Original Investigation

Posttraumatic Stress Symptoms and Cigarette Deprivation in the Prediction of Anxious Responding among Trauma-Exposed Smokers: A Laboratory Test

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Abstract

Introduction: The present investigation examined the main and interactive effects of posttraumatic stress symptom severity and 12-hr cigarette deprivation (cf. smoking as usual) in the prediction of anxious responding during a 4-min 10% carbon dioxide (CO₂)–enriched air laboratory challenge. It was hypothesized that 12-hr cigarette deprivation would exacerbate the effects of posttraumatic stress symptom severity with regard to anxious responding during the challenge.

Methods: Participants were 63 daily smokers (46.0% women; $M_{age} = 30.79$, $SD = 13.12$, range = 18–60) who reported experiencing one or more traumatic events. The study consisted of two laboratory sessions. At the first session, participants were administered a structured diagnostic interview and completed self-reported measures. Eligible participants were randomly assigned to one of two conditions for the second session: (a) 12-hr cigarette deprivation or (b) noncigarette deprivation (i.e., smoking as usual). At the second session, participants' smoking status was biochemically verified, and all eligible participants then were administered the 10% CO₂–enriched air laboratory challenge protocol.

Results: The main and interactive effects of posttraumatic stress symptom severity and the smoking-as-usual condition—not the hypothesized 12-hr cigarette deprivation condition—were significantly predictive of peri-challenge anxiety. The interactive effect of posttraumatic stress by smoking as usual was significant at Minutes 3 and 4 of the challenge specifically.

Conclusions: The present investigation provided novel findings related to the roles of cigarette deprivation and smoking with

regard to self-reported anxious responding, among trauma-exposed smokers, during a challenge paradigm.

Introduction

One promising avenue for better understanding the association between posttraumatic stress and smoking may involve exploring the role(s) of cigarette deprivation and nicotine withdrawal symptoms (i.e., symptoms elicited by nicotine deprivation among smokers). The nicotine withdrawal syndrome, experienced between smoked cigarettes and more intensively during a cessation attempt or longer period of cigarette smoking deprivation, is characterized by a consistent set of symptoms. Smokers experiencing posttraumatic stress symptoms are likely to report (a) increased nicotine withdrawal symptom severity in response to aversive interoceptive sensations (e.g., autonomic arousal) elicited by trauma-related stimuli (Beckham et al., 1995) and (b) greater levels of withdrawal-related anxious and depressive symptoms during periods of cigarette deprivation (Pomerleau, Marks, & Pomerleau, 2000). Thus, nicotine withdrawal symptoms may amplify anxious and fearful responding to aversive internal sensations among trauma-exposed cigarette-deprived smokers. This enhanced anxious responding to aversive internal cues, such as bodily sensations, may increase the probability of smoking in response to negative affect and may, in turn, lead to lower rates of smoking cessation.

In one relevant study, Feldner, Vujanovic, Gibson, and Zvolensky (2008) found that nicotine withdrawal symptom severity, among daily smokers undergoing 12 hr of cigarette deprivation, significantly mediated the association between posttraumatic stress disorder (PTSD) diagnostic status

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(as compared with a no current psychopathology control group) and cognitive and physical panic symptoms elicited by a 3-min voluntary hyperventilation challenge procedure. Although this study offered preliminary evidence of the significant role of nicotine withdrawal symptom severity in terms of the association between PTSD and anxious reactivity during a period of cigarette deprivation, there are a number of outstanding issues in need of further inquiry. First, the Feldner et al. (2008) investigation utilized a 3-min voluntary hyperventilation paradigm, which lacks the methodological rigor of more controlled experimental paradigms (i.e., carbon dioxide [CO₂]-enriched air laboratory challenge paradigm; Zvolensky & Eifert, 2001). Second, the Feldner et al. (2008) investigation did not experimentally manipulate cigarette deprivation via random assignment but rather examined nicotine withdrawal symptoms among smokers who were undergoing a 12-hr period of cigarette deprivation. This methodological design does not allow for the evaluation of experimental group differences based on cigarette deprivation status. Third, the investigation examined PTSD diagnostic status categorically and did not provide a continuous measure of posttraumatic stress symptom severity to examine the interactive effect of symptom severity and nicotine withdrawal on anxious reactivity to bodily sensations.

The present investigation sought to address the limitations of the Feldner et al. (2008) study by (a) utilizing a well-controlled 4-min 10% CO₂-enriched air laboratory challenge to induce somatic perturbation (Zvolensky & Eifert, 2001), (b) experimentally manipulating nicotine levels via random assignment to 12-hr cigarette deprivation and smoking-as-usual groups, and (c) examining posttraumatic stress symptom severity continuously among trauma-exposed adult daily smokers. It was theorized that a state of 12-hr cigarette deprivation (i.e., nicotine withdrawal), as compared with smoking as usual, would exacerbate—or amplify—the expected effects of posttraumatic stress symptom severity on anxious responding during a biological challenge paradigm. Specifically, it first was hypothesized that the main effects of posttraumatic stress symptom severity and cigarette deprivation group status (cf. smoking-as-usual group status) would significantly predict anxious responding to bodily sensations over the course of the CO₂-enriched air challenge. Second, it was hypothesized that posttraumatic stress symptom severity would interact with cigarette deprivation group status (cf. smoking-as-usual group status) to significantly predict anxious responding over the course of the challenge, above and beyond the main effect terms. All effects were expected, after controlling for the variance contributed by anticipatory anxiety (anxiety ratings at Minute 9 of the prechallenge baseline period) and relevant covariates (i.e., age). No effects for physiological reactivity were expected as per the null findings of Feldner et al. (2008).

Methods

Participants

Participants were 63 daily smokers (46.0% women; $M_{\text{age}} = 30.79$, $SD = 13.12$, range = 18–60) who reported having experienced one or more DSM-IV-TR PTSD Criterion A traumatic events on the Posttraumatic Diagnostic Scale (PDS; Foa, 1995). This study was approved by the Institutional Review Board at the University of Vermont. Participants in the current report repre-

sent a trauma-exposed subset of individuals who participated in a larger study on cigarette deprivation and anxious responding (Vujanovic & Zvolensky, 2009). The racial composition of the sample was consistent with that of the state of Vermont population (State of Vermont Department of Health, 2008): approximately 93.7% of the sample identified as White/Caucasian, 1.6% identified as Black/African-American, 1.6% identified as Hispanic/Latino, and 3.2% identified as “other.”

Participants reported smoking an average of 13.70 ($SD = 6.99$) cigarettes/day and smoking for an average of 12.49 ($SD = 11.79$) years. Participants reported initiating daily smoking at a mean age of 17.83 ($SD = 6.06$) years. Participants reported making an average of 2.65 ($SD = 2.49$) lifetime quit attempts, with a mean of 3.45 ($SD = 4.16$) occasions of at least 12-hr abstinence from smoking. Participants scored an average of 3.47 ($SD = 1.74$) on the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991), indicating low to moderate levels of nicotine dependence.

Based on the *Structured Clinical Interview for DSM-IV Axis I Disorders* (SCID-I; First, Spitzer, Gibbon, & Williams, 1995), 36.5% ($n = 23$) of the sample met criteria for at least one Axis I disorder. Among those who met criteria for Axis I psychopathology, individuals met criteria for an average of 1.82 psychological disorders ($SD = 0.78$). Among those with Axis I psychopathology, approximately 47.8% ($n = 11$) met criteria for major depressive disorder, 43.4% ($n = 10$) for generalized anxiety disorder, 26.1% ($n = 6$) for specific phobia, 21.7% ($n = 5$) for panic disorder with or without agoraphobia, 21.7% ($n = 5$) for social phobia, 8.7% ($n = 2$) for PTSD, 4.3% ($n = 1$) for agoraphobia with no history of panic disorder, 4.3% ($n = 1$) for bipolar disorder, and 4.3% ($n = 1$) for bipolar II disorder. The smoking-as-usual group evidenced 23 total Axis I diagnoses (among 36 individuals), while the cigarette deprivation group manifested a total of 13 Axis I diagnoses (among 27 individuals).

According to the PDS (Foa, 1995), participants met criteria for an average of 3.11 traumatic events ($SD = 2.13$), and the sample averaged a PDS—total score of 11.84 ($SD = 12.06$, range = 0–42). Approximately 52.4% of the sample reported experiencing a transportation accident, 38.1% reported a nonsexual assault by someone they know, 36.5% reported a natural disaster, 34.9% reported an “other” event (e.g., unexpected death of a loved one), 33.3% reported a nonsexual assault by a stranger, 31.7% reported sexual contact under the age of 18 years with an adult five or more years older, 28.6% reported a sexual assault by someone they know, 19.0% reported imprisonment, 14.3% reported a life-threatening illness, 9.5% reported a sexual assault by a stranger, 6.3% reported exposure to combat, and 6.3% reported torture.

For inclusion in the study, participants (a) were between 18 and 65 years of age, (b) were daily smokers for at least the past year, (c) were currently (past month) smoking at least 10 cigarettes/day, (d) had not decreased the number of cigarettes smoked per day by more than half in the past six months, and (e) reported a willingness to abstain from smoking for a 12-hr period, as determined by CO analysis of breath samples (10 ppm cutoff; Cocores, 1993). Participants were excluded from the study based on evidence of (a) limited mental competency and the inability to give informed, voluntary written consent to participate; (b) current or past psychotic-spectrum symptoms;

(c) current (past week) suicidal intent; (d) for women, the possibility of being pregnant (by self-report); (e) current or past chronic illness (e.g., heart disease, chronic obstructive pulmonary disease); and (f) self-reported past participation in a CO₂-enriched air laboratory challenge study.

Measures

Structured Clinical Interview for DSM-IV Axis I Disorders/Non-Patient Version (SCID-I/NP)

Diagnostic assessments were conducted using the SCID-I/NP (First et al., 1995). Interviews were audio taped, and the reliability of a random selection of 20.6% of interviews ($n = 24$) was determined and checked for accuracy by a doctoral-level independent rater; no cases of diagnostic coding disagreement were noted.

Posttraumatic Diagnostic Scale

The PDS (Foa, 1995) is a 49-item self-report instrument designed to assess the presence of posttraumatic stress symptoms based on DSM-IV criteria (American Psychiatric Association [APA], 1994, 2000). Respondents report if they have experienced any of 12 traumatic events, including an “other” category, and then indicate which event was most disturbing. Respondents also rate the frequency (0 = *not at all or only one time* to 3 = *five or more times a week/almost always*) of 17 PTSD symptoms experienced in the past month in relation to the most-disturbing event endorsed (total score range of 0–51). The PDS is a measure of trauma-related symptoms with generally excellent psychometric properties (Foa, Cashman, Jaycox, & Perry, 1997), and it has been utilized among samples of trauma-exposed individuals with and without PTSD (e.g., Foa et al.; Vujanovic, Youngwirth, Johnson, & Zvolensky, 2009). The PDS has demonstrated high internal consistency ($\alpha = .92$) and high test–retest reliability ($\kappa = .74$). In this study, the PDS was utilized to index traumatic event exposure and to assess posttraumatic stress symptom severity.

Smoking History Questionnaire

Smoking history and pattern were assessed with the well-established Smoking History Questionnaire (SHQ). The SHQ has been successfully used in previous studies as a descriptive measure of smoking history (Brown, Lejuez, Kahler, & Strong, 2002; Zvolensky, Lejuez, Kahler, & Brown, 2004).

Fagerström Test for Nicotine Dependence

The FTND is a six-item scale designed to assess gradations in tobacco dependence (Heatherton et al., 1991). The FTND is a revision of the Fagerström Tolerance Questionnaire (Fagerstrom, 1978). The FTND has demonstrated good psychometric properties (Heatherton et al.; Payne, Smith, McCracken, McSherry, & Antony, 1994; Pomerleau, Carton, Lutzke, Flessland, & Pomerleau, 1994).

Minnesota Nicotine Withdrawal Scale

The Minnesota Nicotine Withdrawal Scale (MWS; Hughes & Hatsukami, 1986) is a reliable and sensitive seven-item self-report scale that was utilized to measure current nicotine withdrawal symptoms. On the MWS, participants are asked to rate their nicotine withdrawal symptoms on a 4-point Likert-type scale (0 = *not present* to 3 = *severe*). As recommended by Hughes and Hatsukami (1998), only DSM-IV nicotine withdrawal symptom items were included in the computation of the MWS

total score. The MWS was administered at the second session, upon arrival to the laboratory, to index prechallenge nicotine withdrawal symptoms as per the between-group manipulation check.

Carbon monoxide Analysis

A noninvasive biochemical verification of recent smoking history was completed using carbon monoxide (CO) analysis of breath samples (10 ppm cutoff; Cocomore, 1993). Expired air CO levels were assessed using a CMD/CO Carbon Monoxide Monitor (Model 3110; Spirometrics, Inc., Gray, ME).

Subjective Units of Distress Scale

Subjective Units of Distress Scale (SUDS) ratings (Wolpe, 1958) were used to index self-reported anxiety focused on bodily sensations. This Likert-type scale ranges from 0 (*no anxiety*) to 100 (*extreme anxiety*). Participants completed ratings at prechallenge to index of anticipatory anxiety (Minute 9 of prechallenge baseline) as well as at 1-min intervals during the challenge (Minutes 1–4 of challenge procedure) to index anxiety focused on bodily sensations. Peri-challenge anxiety ratings refer to SUDS anxiety ratings at Minutes 1–4 of the challenge.

Physiological Data

A J&J Engineering I-330-C2 system was used to digitally record physiological data online at a sample rate of 1,024 samples per second across all channels using J&J Engineering Physiolog Software. For a full description of the physiological data recording system, please see Vujanovic and Zvolensky (2009).

Procedure

Daily smokers were recruited through newspaper advertisements and flyers posted in local businesses and on community bulletin boards. This study was conducted in the Anxiety and Health Research Laboratory at the University of Vermont. The study consisted of two appointments. Participants received \$10 at the completion of the first session and \$25 at the conclusion of the second session. At the baseline session, participants completed informed verbal and written consent and then were administered a complete diagnostic interview, a validated medical screening interview, and CO analysis of breath samples. If eligible after these procedures, random assignment was utilized to assign participants to either (a) cigarette deprivation—CO₂ (please see Description below) or (b) noncigarette deprivation—CO₂ condition (i.e., smoking as usual). Eligible participants then completed a battery of self-report questionnaires. Participants in the cigarette deprivation group were asked to refrain from smoking for 12 consecutive hours prior to their second scheduled appointment. The 12-hr cigarette deprivation interval was standardized so that all participants were instructed to refrain from smoking for 12 hr overnight. Participants in the smoking-as-usual group were instructed to smoke “as usual” between appointments as well as 15 min prior to arriving for the second appointment.

The second session was scheduled for a date within 2 weeks of the baseline assessment; the mean duration of time between appointments was 5.89 days ($SD = 4.22$, range = 1–19 days). Participants were specifically instructed to not use any form of nicotine replacement therapy for the duration of their involvement in the study. The second session consisted of biochemical verification of smoking status to confirm adherence to group

assignment and the CO₂-enriched air challenge procedure. Participants whose biochemically verified smoking status did not adhere to their group assignment (i.e., required CO < 10 ppm for cigarette deprivation group) were discontinued from the study; and one participant was discontinued at the second session (prior to engaging in the challenge procedure) due to biochemically verified nonadherence to the cigarette deprivation condition.

Challenge Procedure

At the second scheduled session, each participant was introduced to a controlled laboratory setting with intercom and audio–visual communication with the experimenter in the adjacent room. The experimenter attached psychophysiological monitoring electrodes and a C-Pap respiratory mask to each participant. Participants listened to a standardized audio-taped description of the challenge procedure, successfully used in past work, to equate expectancy effects (Feldner, Zvolensky, Eifert, & Spira, 2003; Spira, Zvolensky, Eifert, & Feldner, 2004).

There were three main recording phases during the challenge. The first phase consisted of a 10-min prechallenge baseline. The second phase involved a 4-min 10% CO₂-enriched air biological challenge (see Lejuez, Forsyth, & Eifert, 1998), a commonly employed tactic that effectively elicits fear responses (Abrams et al., 2008; Zvolensky & Eifert, 2001). This CO₂ concentration has been used successfully in past work to elicit anxious and fearful responding to bodily sensations (Bernstein, Zvolensky, Marshall, & Schmidt, 2009), although it is not fully clear what mechanisms contribute to such effects (Abrams et al.). The third phase consisted of a 5-min postchallenge recovery period. Participants completed anxiety ratings throughout the

procedure as instructed by an audio recording (for a full summary of the challenge procedure, please see Vujanovic & Zvolensky, 2009). Two participants removed their masks and requested discontinuation of the CO₂-enriched air administration at Minutes 3.03 and 3.35 of the 4-min challenge procedure, respectively. Both participants completed all remaining self-report questionnaires and physiological monitoring.

Results

Manipulation Checks and Descriptive Characteristics

Please see Table 1 for descriptive data and group differences in prechallenge (Minute 9 of prechallenge baseline) and postchallenge (Minute 4 of challenge, immediately after termination of CO₂ administration) anxiety measures. Within the total sample, heart rate, $t(57) = 6.94, p < .001$, and skin conductance level, $t(57) = 5.99, p < .001$, significantly increased from prechallenge to postchallenge. Respiration rate, $t(31) = 1.82, p = .08$, and SUDS ratings, $t(61) = 1.88, p = .07$, did not significantly increase from prechallenge to postchallenge, although a trend toward formal levels of statistical significance emerged for both variables. When examining the cigarette deprivation and smoking-as-usual groups separately, the pattern remained the same with the exception that the smoking-as-usual group evidenced a significant increase in SUDS ratings from prechallenge to post challenge, $t(34) = 3.37, p < .01$.

Tests of between-group differences were conducted to identify covariates that might correct for any potential failures of randomization indicated by significant group differences.

Table 1. Carbon dioxide–Enriched Air Laboratory Challenge Manipulation Checks: Prechallenge to Postchallenge Comparisons on Self-report Anxiety Ratings and Physiological Responding

Variables	Group	Prechallenge ^a , <i>M</i> (<i>SD</i>)	Postchallenge ^b , <i>M</i> (<i>SD</i>)	Tests of prechallenge to postchallenge change
SUDS ^c anxiety ratings	Total	51.97 (29.84)	60.32 (31.62)	$t(61) = 1.88$
	Cigarette deprivation ^d	56.30 (30.81)	50.93 (32.88)	$t(26) = -.85$
	Smoking as usual ^e	48.63 (29.07)	67.57 (29.04)	$*t(34) = 3.37$
Skin conductance	Total	1.97 (1.81)	4.65 (4.09)	$**t(57) = 5.99, p < .001, d = 1.58$
	Cigarette deprivation	1.90 (1.57)	4.34 (2.52)	$**t(23) = 5.92, p < .001, d = 2.46$
	Smoking as usual	2.02 (1.99)	4.87 (4.94)	$**t(33) = 4.02, p < .001, d = 1.39$
Heart rate	Total	79.35 (12.11)	89.31 (13.85)	$**t(57) = 6.94, p < .001, d = 1.83$
	Cigarette deprivation	73.08 (10.81)	85.08 (13.57)	$**t(23) = 5.76, p < .001, d = 2.40$
	Smoking as usual	83.79 (11.09)	92.30 (13.45)	$**t(33) = 4.38, p < .001, d = 1.52$
Respiration rate	Total	16.91 (4.55)	18.63 (4.50)	$t(31) = 1.82, p = .08$
	Cigarette deprivation	16.02 (5.71)	18.14 (3.73)	$t(13) = 1.78, p = .098$
	Smoking as usual	17.60 (3.42)	19.02 (5.09)	$t(17) = .99, p = .34$

Note. *N* = 63 (cigarette deprivation group: *n* = 27 and smoking-as-usual group: *n* = 36). *d* = Cohen's *d* effect size estimate; SUDS = Subjective Units of Distress Scale.

^aLevels at Minute 9 of prechallenge baseline period.

^bLevels immediately postchallenge (Minute 1 of postchallenge recovery period).

^cSUDS ratings (self-reported anxiety ratings, 0–100 scale).

^dCigarette deprivation group (no smoking for 12 hr prior to challenge).

^eSmoking-as-usual group (smoking as usual and 15 min prior to challenge).

* $p < .01$; ** $p < .001$.

Significant differences between groups were found in terms of age, CO analysis of breath sample readings (prechallenge), and nicotine withdrawal symptoms (prechallenge). No gender differences were noted with regard to any of the studied variables. The smoking-as-usual group was significantly older than the cigarette deprivation group ($M = 34.1$, $SD = 13.9$ and $M = 26.3$, $SD = 10.5$; $t(61) = -2.41$, $p < .05$). Therefore, age was entered as a covariate in each of the models to correct for failure of randomization. As expected, upon arrival to the laboratory for the challenge session, the cigarette deprivation group endorsed significantly higher levels of nicotine withdrawal symptoms than the smoking-as-usual group ($M = 8.2$, $SD = 4.6$ and $M = 4.4$, $SD = 5.1$; $t(61) = 2.99$, $p = .004$); however, these effects dissipated by Minute 9 of the prechallenge baseline. Also as expected, at the laboratory session, the cigarette deprivation group evidenced significantly lower CO analysis of breath sample readings (10 ppm cutoff for deprivation group) than the smoking-as-usual group ($M = 6.8$, $SD = 2.6$ and $M = 21.92$, $SD = 11.14$; $t(61) = -6.85$, $p < .001$). Notably, the groups did not differ significantly (p 's $> .05$) with regard to any other variables of interest, including gender, psychotropic medication use, education, number of current Axis I diagnoses, daily smoking rate (past week), age of onset of daily smoking, nicotine dependence, number of traumas, posttraumatic stress symptom severity, or anticipatory anxiety prior to the challenge.

Analysis of Variance Results

Please see Table 2 for a summary of analyses and Figure 1 for a depiction of the interactive effects over time. First, a 2 (group status: cigarette deprivation vs. smoking as usual) $\times$ 4 (SUDS assessment: Minutes 1–4) repeated measures analysis of variance (ANOVA) was conducted, and the between-subjects effects were evaluated in terms of the predictive validity of the covariates, main effects, and interaction term (PDS $\times$ group status) on the SUDS within-subjects variable. In terms of between-subjects effects, higher prechallenge SUDS anxiety ratings (Minute 9 of prechallenge baseline), higher PDS scores, smoking-as-usual group status, and the PDS by group interaction effect were each significant predictors of higher peri-challenge SUDS anxiety ratings (p 's $< .05$); age was not a significant predictor ($p > .05$).

Second, four univariate ANOVAs were performed, using the same model, to examine the timepoints at which significant PDS by group status interactive effects was noted. In terms of Challenge Minute 1, SUDS anxiety ratings, prechallenge SUDS anxiety ratings, and smoking-as-usual group status were each significant predictors (p 's $< .05$), and of note, PDS total score was a marginally significant predictor ($p = .07$). In regard to Challenge Minute 2, SUDS anxiety ratings and prechallenge SUDS anxiety ratings were the only significant predictor ($p < .05$), and again, PDS total score was a marginally significant predictor ($p = .07$). In terms of Challenge Minute 3, SUDS anxiety ratings, prechallenge SUDS anxiety rating, PDS total, and smoking-as-usual group status were significant predictors (p 's $< .05$). The PDS by group interactive effect was approaching statistical significance ($p = .06$). In terms of Challenge Minute 4, SUDS anxiety ratings, prechallenge SUDS anxiety ratings, PDS total score, smoking-as-usual group status, and the PDS by group interactive effect were significant predictors (p 's $\leq .05$).

Table 2. Repeated Measures Analysis of Variance: Interactive Effects of Posttraumatic Stress and Cigarette Deprivation Group Status in the Prediction of Peri-Challenge Anxiety Ratings

	<i>F</i>	η^2	<i>p</i> Value
Dependent variable: peri-challenge anxiety, Minutes 1–4 ^a			
Covariates			
Prechallenge SUDS ratings ^b	26.83	.33	<.001
Age	.27	.00	.60
Main effects			
PDS—total ^c	7.20	.12	.01
Group status ^d	8.74	.14	<.01
Interactive effect			
PDS $\times$ Group	5.05	.08	.02
Dependent variable: perichallenge anxiety—Minute 1 ^e			
Covariates			
Prechallenge SUDS ratings ^b	28.05	.33	<.001
Age	.14	.00	.70
Main effects			
PDS—total ^c	3.31	.05	.07
Group status ^d	4.59	.07	.03
Interactive effect			
PDS $\times$ Group	2.00	.03	.16
Dependent variable: peri-challenge anxiety—Minute 2 ^f			
Covariates			
Prechallenge SUDS ratings ^b	29.96	.35	<.001
Age	.04	.00	.70
Main effects			
PDS—total ^c	3.25	.05	.07
Group status ^d	2.26	.04	.03
Interactive effect			
PDS $\times$ Group	2.83	.05	.16
Dependent variable: peri-challenge anxiety—Minute 3 ^g			
Covariates			
Prechallenge SUDS ratings ^b	9.65	.15	<.01
Age	.59	.01	.44
Main effects			
PDS—total ^c	5.14	.08	.02
Group status ^d	13.32	.19	.001
Interactive effect			
PDS $\times$ Group	3.68	.06	.06
Dependent variable: postchallenge anxiety—Minute 4 ^h			
Covariates			
Prechallenge SUDS ratings ^b	9.30	.13	<.01
Age	.44	.00	.50
Main effects			
PDS—total ^c	5.70	.08	.02
Group status ^d	3.85	.06	.05
Interactive effect			
PDS $\times$ Group	3.93	.06	.05

Note. $N = 63$. PDS = Posttraumatic Diagnostic Scale; SUDS = Subjective Units of Distress Scale.

^aSUDS anxiety ratings, Challenge Minutes 1–4.

^bSUDS anxiety ratings, Challenge Minute 1.

^cSUDS anxiety ratings, Challenge Minute 2.

^dSUDS anxiety ratings, Challenge Minute 3.

^eSUDS anxiety ratings, Challenge Minute 4.

^fPre challenge SUDS ratings (Minute 9 of pre challenge baseline).

^gPDS—total score (mean centered).

^hGroup status (1 = cigarette deprivation and 2 = smoking as usual).

Figure 1. Interactive effects of posttraumatic stress and cigarette deprivation group status in the prediction of peri-challenge Subjective Units of Distress Scale (SUDS) anxiety ratings. High and low PDS groups were defined as half *SD* above and below the mean, respectively.

Mapping the Forms of the Significant Interactions

Based on the recommendations of Cohen and Cohen (1983, p. 323), the forms of the significant interactions were examined by inserting specific values for each predictor variable into the equations associated with the described analysis (half *SD* above and below the mean for PDS total). As depicted in Figure 1, the significant interactive effects are evident at Minutes 3 ($p = .06$) and 4 ($p < .05$) of the challenge paradigm only. Inconsistent with prediction, the highest levels of anxiety ratings were reported by the smoking-as-usual groups.

Discussion

Consistent with prediction, posttraumatic stress symptom severity was significantly predictive of peri-challenge anxiety. Specifically, posttraumatic stress symptom severity was incrementally predictive of anxious responding at Minutes 3 and 4 of the challenge, though it demonstrated only a trend toward statistical significance at Minutes 1 and 2 of the challenge (p 's = .07). This finding is consistent with past work (Feldner et al., 2008). These results utilize a trauma-exposed sample with varying levels of posttraumatic stress (mostly without PTSD) to extend previous work, which demonstrated that smokers with PTSD compared with those without PTSD report more anxiety and smoking craving following both trauma-related and general stress scripts (Beckham et al., 2007). Furthermore, the observed difference with respect to the role of posttraumatic stress symptom severity and anxious arousal at Minutes 1–2, and in contrast to Minutes 3–4 of the challenge, may be due to an increasing perceived intensity of the challenge over time as well as limited statistical power as a function of the sample size.

Contrary to prediction, the main effect of 12-hr cigarette deprivation was not a significant predictor of peri-challenge anxious responding. The smoking-as-usual group (in contrast to cigarette deprivation) emerged as a significant incremental predictor of anxious responding at Minutes 1, 3, and 4 of the challenge paradigm. This finding is consistent with the cigarette

deprivation effects noted in at least one previous study using the identical laboratory paradigm (Vujanovic & Zvolensky, 2009). Furthermore, this unexpected finding might be attributable to at least three possible nonmutually exclusive reasons. First, despite random assignment of participants to the cigarette deprivation versus smoking-as-usual groups, the latter group evidenced a higher total number of Axis I diagnoses (23 total diagnoses among 36 individuals) as compared with the cigarette deprivation group (13 total diagnoses among 27 individuals). Although the number of diagnoses did not differ significantly at the individual level, this group-based comparison indicates that the smoking-as-usual group evidenced greater overall psychopathology, a factor potentially responsible for the discrepant findings. Second, it is possible that the acute oxygen-depleting effects of smoking (Jensen, Goodson, Hopf, & Hunt, 1991) may have intensified anxious responding reported by the smoking-as-usual group, and these effects may have been further exacerbated by the administration of 10% CO₂-enriched air. This possible methodological artifact might be explored in future work to determine whether the CO₂-enriched air paradigm is indeed useful in the comparison of smoking versus cigarette deprivation in anxious responsivity. Lastly, since nicotine administration has been shown to have acute attention-amplifying effects as a stimulant drug (Peeke & Peeke, 1984; Rusted & Warburton, 1992), it is possible that the smoking-as-usual group was more attuned to their anxiety and to the laboratory challenge paradigm amplifying anxiety levels overall.

In terms of interactive effects, the posttraumatic stress by group effect was significant with regard to peri-challenge anxiety ratings. More specifically, the significant interactive effects emerged for Minutes 3 and 4 of the challenge only. However, the highest levels of anxiety were reported by the high posttraumatic stress/smoking-as-usual group at Minutes 3 and 4. During that time interval, comparably high anxiety levels were evidenced by the low posttraumatic stress/smoking-as-usual group.

The cigarette deprivation groups with high and low posttraumatic stress symptom severity, respectively, manifested the lowest levels of anxiety at Minutes 3 and 4. Here, it might be noted that only five individuals comprised the high posttraumatic

stress/cigarette deprivation group as compared with the 11–13 individuals comprising each of the other groups. As the high and low groups were defined as one-half *SD* above and below the mean for posttraumatic stress symptom severity, this might indicate that disproportionately fewer individuals with high levels of posttraumatic stress were randomized to the cigarette deprivation group contributing to the observed effects. These results may indicate that cigarettes function differently in smokers with greater psychopathology. This perspective would be consistent with studies documenting the greater likelihood of panic symptoms following usual smoking among individuals with panic disorder (Cosci et al., 2010). Future studies that incorporate multiple challenge types with controlled smoking paradigms may help delineate this potentially provocative finding. It also is interesting to note that the cigarette deprivation group appeared to show greater prechallenge to postchallenge change in physiological responding as compared with self-reported anxiety (see Table 1). Although such response discordance is common to studies of anxiety (Rachman, Craske, Tallman, & Solyom, 1986), this pattern of data is somewhat consistent with the original hypotheses. Future research should therefore attempt to replicate this finding in order to better ascertain what factors may be producing this type of response discordance in the context of cigarette deprivation.

The results of the current study broadly suggest that posttraumatic stress symptoms, even among smokers without the full diagnosis of PTSD, play a role in potentially exacerbating anxious responding to bodily sensations. It may be important to address posttraumatic stress symptoms prior to quitting in order to lessen anxiety symptoms to somatic stress. Such intervention tactics could possibly improve cessation success among smokers with posttraumatic stress symptoms.

This study has a number of limitations worthy of comment. First, this community sample was comprised of a relatively homogeneous sample in terms of racial/ethnic composition. It would be important for future work to replicate and extend these findings among more diverse clinical samples. Notably, although no gender differences were noted in the present investigation, future examination of these findings among larger samples is necessary to clarify potential gender differences with regard to smoking cessation and anxious responding to CO₂-enriched air laboratory paradigms (e.g., Brown, Lejuez, Kahler, & Strong, 2002). Second, participants were trauma-exposed smokers reporting low overall levels of posttraumatic stress symptoms, with few participants meeting current diagnostic criteria for PTSD. Thus, the present investigation may serve only as preliminary test of the interactive effect of posttraumatic stress and cigarette deprivation/smoking as usual with respect to anxious responding, until further replication and extension of this work is conducted among participants meeting diagnostic criteria for PTSD. It also is possible that the observed effect is not specific to posttraumatic stress symptoms per se and therefore may be more broadly applicable to anxiety and other types of negative mood (Vujanovic & Zvolensky, 2009). Third, trauma exposure and posttraumatic stress symptom severity were indexed with the PDS (Foa, 1995), a self-report measure. It would be important for future work to replicate and extend these findings using interview-based measures of trauma and posttraumatic stress, such as the Clinician-Administered PTSD Scale (Blake et al., 1995). This type of additional assessment would provide a more detailed description of the nature of trauma-

matic events among the sample. Fourth, the sample evidenced relatively low levels of nicotine dependence. Since nicotine dependence has been associated with self-reported intensity of nicotine withdrawal symptoms (Hughes, 2007), it is possible that the lower levels of dependence reported by this sample attenuated the hypothesized effects of the cigarette deprivation group. Fifth, DSM-IV substance use disorders were not formally assessed in the present study. Although concurrent substance use was not conceptualized a priori as a potential confound due to the unique withdrawal profile for nicotine, there is the potential that use of other substances may have affected self-reported nicotine withdrawal symptoms and anxious responding. Sixth, the current study did not involve an assessment of expired partial pressure of CO₂. Future work may benefit by the inclusion of expired CO₂ in an effort to more comprehensively characterize the challenge paradigm. Finally, cigarette levels were not standardized in the smoking group as participants smoked a cigarette of their choice prior to the challenge. Future studies would benefit from the standardization and investigation of various levels of cigarette on biological challenge responding. A counterbalanced within-subjects design, in particular, would likely help address this and related caveats to the current methodology.

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Declaration of Interests

The authors have no competing interests to declare. The views expressed here are those of the authors and do not necessarily represent those of the Department of Veterans Affairs.

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