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# Panic Reactivity to Voluntary Hyperventilation Challenge Predicts Distress Tolerance to Bodily Sensations among Daily Cigarette Smokers

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## Abstract

The present investigation examined the extent to which panic reactivity to bodily sensations is related to distress tolerance (DT) among daily smokers. It was hypothesized that panic reactivity to an initial voluntary hyperventilation (i.e., whether participants met criteria for a DSM-IV panic attack; PA) would predict the relative degree of task persistence on a second hyperventilation trial (DT) above and beyond the variance accounted for by anxiety sensitivity (AS), negative affectivity (NA), cigarette smoking rate, and self-reported discomfort intolerance (DI). Participants were 95 daily smokers (58% women; $M_{age}$ = 29.0, *SD* = 12.2) who completed a battery of questionnaires and two voluntary hyperventilation procedures. Results indicated PA status significantly predicted DT, above and beyond the theoretically relevant covariates of AS, NA, cigarettes per day, and DI ($p < .05$). Such a result is consistent with theoretical models and empirical findings on emotional reactivity that suggest panic responsivity to internal cues may represent a key explanatory construct in terms of level of DT to interoceptive stimuli.

### Keywords

Panic; Distress Tolerance; Emotion Vulnerability; Smoking

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There has been increased scientific attention addressing factors related to early lapse and relapse in smoking cessation (Brown, Lejuez, Kahler, & Strong, 2002; Brown, Lejuez, Kahler, Strong, & Zvolensky, 2005). This scientific work has been largely stimulated by the observation that many smokers attempting cessation who lapse early in a quit attempt subsequently have difficulty maintaining longer-term abstinence (Brown, Kahler et al., 2001; Cook, Gerkovich, O'Connell, & Potocky, 1995; Doherty, Kinnunen, Militello, & Garvey, 1995; Zvolensky, Bernstein et al., 2007). To improve cessation success, there has been an effort to develop specialized treatments for smoking cessation that are expressly oriented to facilitating sustained abstinence (Brown, Lejuez et al., 2005; Brown, Palm et al., in press). Although the results from such intervention work are in an early stage of development, they highlight the clinical need to understand the processes underlying failure to maintain abstinence, generally, and early lapse and relapse, in particular.

One promising line of inquiry on sustained abstinence has focused on the role of distress tolerance (DT). DT is typically defined as the ability to tolerate negative affect or related aversive psychological as well as physical states (Brown, Lejuez, et al., 2005). Conceptual models of early smoking lapsers during quit attempts posit that persons with low DT may be characterized by an inability to tolerate negative affect, withdrawal symptoms, bodily states, and other aversive interoceptive cues (Brown, Lejuez et al., 2005). To illustrate, a low threshold for tolerating negative affect and other aversive internal states that routinely occur during cessation (e.g., withdrawal symptoms, bodily sensations) may be associated with increased smoking behavior that is aimed at temporarily ameliorating - perceptually or objectively - such experiential discomfort (Baker, Piper, McCarthy, Majeskie, & Fiore, 2004; Hajek, 1991; Parrott, 1999; Zvolensky, Schmidt, & Stewart, 2003). Consistent with this type of perspective, studies have indicated that DT may be related to sustained abstinence during a quit attempt. For example, Hajek and colleagues (Hajek, 1991; Hajek, Belcher, & Stapleton, 1987; West, Hajek, & Belcher, 1989) found that daily smokers with DT for physical discomfort report longer duration of abstinence from smoking. Others have similarly found that daily smokers who relapse faster than their counterparts are also more likely to terminate aversive bodily and psychological sensations elicited by laboratory-based provocation tactics (e.g., difficult math tests, biological challenge procedures; Brandon et al., 2003; Brown et al., 2002). This corpus of empirical work suggests that DT is an important explanatory factor in sustained smoking abstinence and early lapse.

Whereas extant work has focused on the role of DT in predicting sustained smoking abstinence, considerably less is known about the types of factors that account for individual differences in DT. DT is assumed to be a malleable construct, and by extension a clinical target, in smoking cessation work (Brown et al., in press). Thus, the absence of knowledge about factors that account for individual differences in DT hinders efforts to target and increase DT in smoking cessation work. It also should be noted here that while DT has been predominately studied in relation to smoking (Brandon et al., 2003; Brown et al., 2002), the construct may have more broad-based relevance to other forms of psychopathology and addictive behavior.

One possible factor likely to result in lower DT may be a tendency to have panic reactions to aversive interoceptive cues. A panic attack represents a state of discrete fear that indexes active fight-flight-freeze response (Barlow, 2002); it is characterized by a high degree of physiological activation (e.g., rapid heart rate change), threat-oriented behavioral responses (e.g., escape), and low-level (i.e., not elaborative, higher-order) cognition (e.g., "I need to flee this situation now"). Models of emotion describe panic attacks as an exemplar instance of emotional reactivity (Watson & Clark, 1992). There are at least two key reasons why panic attacks may be relevant to better understanding distress tolerance. Theoretically, to the extent an individual is prone to high levels of panic reactivity to interoceptive cues, this individual would be expected to attempt to escape from such stimuli (i.e., evidence lower DT during

exposure to the stressor). This perspective is consistent with theoretical perspectives of fear reactivity that denote such a response as being 'evolutionarily designed' to promote escape and avoidance behavior (Frijda, 1988). Second, empirical research has indicated that increased emotional reactivity, although not measured via panic attacks as of yet, is related to shorter duration of smoking abstinence (Brown et al., 2002; Calhoun, Dennis, & Beckham, 2007; Zvolensky, Feldner, Eifert, & Stewart, 2001). To the extent smoking behavior is aimed at alleviating short-term spikes of negative affect, bodily sensations, or nicotine withdrawal symptoms, as predicted by integrative theoretical models describing smoking self-regulation processes (Baker et al, 2004; Brown et al., 2005), the tendency to be emotionally reactive to internal cues may be related to tolerance for such affect-relevant stimuli. Overall, building from theoretical models of panic (e.g., Barlow, 2002; Fridja, 1988) and convergent empirical findings on emotional reactivity and sustained smoking abstinence (e.g., Brown et al., 2002; Calhoun et al., 2007), panic responsivity to internal cues – a prototypical index of emotional reactivity - may represent a key explanatory construct in terms of DT to interoceptive stimuli.

Together, the overarching purpose of the present, preliminary investigation was to examine the extent to which panic reactivity to bodily sensations is related to DT among daily smokers. The present study was one component of a larger investigation focused on the role of anxiety disorders in early smoking lapse and relapse during a self-guided smoking cessation attempt (Zvolensky, Gibson, et al., in press). It was hypothesized that panic reactivity to an initial voluntary hyperventilation would predict the relative degree of task persistence on a second hyperventilation trial (lower levels of DT). This panic responsivity effect was expected to be evident above and beyond the variance accounted for by other competing explanatory variables most strongly related to emotional reactivity to bodily sensations and duration of smoking abstinence in past work; namely, anxiety sensitivity (fear of the negative consequences of anxiety-related states; McNally, 2002), negative affectivity (tendency to experience negative affect; Watson, 2000), cigarette smoking rate (Zvolensky, Schmidt, Bernstein, & Keough, 2006), and self-reported discomfort intolerance (DI; Schmidt, Richey, & Fitzpatrick, 2006). DI refers, specifically, to low tolerance of negative physical sensations and uncomfortable bodily states (Schmidt et al., 2006). Therefore, any relationship detected between the acute experience of PA and subsequent DT is likely to reflect more than a general intolerance of physical distress.

## Method

### Participants

Participants were 95 daily smokers (58% women) with a mean age of 29.0 (*SD* = 12.2). The racial distribution generally reflected that of the State of Vermont (State of Vermont Department of Health, 2007), with 91.6% of the sample identifying themselves as Caucasian, 6.4% as Hispanic, 2.2% as African American, and 1.1% as "other." Participants, on average, smoked 15.9 cigarettes per day (*SD* = 7.31; *Range* = 4 – 50) and reported having been regular (daily) smokers for approximately 12.0 years (*SD* = 10.6; *Range* = 1 – 45). The mean score on the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991) was 3.11, indicating relatively low levels of nicotine dependence. The low FTND average is partially due to a third of participants having decreased their smoking rate in the past month. According to the Smoking History Questionnaire (SHQ; Brown et al., 2002), approximately 33 participants (35%) reported decreasing their smoking rate during the one-month prior to participating in the study, cutting down by an average of 5.76 cigarettes per day (*SD* = 5.37). With regard to alcohol consumption as measured by the Alcohol Use Disorders Identification Test (AUDIT; Babor, De La Fuente, Saunders, & Grant, 1992), approximately 20% of the sample reported not currently consuming alcohol, 11% reported drinking monthly or less, 18% reported drinking 2–4 times per month, 25% reported drinking

2–3 times per week, and 26% reported drinking 4 or more times per week. Participants reported consuming about 3–4 drinks per occasion and scored an average of 9.20 (*SD* = 7.71) on the AUDIT, indicating moderate alcohol use problems.

Approximately 57.9% of the sample met criteria for one or more current Axis I disorders. Specifically, 14.7% of the sample met criteria for one psychological disorder, 13.7% met criteria for two disorders, 23.2% met criteria for three disorders, 4.2% met criteria for four disorders, and 2.1% met criteria for five disorders. Approximately 32.7% of the current sample met criteria for Posttraumatic Stress Disorder, 26.3% for Major Depressive Disorder, 22.3% for Panic Disorder with or without Agoraphobia, 22.1% for Generalized Anxiety Disorder, 19.0% for Social Phobia, 5.3% for Specific Phobia, 4.3% for Alcohol Abuse, 4.3% for Substance Abuse, 1.1% for Alcohol Dependence, 1.1% for Obsessive Compulsive Disorder, and 1.1% for Dysthymia.

Participation in the larger study consisted of eight total appointments: baseline assessment session, voluntary hyperventilation session, self-selected smoking cessation date (approximately within 28 days of the baseline session), and 3-day, 7-day, 14-day, 28-day, and 90-day post-cessation follow-up appointments (Zvolensky, Gibson et al., in press). (Note: The inclusion criteria for the current investigation were identical to those for the larger study.) For inclusion in the study, participants were required to meet the following criteria: (1) be between 18 and 65 years of age; (2) have been a daily smoker for at least one year; (3) be currently smoking an average of at least 10 cigarettes per day; (4) report motivation to quit of at least 5 on a 10-point Likert-style scale (0 = *no motivation to quit*; 10 = *extreme motivation to quit*); (5) express interest in making a serious quit attempt in the next month; and (6) not have decreased the number of cigarettes smoked by more than half in the past six months. Exclusionary criteria for the investigation included: (1) limited mental competency or the inability to provide informed, written consent; (2) current suicidal or homicidal ideation; (3) current or past history of psychotic-spectrum symptoms or disorders; (4) current major medical problems (e.g., heart disease, cancer); (5) current use of nicotine replacement therapy (e.g., patches or nicotine gum); (6) current, regular use of tobacco products other than cigarettes (e.g., cigars, chewing tobacco); (7) current substance dependence (other than nicotine); and (8) self-reported pregnancy (women only).

## Pre-Challenge Measures

**Anxiety Disorders Interview Schedule for DSM-IV: Client Interview Schedule—** (ADIS-IV; Brown, Di Nardo, & Barlow, 1994). The ADIS-IV is a semi-structured diagnostic tool used to assess DSM-IV anxiety, mood, somatoform, and substance use disorders as well as screen for the presence of psychotic disorders. Reliability of this measure has shown good to excellent inter-rater agreement for the majority of anxiety and mood disorders among patients who were given two independent administrations of the ADIS-IV (Brown, Di Nardo, Lehman, & Campbell, 2001). The presence of current axis I psychopathology was assessed using the ADIS-IV in the present study. Diagnostic reliability ratings by an independent rater (MJZ) were completed on a random selection of 20% of the protocols, with no cases of disagreement being noted.

**Smoking History Questionnaire—**(SHQ; Brown et al., 2002). The SHQ is a self-report questionnaire used to assess smoking history and pattern. The SHQ includes items pertaining to smoking rate, age of onset of smoking initiation, and years of being a daily smoker. The SHQ has been successfully used in previous studies as a measure of smoking history, pattern, and symptoms and related problems during quitting (Zvolensky, Leen-Feldner et al., 2004; Zvolensky, Lejuez, Kahler, & Brown, 2004).

**Fagerström Test for Nicotine Dependence—**(FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991). The FTND is a 6-item scale designed to assess gradations in tobacco dependence (Heatherton et al., 1991). The FTND has shown good internal consistency, positive relations with key smoking variables (e.g., saliva cotinine; Heatherton et al., 1991; Payne, Smith, McCracken, McSherry, & Antony, 1994), and high degrees of test-retest reliability (Pomerleau, Carton, Lutzke, Flessland, & Pomerleau, 1994).

**Alcohol Use Disorders Identification Test—**(AUDIT; Babor et al., 1992). The AUDIT is a 10-item self-report screening measure developed by the World Health Organization to identify individuals with alcohol problems (Babor et al., 1992). There is a large body of literature attesting to the validity of the AUDIT (Saunders, Aasland, Babor, de la Fuente, & Grant, 1993). In the present study, we utilized: (1) the frequency and quantity items to index current alcohol consumption; and (2) the total score to measure alcohol use problems (Babor et al., 1992).

**Positive Affect Negative Affect Scale—**(PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item measure in which respondents indicate on a 5-point Likert-type scale (1 = *very slightly or not at all* to 5 = *extremely*) the extent to which they generally feel different feelings and emotions (e.g., "*Hostile*"). The PANAS is a well-established mood measure commonly used in psychopathology research (Watson et al., 1988). Factor analysis indicates that it assesses two global dimensions of affect: negative affect (PANAS-NA) and positive affect (PANAS-PA). Both the negative affectivity as well as the positive affectivity scales of the PANAS have demonstrated high levels of internal consistency (range of alpha coefficients: . 83 to .90 and .85 to .93, respectively). A large body of literature supports the psychometric properties of the PANAS (see Watson, 2000). Only the PANAS-NA was utilized in the current study.

**Anxiety Sensitivity Index (ASI)—**To assess sensitivity to, and discomfort with, anxious arousal, the 16-item ASI (Reiss, Peterson, Gursky, & McNally, 1986) was employed. The ASI is a self-report measure on which respondents indicate, on a 5-point Likert-style scale (0 = *very little* to 4 = *very much*), the degree to which they fear the potential negative consequences of anxiety-related symptoms and sensations. The ASI has high internal consistency ranging from .84 for a sample of college students to .88 –.90 for a clinical sample of anxiety-disordered patients (Reiss et al., 1986). The ASI is unique from, and demonstrates incremental predictive validity relative to, trait anxiety (McNally, 2002) and negative affectivity (Zvolensky, Kotov, Antipova, & Schmidt, 2003).

**Discomfort Intolerance Scale (DIS)—**To assess baseline levels of discomfort intolerance, the 5-item DIS (Schmidt et al., 2006) was administered. The DIS is a self-report measure on which individuals rate the degree to which they can tolerate uncomfortable physical sensations on a scale from 0 (*not at all*) to 6 (*extremely*). The DIS evidences good convergent and discriminant validity (Schmidt et al., 2006).

### Challenge Measures

**Diagnostic Sensations Questionnaire—**(DSQ; Sanderson, Rapee, & Barlow, 1988, 1989). The DSQ was administered to assess DSM-IV physical (e.g., "*Pounding or racing heart," "Breathlessness or smothering sensation*") and cognitive (e.g., *"Fear of going crazy," "Fear of losing control"*) panic attack symptoms immediately post-challenge. Specifically, the DSQ consists of 12 physical symptom items, 3 cognitive symptom items, and 1 item targeting whether participants experienced a "sense of panic." This measure is frequently employed in challenge work (Zvolensky, Lejuez, & Eifert, 1998). Ratings for the DSQ are made on a 9-point Likert-type scale (0 = *not at all* to 8 = *very strongly felt*). Past work has

successfully used the DSQ to index the intensity of panic symptoms and DSM-IV presence/absence of panic attacks in challenge studies (Forsyth, Eifert, & Canna, 2000; Schmidt, Forsyth, Santiago, & Trakowski, 2002). Consistent with past recommendation and biological challenge work and DSM-IV classification of panic, individuals who reported 4 or more post-challenge panic attack symptoms (at least one of which was cognitive) at a severity rating of 4 or greater, as well as a self-reported sensation of panic at a severity rating of 4 or greater, were coded as having had a panic attack during the hyperventilation challenge in the present study (Barlow, Brown, & Craske, 1994; Sanderson et al., 1989). Based on these criteria, a categorical variable (PA) was created wherein participants were dummy coded as either 0 (no panic attack during challenge) or 1 (panic attack during challenge).

**Physiological Variables—**A J&J Engineering I-330-C2 system was used to digitally record physiological data on-line at a sample rate of 1024 samples per second across all channels using J&J Engineering Physiolab Software during both challenge procedures. In total, two physiological variables were measured: heart rate and respiration rate; a ground electrode was used for heart rate sampling. Raw electrocardiogram data were collected with disposable Ag/AgCl electrodes placed in a standard bilateral configuration on the palmar side of each wrist. The data were processed through a 1-100Hz bandpass filter designed to maximize R-wave frequency. Respiration rate was obtained using a Pneumograph sensor cable with PS-2 sensors. The sensors were placed across the chest and secured with a Velcro strap, allowing a measure of chest excursion during respiration; a breaths-per-minute value was derived through software calculation. For the present investigation, pre-heart rate and pre-respiration rate values were obtained by averaging the values during the last minute of the baseline period prior to the initial hyperventilation challenge. Heart rate and respiration rate were obtained by averaging the values during the last minute of the initial hyperventilation challenge.

**Distress Tolerance—**As a behavioral measure of tolerance for interoceptive distress, task persistence on the hyperventilation challenge was measured as latency in seconds to task termination (for the second hyperventilation trial; see Procedure Section for details).

## Procedure

Data for the current investigation were gathered at the baseline and hyperventilation appointments, before participants set a smoking cessation date. During the baseline appointment, participants (1) provided verbal and written informed consent; (2) completed a medical screen; (3) underwent a diagnostic evaluation (ADIS-IV) to determine if any exclusion criteria were met; and (4) completed an initial battery of self-report assessments.

Eligible participants were then scheduled for the hyperventilation procedure within four weeks from the baseline appointment. Eligible participants were instructed not to smoke for 12 hours prior to their scheduled hyperventilation appointment. The 12-hour period of smoking abstinence was selected for three key reasons: (1) it was viewed as a significantly long enough duration to elicit a minimal level of DT (i.e., all smokers could ‘tolerate’ smoking abstinence for a minimally sufficient period of time), and (2) it was similar to past work (Brown et al., 2002), and therefore, facilitates comparison to the larger empirical literature. At the hyperventilation appointment, smoking abstinence was verified verbally and using CO analysis of breath samples (10 ppm cut-off; Society for Research on Nicotine and Tobacco Research Subcommittee on Biochemical Verification, 2002). Participants were instructed not to use nicotine replacement therapy during the 12-hour quit period. Participants were not scheduled systematically over night or any other part of the day. Rather, they came to their appointment at a time that was convenient for them and the research team. Participants received $25 for completion of the baseline assessment session and $25 for completion of the hyperventilation

procedure (and a total of $225 for completing the entire protocol for the larger smoking cessation study).

The hyperventilation procedure was administered in an 8-foot × 12-foot room. Participants sat alone in the experiment room throughout the procedure listening to an audiotape that guided them through the procedure, while being monitored by the experimenter (in the adjacent room) using audio-visual equipment. The hyperventilation procedure appointment consisted of the following five components: (1) 10-minute baseline adaptation period, (2) 3-minute voluntary hyperventilation period, (3) 10-minute recovery period, (4) 5-minute voluntary hyperventilation period, which participants were instructed to continue for as long as possible and to discontinue (i.e., stop the tape and breathe normally) when they could no longer continue (5-minute maximum, if participant did not stop tape), and (5) 5-minute final recovery period. All participants completed the full 3 minutes of the first hyperventilation procedure, although it is possible that some participants altered their breathing rate or volume in order to complete the first hyperventilation. Given the level of participant control inherent in hyperventilation procedures, a physiological manipulation check was also conducted to ensure that the procedure elicited changes associated with anxiety. (Please see below for the results of the manipulation check.)

At the outset of the procedure, the experimenter attached physiological electrodes and exited the room. A standardized audio-tape provided directions at the outset of the procedure and then guided participants through the procedure. This procedure was used to standardize participants' breathing rates (at 30 breaths per minute).The audio-tape described the overall procedure, reminded participants that they would be asked to participate in two hyperventilation procedures, and instructed the participant about the completion of questionnaires. Participants were informed initially (and reminded later) that they were to continue the second hyperventilation for as long as possible and to stop the tape when they could no longer continue.

This acute hyperventilation procedure reduces the partial pressure of arterial carbon dioxide, increases pH in the blood and cerebrospinal fluid (alkalosis; Nunn, 1987), and elicits a variety of panic-related symptoms such as dizziness, parethesias, palpitations, and dyspnea (Fried & Grimaldi, 1993). Physiological data were gathered continuously throughout the laboratory session. DSQ ratings were made immediately following both hyperventilation procedures.

## Results

A manipulation check was first conducted to ensure that the initial hyperventilation challenge sufficiently elicited physiological arousal. Specifically, paired samples t-tests were conducted between pre- (i.e., baseline) and hyper- (i.e., challenge) heart rate (HR) and respiration rates for the first hyperventilation. A paired samples t-test revealed that post-HR levels ($M$ = 88.47, $SD$ = 16.45) were significantly greater than pre-HR levels ($M$ = 75.45, $SD$ = 13.87; $t(90)$ = 8.40, $p < .001$). A paired samples t-test revealed that hyper-respiration levels ($M$ = 25.16, $SD$ = 3.86) were significantly greater than pre-respiration levels ($M$ = 17.44, $SD$ = 4.90; $t(75)$ = 9.19, $p < .001$).

Second, individuals who did meet criteria for a panic attack (PA) were compared to those who did not regarding physiological responding (i.e., HR and respiration rate) during each hyperventilation. Specifically, difference scores were created, such that pre-challenge HR and respiration rate were subtracted from post-challenge HR and respiration rate for both hyperventilation challenges. For the first hyperventilation challenge, a one-way ANOVA revealed no significant differences between individuals who did and did not meet criteria for a PA on change in HR ($F(1, 90) = 1.44$, ns) or change in respiration rate ($F(1, 75) = .25$, ns). For the second hyperventilation challenge, a one-way ANOVA revealed no significant

differences between individuals who did and did not meet criteria for a PA during the second challenge on change in HR ($F(1, 86) = 2.07$, ns) or change in respiration rate ($F(1, 74) = .09$, ns).

Third, patterns of the relations between predictor and criterion variables were examined. Please see Table 1 for descriptive statistics and zero-order correlations. As expected, PA status was significantly related to DT ($p < .05$). With regard to relations among the covariate and predictor variables, NA was significantly related to AS ($p < .001$), DI ($p < .01$) and PA status ($p < .01$). AS was significantly related to DI ($p < .001$) and PA status ($p < .01$). Finally, DI also was significantly related to smoking rate ($p = .05$) and DT ($p < .05$).

Fourth, a hierarchical multiple regression was conducted to examine the primary hypothesis. Specifically, the covariates of AS, NA, cigarettes per day, and DI were entered at level 1 of the regression, and PA status was entered at level 2 of the regression. The regression revealed that PA status significantly predicted DT, after controlling for the theoretically relevant covariates ($F = 2.92$, $p < .05$, $R^2 = .14$). Level 1 of the model accounted for a non-significant 8.3% of the variance in DT ($p > .05$). DI was the only significant predictor at level 1 of the regression ($t = -2.71$, $p < .01$, $\beta = -.31$), such that greater DI was related to lower DT. Level 2 of the model accounted for an additional, statistically significant 5.8% of the variance in DT ($p < .05$), with PA being a significant predictor ($t = -2.44$, $p < .05$, $\beta = -.26$). Specifically, individuals who endorsed having a PA during the first hyperventilation challenge evidenced significantly lower DT (i.e., ended the second hyperventilation challenge earlier) than individuals who did not endorse having a PA during the first hyperventilation challenge.[1,2,3,4]

## Discussion

A growing corpus of empirical work suggests DT focused on interoceptive cues is related to early smoking lapse and relapse (Brandon et al., 2003; Brown et al., 2002). There is considerably less known about the types of factors that account for individual differences in DT. To fill this gap in the existing literature, the present investigation represents a preliminary attempt to examine the extent to which panic reactivity to bodily sensations is related to DT to bodily sensations among daily smokers.

First, as predicted, individuals who experienced a panic attack during an initial voluntary hyperventilation challenge were significantly more likely to evidence lower levels of DT during a second voluntary hyperventilation in the form of shorter latency to challenge termination. The significant effect of panic responding on DT levels was evident above and beyond the variance accounted for by anxiety sensitivity, negative affectivity, smoking rate, and DI. This panic reactivity effect is therefore not attributable to fears about the negative consequences of internal sensations (anxiety sensitivity), a broad-based tendency to experience negative emotions (negative affectivity), level (frequency) of daily smoking, or pre-challenge self-

[1]We also conducted this analysis including physiological variables (i.e., change in heart rate and change in respiration from baseline to post-hyperventilation for the first hyperventilation challenge) as covariates. Results did not differ in either the pattern or magnitude of those reported when including these additional covariates. The results of this analysis can be obtained upon request from Dr. Zvolensky.
[2]Additionally, this same analysis was re-run in exploratory fashion using pre-challenge nicotine withdrawal symptom severity, as indexed by the Minnesota Withdrawal Scale (Hughes & Hatsukami, 1986), instead of negative affectivity. Results did not differ in pattern or magnitude of those reported. Thus, the results did not vary whether nicotine withdrawal symptoms, rather than negative affectivity, were included as a covariate. The results of these additional analyses can be obtained upon request from Dr. Zvolensky.
[3]We also conducted this analyses using whether participants met criteria for any psychopathology (dichotomous) as a covariate in level 1 of the model. Results did not differ in either the pattern or magnitude of those reported when including psychopathology as a covariate. The results of this additional analysis can be obtained upon request from Dr. Zvolensky.
[4]We conducted the analyses excluding participants who reduced the number of cigarettes smoked per day in the past month. Results did not differ in either the pattern or magnitude of those reported; therefore, we retained the full sample for the reported analyses. The results of this additional analysis can be obtained upon request from Dr. Zvolensky.

reported levels of DI. Such a result is consistent with theoretical models of panic (e.g., Barlow, 2002; Fridja, 1988) and empirical findings on emotional reactivity and sustained smoking abstinence (e.g., Brown et al., 2002; Calhoun et al., 2007) that suggest panic responsivity to internal cues – a prototypical index of emotional reactivity - may represent a key explanatory construct in terms of level of DT to interoceptive stimuli. Future work could usefully build upon these laboratory findings by exploring whether panic responsivity predicts shorter duration of continuous smoking abstinence during a quit attempt.

Second, in regard to physiological responding in the laboratory, participants who did and did not experience a PA during the first hyperventilation procedure did not differ on degree of change in HR or respiration rate. The lack of difference in terms of physiological responsivity may suggest that the participants who did and did not panic during the challenge differed on their perceptions of the change in bodily sensations, rather than the objective degree of those sensations. In addition, although data are limited regarding physiological changes during real-world PAs, it seems that participants in the current study experienced changes in heart rate similar to those observed during actual panic attacks. Specifically, White and Baker (1987) reported that individuals with panic disorder who were monitored in day-to-day life evidenced an increase in heart rate of approximately 14 beats per minute (*SD* = 6) during PA episodes; in the current study, participants evidenced an increase in heart rate of approximately 13 beats per minute (*SD* = 14), suggesting that physiological changes were likely similar to those experienced during actual PAs.

Overall, the present findings suggest that panic responsivity may be a useful clinical target for better understanding DT among daily smokers. However, future work in the realm of DT could greatly benefit from further clarification of potential subtypes of DT (DI; e.g., Schmidt et al., 2006), as well as relations among various measures of DT and other emotional vulnerability variables. For example, in the current study, it is unclear as to whether individuals experiencing a PA are at greater risk for decreased subsequent DT due to a general tendency to have low emotional DT (above and beyond the self-reported levels of DI, a measure tapping into tolerance of uncomfortable physical sensations, more specifically), or whether the experience of a PA itself had an acute effect on these individuals' levels of DT. Clarifying these relations through use of multiple measures of DT and experimental manipulation would prove highly useful.

A number of limitations of the present investigation and points for future direction should be considered. First, the present study was focused on daily, but not necessarily, heavy smokers, as indexed by the rate of smoking per day and level of nicotine dependence. One next step for future work would be to study participants with greater smoking rates and levels of nicotine dependence to aid understanding of the observed effects from a generalizability perspective. Second, the present sample is limited in that it is comprised of a relatively homogenous (e.g., primarily Caucasian) group of adult smokers who volunteered to participate for financial compensation. To rule out potential self-selection bias among persons with these characteristics and increase the generalizability of these findings, it will be important for researchers to draw from other populations and utilize recruitment tactics other than those used in the present study. Third, the sample was comprised of smokers with and without psychopathology. Given the broad range of Axis I disorders evidenced in the current study, there was insufficient power to examine effects of various forms of psychopathology on the outcomes of interest. Future work might extend the current model to specific clinical samples and compare rates of DT between different subsets of smokers with particular psychological disorders. Here, it is noteworthy that PAs are particularly common among smokers that smoke at higher rates compared to non-smokers (Goodwin, Zvolensky, & Keys, in press). Although studying PAs may therefore be useful for expanding knowledge about DT among smokers, it will not be broadly applicable for all individuals (e.g., non-smokers, lighter smokers). Similarly, it would be useful to

investigate the proposed relations among smokers without any psychiatric disorders. Fourth, we employed a behavioral index of DT to bodily sensations due to the relevance of aversive internal cues to smoking cessation (Hughes, 2007). This type of DT paradigm represents only one possibility. Future work could usefully evaluate the relative explanatory consistency of panic responsivity to other measures of DT, including self-report (Distress Tolerance Scale; Simons, & Gaher, 2005) and behavioral tasks (e.g., difficult math tests; Deary et al., 1994). For example, it is presently unclear if fear reactivity to bodily sensations would similarly predict DT using psychologically-based stress tasks.

Fifth, there was no investigation or statistical control for psychotropic medication use in the current study. Future work would benefit from exploring potential confounding effects of such medication on DT processes as well as emotional reactivity to somatic perturbation. In a same vein, it may be useful to explore whether other factors, such as respiratory function or oxygen saturation, affect DT during exposure to bodily sensations. Sixth, there is generally little empirical literature on the smoking-related factors that may affect DT. Future work is needed to address such variables and how they may affect DT processes. For example, it would be advisable in future work to empirically explore whether DT is affected by the nature of smoking behavior (e.g., light versus heavy smokers). It also is presently unclear whether DT effects are specific to smokers. Given DT may have broader relevance to explaining psychopathological behavior than just early smoking lapse and relapse (Simons & Gaher, 2005), it may indeed be useful to evaluate DT across diverse clinical populations. Seventh, the present investigation was oriented theoretically as to whether PA predicts DT among smokers. It is possible that there are bi-directional effects between PA and DT, or some other third factor accounts for their relation to one another. Future work could benefit by exploring such putative bi-directional effects in an effort to tease apart possible causal relations. Eigth, the behavioral DT paradigm utilized in the current study involved a standardized period of 12-hour smoking abstinence for all participants prior to the laboratory challenge. The relevance of the 12-hour smoking abstinence period, relative to other deprivation periods, is as of yet unclear in the context of DT. Future work could therefore usefully conduct a parametric analysis of the role of distinct smoking deprivation time periods (e.g., 12 hours versus 6 hour versus 2 hour) on DT. And finally, despite the use of a 12- hour deprivation period, the period of the day (e.g., overnight vs. during the day) participants implemented this deprivation period was not recorded. Therefore, it was not possible to examine potential variability in time of day of deprivation or total length of nicotine deprivation (i.e., whether any participants abstained for more than 12 hours) in the current study. Future work would benefit from collecting additional data in this domain.

Overall, the present study suggests individuals demonstrating greater panic reactivity to a voluntary hyperventilation challenge evidenced significantly lower levels of DT during a second voluntary hyperventilation challenge. These results suggest panic responsivity to internal cues may represent a key explanatory construct for better understanding DT to interoceptive stimuli among adult daily smokers.

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**Table 1**

Descriptive and Zero-Order Relations among Theoretically Relevant Variables

| | NA | AS | Cigs | DI | PA | DT | Mean (*SD*) |
|---|---|---|---|---|---|---|---|
| NA | 1 | .76** | .09 | .31* | .31* | −.03 | 21.54 (8.68) |
| AS | | 1 | .15 | .47** | .30* | .02 | 21.32 (12.57) |
| Cigs | | | 1 | .20† | −.12 | .06 | 15.95 (7.31) |
| DI | | | | 1 | .16 | −.22† | 11.91 (5.13) |
| PA | | | | | 1 | −.25† | 45.3% yes |
| DT | | | | | | 1 | 3.79 (1.30) |

†*Note:* $p < .05$

* $p < .01$

** $p < .001$.

NA = Negative Affect subscale of PANAS; AS = ASI total; Cigs = Cigarettes smoked per day; DI = DIS total; PA = Panic Attack status during first hyperventilation challenge (yes/no); DT = Distress Tolerance during second hyperventilation challenge (i.e. time in minutes of voluntary hyperventilation)