pre-cigarette rating as a covariate. Because the CEQ was administered only at the post-smoking assessment, models predicting CEQ outcomes included only anxiety variables as predictors. All tests were two-tailed and employed a significance level of .05.

RESULTS

Sample Characteristics

The sample ($N = 87$) was comprised of 67% men, and the average age was 43.7 ($SD = 9.9$). The majority of participants identified their race as African American (63%) or Caucasian (37%). About 14% of the sample were also identified as Hispanic/Latino. On average, participants smoked 16.7 ($SD = 7.2$) cigarettes a day, began smoking regularly at age 18.3 ($SD = 3.8$), and had an FTND score of 5.4 ($SD = 2.1$). Regarding participants preferred brand of cigarettes smoked during the cigarette administration procedure, the average tar and nicotine yields were 15.1 ($SD = 14.7$) mg and 1.2 ($SD = 0.3$) mg per cigarette, respectively. On average, participants reported smoking their last cigarette 1.14 ($SD = 2.53$) hours prior to the beginning of the cigarette administration procedure. On average, there were moderate levels of emotional distress in the sample with prominent between-participant variability (ASI, M [SD] = 18.6 [10.1]; MASQ-AA, M [SD] = 21.0 [5.3]; CESD, M [SD] = 9.5 [7.4]).

Associations of Anxiety to Baseline Characteristics and Pre-Cigarette Assessments

ASI was not significantly associated with demographic variables, FTND scores, time since last cigarette, or tar and nicotine yield. ASI scores were significantly associated with MASQ-AA ($r = .44$, $p < .0001$), but not CESD ($r = .16$, $p = .14$). Regarding pre-cigarette assessments, ASI was significantly associated with TCQ-emotionality ($r = .31$, $p = .004$), TCQ-purposefulness ($r = .29$, $p = .006$), and TCQ-compulsivity ($r = .30$, $p = .005$), but was not significantly associated with pre-cigarette TCQ-expectancy, PANAS-positive affect, PANAS-negative affect, or CO.

Smoking Effects During the Cigarette Administration Procedure

Descriptive statistics of smoking effects are reported in Table 1. Paired-samples t tests illustrated significant reductions from pre- to post-cigarette ratings for all craving scales and negative affect in the overall sample (p's < .0001). On average, the change from pre- to post-cigarette levels of positive affect was not significant.

Table 1 reports the results of regression models examining ASI and MASQ-AA as predictors of the subjective effects of smoking. Higher AS predicted higher ratings of smoking satisfaction, psychological reward, and enjoyment of sensory tract sensations, as well as higher smoking-induced enhancement of positive affect. The strength of these relations was partially diminished after controlling for anxiety symptoms, though most relations remained statistically significant (see Table 1). AS was not associated with other outcomes.

Anxiety symptoms (MASQ-AA) were not associated with smoking effects after accounting for variance associated with AS, with the exception of significant relations with higher CO-boosts and lower reduction in TCQ-purposefulness.

DISCUSSION

Consistent with our hypotheses, AS predicted several acute subjective reinforcing effects of smoking. It is unlikely that these effects are explained by CO boost or the tendency for high-AS individuals to smoke more potent cigarettes than low-AS smokers, given that AS was not associated with FTC estimates of the nicotine and tar yields of the cigarette brand participants smoked during the cigarette administration procedure. Because AS was not associated with pre-smoking CO levels or the self-reported time since a cigarette was last smoked, it is also improbable that our findings are accounted for by levels of recent tobacco exposure in high-AS smokers, which would impact sensitivity to cigarette administration. Rather, these findings indicate that individuals with higher AS may be disproportionately sensitive to some positive reinforcing effects of smoking.

This investigation extends previous findings demonstrating that AS is associated with subjective effects of smoking (Evatt & Kassel, 2010; Perkins et al., 2010) by examining a larger battery of subjective effects. This approach proved to be useful, as AS predicted a qualitatively unique profile of subjective effects. AS was associated with greater smoking satisfaction, psychological rewarding effects, enjoyment of the respiratory tract sensations of smoking, and positive affect enhancement, but not with degree of aversive effects, craving suppression, or negative affect reduction. This pattern suggests that certain motivationally relevant psychopharmacological processes (e.g., smoking-induced affect modulation) but not others (e.g., smoking-induced craving suppression) are disproportionally prominent for high-AS smokers. Thus, these particular processes may underlie the well-documented relation between AS and persistent smoking (e.g., Brown et al., 2001; Zvolensky, Bernstein, et al., 2007; Zvolensky et al., 2009).

We also extend results from previous studies that did not control for AS as a possible proxy for anxiety symptoms, which could account for all AS-related variability in smoking effects. In the current study, AS showed comparatively stronger associations with subjective smoking effects than with the relations between anxiety symptom severity and smoking effects. Importantly, AS predicted several subjective reinforcing effects of smoking over and above covariance with anxiety symptoms. Thus, the current results indicate that the fear and anticipation of anxiety symptoms prominent in AS, rather than experience of anxiety symptoms per se, accounts for variability in smoking effects.

Prior findings illustrate that AS is more strongly associated with self-reported motivation to smoke for negative affect reduction than positive affect enhancement (Battista et al.,

Table 1. Prediction of Subjective Effects of Smoking by of Anxiety Sensitivity and Anxiety Symptoms

	Descriptive statistics						
	Pre-cigarette	Post-cigarette	Change (post – pre)	Prediction by ASI		Prediction by MASQ-AA	
Subjective effect measure	M (*SD*)	M (*SD*)	M (*SD*)	β^a	β^b	β^c	β^b
Carbon monoxide (ppm)[d]	22.3 (11.5)	28.6 (12.3)	6.3 (5.3)	.06	–.06	.31***	.34***
CEQ (range: 0–100)[e]							
Smoking satisfaction	-	61.7 (27.2)	-	.27***	.32***	.05	–.09
Psychological reward	-	43.8(27.2)	-	.47*****	.46*****	.22**	.02
Aversion	-	16.3 (18.4)	-	.09	.14	–.06	–.12
Enjoy sensations in throat/chest?	-	45.2 (33.7)	-	.28***	.20*	.27**	.18
Reduce craving for cigarettes?	-	62.9 (34.2)	-	.16	.13	.13	.07
PANAS (range: 1–5)[d]							
Positive affect	3.46 (0.85)	3.47 (0.95)	0.00 (0.40)	.30**	.25**	.23**	.12
Negative affect	1.43 (0.52)	1.26 (0.42)	–0.17 (0.33)	–.08	–.02	–.14	–.13
TCQ (range: 1–7)[d]							
Emotionality	2.98 (1.72)	1.91 (1.35)	–1.07 (1.53)	.02	–.02	.13	.14
Expectancy	4.61 (1.68)	2.50 (1.58)	–2.12 (1.83)	.06	.05	.06	.04
Compulsivity	2.80 (1.47)	1.88 (1.32)	–0.91 (1.31)	.03	–.04	.16	.18
Purposefulness	4.13 (1.36)	2.51 (1.53)	–1.62 (1.59)	.10	.01	.23**	.22**

*Note. N*s vary from 84 – 87 due to missing data. ASI = Anxiety Sensitivity Index; CEQ = Cigarette Evaluation Questionnaire; MASQ-AA = Mood and Anxiety Symptom Questionnaire-Anxious Arousal Scale.
[a]Regression models include ASI score as sole predictor and subjective effect as outcome.
[b]Model includes both ASI and MASQ-AA Scale as simultaneous predictors.
[c]Models include MASQ-AA score as sole predictor and subjective effect as outcome.
[d]Dependent variable is change score (post – pre) and model adjusted for corresponding pre-cigarette score.
[e]Dependent variable is post-cigarette score because the CEQ is designed to be administered only after cigarette.
**$p < .05$; ***$p < .01$; ****$p < .001$; *****$p < .0001$

2008; Brown et al., 2001; Leyro et al., 2008). Thus, it is surprising that AS exhibited more consistent associations with measures indicative of positive reinforcement processes, including smoking satisfaction, psychological reward, and positive affect enhancement, than those indicative of negative reinforcement processes (e.g., negative affect suppression) in this study.

It is important to note that participants were tested under typical conditions with no experimental manipulation to provoke negative affect in this study. In contrast, prior results suggest that relations between AS and smoking-induced negative affect reduction may be more robust following experimental manipulations designed to provoke pre-smoking negative affect, such as stress and tobacco deprivation (Evatt & Kassel, 2010; Perkins et al., 2010). Taken together, it is possible that negative reinforcement processes maintain smoking behavior in high-AS individuals during situations characterized by high-state negative affect, whereas positive reinforcement processes may maintain smoking behavior in otherwise typical circumstances. This account is consistent with the notion that high-AS smokers are more sensitive to all types of interoceptive cues. Thus, in states of low negative affect, high-AS smokers may perceive stronger changes in smoking-induced reward as compared with smoking-induced relief. Overall, the pattern of results across studies indicates that smoking to modulate affect (either positive or negative) is likely a central factor linking AS and tobacco dependence.

Several study limitations should be considered. Because we excluded smokers with current drug or alcohol dependence and those taking psychiatric medications, our findings may not extend to individuals with these comorbidities. Additionally, we did not test across-experimental conditions known to increase smoking motivation, such as tobacco deprivation or stress, and therefore cannot conclude that these results generalize across a wider variety of situations. Also, although we included a relatively comprehensive battery of subjective measures, it would have been useful to examine if these findings extended to behavioral and physiological indices of smoking reinforcement, such as rate of tobacco self-administration, willingness to pay or execute instrumental responses for cigarettes, or imaging brain reward system activity during smoking. Additionally, we did not utilize objective smoking topography measures (e.g., puff volume, duration, frequency). Thus, even though smoking-induced CO boost was not associated with AS, we cannot rule out the possibility that smoking topography during cigarette administration differed as a function of AS, which might have influenced the subjective effects of smoking. Indeed, it is possible that high-AS individuals took longer puffs at greater velocity or smoked their cigarettes more rapidly, which could have influenced the rate of nicotine absorption and hence the subjective effects caused by smoking. Furthermore, we did not include measures of trait or state anxiety in this study. Therefore, we cannot clarify the extent to which trait anxiety overlaps with AS with regards to variation in smoking effects, nor can we determine how AS moderates smoking-induced changes in state anxiety. Change in pre- to post-cigarette ratings for positive affect was not significant when averaged across the sample, which raises questions whether the methodology used in this study was ideal for detecting smoking-induced positive affect enhancement.

Additionally, the null change in positive affect in the overall sample must be taken into account when interpreting the relation between AS and smoking-induced positive affect. Specifically, this pattern indicates that high-AS smokers reported positive affect improvement after smoking, whereas low-AS smokers reported a worsening of positive affect. Concordant with the current findings, Strong et al. (2011) found that changes in positive affect before versus after smoking a cigarette did not differ in the overall sample. However, inter-subject analyses in that study showed associations between degree of smoking-induced positive affect and relapse status. Thus, it is possible that divergent positive affective reactions to smoking may help explain clinically relevant inter-individual variability among smokers.

Limitations notwithstanding, this study advances the literature by indicating that AS may be an important underlying psychological vulnerability factor in the comorbidity between anxiety-related conditions and smoking. Specifically, this study yielded novel data suggesting positive reinforcement processes may play a role in linking AS and smoking behavior. Accordingly, it may behoove nicotine and tobacco researchers studying AS to examine the extent to which high-AS individuals are motivated to smoke for positive affect enhancement, pleasure, stimulation, cognitive improvement, and other positive reinforcement processes. Such mechanisms could underlie risk of smoking onset, escalation, and maintenance of tobacco dependence in high-AS individuals. From a clinical perspective, the current findings suggest that high-AS smokers who wish to quit may benefit from interventions designed to increase access to healthy alternative reinforcers (e.g., interpersonal relationships, physical activity) that provide subjective rewarding effects as a substitute for smoking. Pending the replication and extension of this work along with other research on the mechanisms linking AS and smoking, novel smoking interventions that target AS as a risk factor for smoking dependence could be developed (Feldner, Zvolensky, Babson, Leen-Feldner, & Schmidt, 2008; Zvolensky, Bernstein, Yartz, McLeish, & Feldner, 2008; Zvolensky, Yartz, Gregor, Gonzalez, & Bernstein, 2008) that may help to offset the public health burden associated with anxiety-smoking comorbidity.

FUNDING

This work was supported, in part, by research grants R01DA026831 and K08DA025041.

DECLARATION OF INTERESTS

None declared.

REFERENCES

Battista, S. R., Stewart, S. H., Fulton, H. G., Steeves, D., Darredeau, C., & Gavric, D. (2008). A further investigation of the relations of anxiety sensitivity to smoking motives. *Addictive Behaviors*, *33*, 1402–1408. doi:10.1016/j.addbeh.2008.06.016

Brown, R. A., Kahler, C. W., Zvolensky, M. J., Lejuez, C. W., & Ramsey, S. E. (2001). Anxiety sensitivity: Relationship to negative affect smoking and smoking cessation in smokers with past major depressive disorder. *Addictive Behaviors*, *26*, 887–899. doi:10.1016/S0306-4603(01)00241-6

Brown, R. A., Lejuez, C. W., Kahler, C. W., Strong, D. R., & Zvolensky, M. J. (2005). Distress tolerance and early smoking lapse. *Clinical Psychology Review*, *25*, 713–733. doi:10.1016/j.cpr.2005.05.003

Cappelleri, J. C., Bushmakin, A. G., Baker, C. L., Merikle, E., Olufade, A. O., & Gilbert, D. G. (2007). Confirmatory factor analyses and reliability of the modified Cigarette Evaluation Questionnaire. *Addictive Behaviors*, *32*, 912–923. doi:10.1016/j.addbeh.2006.06.028

Evatt, D. P., & Kassel, J. D. (2010). Smoking, arousal, and affect: The role of anxiety sensitivity. *Journal of Anxiety Disorders*, *24*, 114–123. doi:10.1016/j.janxdis.2009.09.006

Feldner, M. T., Zvolensky, M. J., Babson, K., Leen-Feldner, E. W., & Schmidt, N. B. (2008). An integrated approach to panic prevention targeting the empirically supported risk factors of smoking and anxiety sensitivity: Theoretical basis and evidence from a pilot project evaluating feasibility and short-term efficacy. *Journal of Anxiety Disorders*, *22*, 1227–1243. doi:10.1016/j.janxdis.2008.01.005

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (2002). *Structured clinical interview for DSM-IV-TR axis I disorders, research version, non-patient edition. (SCID-I/NP)*. New York: Biometrics Research, New York State Psychiatric Institute.

FTC. (2008). *Tar, nicotine, and carbon monoxide reports of commercially available cigarettes.* Washington DC: Federal Trade Commission of the United States Government.

Heatherton, T. F., Kozlowski, L. T., Frecker, R. C., & Fagerström, K. O. (1991). The Fagerström Test for nicotine dependence: A revision of the Fagerström Tolerance Questionnaire. *British Journal of Addiction*, *86*, 1119–1127. doi:10.1111/j.1360-0443.1991.tb01879.x

Heishman, S. J., Singleton, E. G., & Pickworth, W. B. (2008). Reliability and validity of a Short Form of the Tobacco Craving Questionnaire. *Nicotine & Tobacco Research*, *10*, 643–651.doi:10.1080/14622200801908174

Johnson, K. A., Stewart, S., Rosenfield, D., Steeves, D., & Zvolensky, M. J. (2011). Prospective evaluation of the effects of anxiety sensitivity and state anxiety in predicting acute nicotine withdrawal symptoms during smoking cessation. *Psychology of Addictive Behaviors, 26(2), 289-297*. doi:10.1037/a0024133

Leyro, T. M., Zvolensky, M. J., Vujanovic, A. A., & Bernstein, A. (2008). Anxiety sensitivity and smoking motives and outcome expectancies among adult daily smokers: Replication and extension. *Nicotine & Tobacco Research*, *10*, 985–994. doi:10.1080/14622200802097555

McLeish, A. C., Zvolensky, M. J., & Bucossi, M. M. (2007). Interaction between smoking rate and anxiety sensitivity: Relation to anticipatory anxiety and panic-relevant avoidance among daily smokers. *Journal of Anxiety Disorders*, *21*, 849–859. doi:10.1016/j.janxdis.2006.11.003

McNally, R. J. (2002). Anxiety sensitivity and panic disorder. *Biological Psychiatry*, *52*, 938–946. doi:10.1016/S0006-3223(02)01475-0

Morissette, S. B., Tull, M. T., Gulliver, S. B., Kamholz, B. W., & Zimering, R. T. (2007). Anxiety, anxiety disorders, tobacco use, and nicotine: a critical review of interrelationships. *Psychological Bulletin*, *133*, 245–272. doi:10.1037/0033-2909.133.2.245

Perkins, K. A., Karelitz, J. L., Giedgowd, G. E., & Conklin, C. A. (2012). The reliability of puff topography and subjective responses during ad lib smoking of a single cigarette. *Nicotine & Tobacco Research*, *14*, 490–494. doi:10.1093/ntr/ntr150

Perkins, K. A., Karelitz, J. L., Giedgowd, G. E., Conklin, C. A., & Sayette, M. A. (2010). Differences in negative mood-induced smoking reinforcement due to distress tolerance, anxiety sensitivity, and depression history. *Psychopharmacology*, *210*, 25–34. doi:10.1007/s00213-010-1811-1

Peterson, R. A. H., Heilbronner, R. L. (1987). The Anxiety Sensitivity index: Construct validity and factor analytic structure. *Journal of Anxiety Disorders*, *1*, 117–121. doi:10.1016/0887-6185(87)90002–8

Radloff, L. S. (1977). The CES-D Scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*, *1*, 385–401. doi:10.1177/014662167700100306

Reiss, S., Peterson, R. A., Gursky, D. M., & McNally, R. J. (1986). Anxiety sensitivity, anxiety frequency and the prediction of fearfulness. *Behaviour Research and Therapy*, *24*, 1–8. doi:10.1016/0005-7967(86)90143–9

Shafer, A. B. (2006). Meta-analysis of the factor structures of four depression questionnaires: Beck, CES-D, Hamilton, and Zung. *Journal of Clinical Psychology*, *62*, 123–146. doi:10.1002/jclp.20213

Stewart, S. H., Buffett-Jerrott, S. E., & Kokaram, R. (2001). Heartbeat awareness and heart rate reactivity in anxiety sensitivity: A further investigation. *Journal of Anxiety Disorders*, *15*, 535–553. doi:10.1016/S0887-6185(01)00080-9

Strong, D. R., Leventhal, A. M., Evatt, D. P., Haber, S., Greenberg, B. D., Abrams, D., & Niaura, R. (2011). Positive reactions to tobacco predict relapse after cessation. *Journal of Abnormal Psychology*, *120*, 999–1005. doi:10.1037/a0023666

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*, 1063–1070. doi:10.1037//0022-3514.54.6.1063

Watson, D., Weber, K., Assenheimer, J. S., Clark, L. A., Strauss, M. E., & McCormick, R. A. (1995). Testing a tripartite model: I. Evaluating the convergent and discriminant validity of anxiety and depression symptom scales. *Journal of Abnormal Psychology*, *104*, 3–14. doi:10.1037//0021-843X.104.1.3

Westman, E. C., Levin, E. D., & Rose, J. E. (1992). Smoking while wearing the nicotine patch: Is smoking satisfying or harmful? *Clinical Research*, *40*, 871A.

Zinbarg, R., Barlow, D., & Brown, T. (1997). Hierarchical structure and general factor structure saturation of the Anxiety Sensitivity Index: Evidence and implications. *Psychological Assessment*, *9*, 277–284. doi:10.1037/1040-3590.9.3.277

Zvolensky, M. J., Bernstein, A., Cardenas, S. J., Colotla, V. A., Marshall, E. C., & Feldner, M. T. (2007). Anxiety sensitivity and early relapse to smoking: A test among Mexican daily, low-level smokers. *Nicotine & Tobacco Research*, *9*, 483–491. doi:10.1080/14622200701239621

Zvolensky, M. J., Bernstein, A., Yartz, A. R., McLeish, A., & Feldner, M. T. (2008). *Cognitive-behavioral treatment of comorbid panic psychopathology and tobacco use and dependence*. New York: Springer.

Zvolensky, M. J., Kotov, R., Antipova, A. V., & Schmidt, N. B. (2005). Diathesis stress model for panic-related distress: A test in a Russian epidemiological sample. *Behaviour Research and Therapy*, *43*, 521–532. doi:10.1016/j.brat.2004.09.001

Zvolensky, M. J., Stewart, S. H., Vujanovic, A. A., Gavric, D., & Steeves, D. (2009). Anxiety sensitivity and anxiety and depressive symptoms in the prediction of early smoking lapse and relapse during smoking cessation treatment. *Nicotine & Tobacco Research, 11*, 323–331. doi:10.1093/ntr/ntn037

Zvolensky, M. J., Vujanovic, A. A., Miller, M. O., Bernstein, A., Yartz, A. R., Gregor, K. L., . . . Gibson, L. E. (2007). Incremental validity of anxiety sensitivity in terms of motivation to quit, reasons for quitting, and barriers to quitting among community-recruited daily smokers. *Nicotine & Tobacco Research, 9*, 965–975. doi:10.1080/14622200701540812

Zvolensky, M. J., Yartz, A.R., Gregor, K., Gonzalez, A., & Bernstein, A. (2008). Interoceptive exposure-based cessation intervention for smokers high in anxiety sensitivity: A case series. *Journal of Cognitive Psychotherapy*, *22*, 346–365. doi:10.1891/0889-8391.22.4.346