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The benefits of being mindful: Trait mindfulness predicts less stress reactivity to suppression

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ABSTRACT

Background and objectives: There has been a recent proliferation of research evaluating the efficacy of mindfulness as a clinical intervention. However, there is still little known about trait mindfulness, or how trait mindfulness interacts with maladaptive emotion regulation strategies. The current study further explores the effect of trait mindfulness on emotion regulation, as well as whether specific factors of trait mindfulness are uniquely associated with subjective and autonomic reactivity to stress.
Methods: Forty-eight healthy male participants were trained in the use of the suppression strategy and then instructed to suppress their responses to the inhalation of a 15% CO_2-enriched air mixture for 90 s while their subjective distress and heart rate were recorded.
Results: After controlling for anxiety-related variables, the ability to provide descriptions of observed experiences predicted less heart rate reactivity to CO_2 inhalation, while skillfulness at restricting attention to the present moment was uniquely predictive of less subjective distress. The tendency to attend to bodily or sensory stimuli predicted greater distress during CO_2 inhalation.
Limitations: The inclusion of only healthy males limits the generalizability of study findings. Also, the sample size was relatively small.
Conclusions: These findings suggest that factors associated with trait mindfulness predict less stress reactivity and distress while engaging in suppression above and beyond other variables that have been shown to predict anxious responding. The implications for emotion and clinical research are discussed.

1. Introduction

The ability to successfully exert control over emotional experiences is a fundamental skill in humans that promotes interpersonal functioning, positive affect, and overall well-being. Individuals differ in their habitual use of emotion regulation strategies, and these differences are associated with specific behavioral, affective, and interpersonal outcomes (Gross & John, 2003; John & Gross, 2004). Maladaptive emotion regulation strategies are associated with psychopathology, greater psychological distress, poorer quality of life, stress-related symptoms, and negative affect (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Amstadter, 2008; Hofmann, Sawyer, Fang, & Asnaani, 2012; Moore, Zoellner, & Mollenholt, 2008).

Research in emotion regulation has recently begun to explore the role of mindfulness as an important factor that might positively influence the stress response and emotion regulation more generally. Mindfulness is a state of consciousness originating in Eastern philosophies and religion that focuses on the practice of directing one's attention to the present moment while adopting a nonjudgmental perspective toward experiences (Kabat-Zinn, 1990). Mindfulness possesses both state- and trait-like characteristics, the former of which is particularly responsive to practice or meditation (Bishop et al., 2004; Brown & Ryan, 2004; Carmody & Baer, 2008). Studies have failed to demonstrate a linear relationship between state- and trait-like characteristics of mindfulness (Thompson & Waltz, 2007), suggesting separate but related constructs.

The construct of trait mindfulness has been theorized to consist of multiple skills or facets, and this factor structure has been empirically validated in multiple studies (Baer, Smith, & Allen, 2004; Baer, Smith, Hopkins, Kriestemeyer, & Toney, 2006; Christopher, Neuser, Michael, & Baitmangalkar, 2012). The factors include the ability to observe and attend to experiences, the ability to describe those experiences, the ability to focus attention on the present moment, and the ability to adopt a kind, nonjudgmental attitude toward experiences (Baer et al.,

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2004). Trait mindfulness has been associated with positive mental health outcomes, including life satisfaction, self-esteem, and optimism (Brown & Ryan, 2003). It has also demonstrated negative correlations with symptoms of depression, anxiety, and stress-related symptoms (Cash & Whittingham, 2010), neuroticism (Giluk, 2009), difficulties in emotion regulation (Baer et al., 2006; Coffey, Hartman, & Fredrickson, 2010), cognitive reactivity (Raes, Dewulf, Van Heeringen, & Williams, 2009), and experiential avoidance (Baer et al., 2004).

A limitation of prior studies of trait mindfulness is the use of measures designed to assess only one facet of mindfulness, namely present-moment awareness (e.g., Brown & Ryan, 2003; Chadwick et al., 2008), which precludes the exploration of which factors of trait mindfulness are most important in predicting outcomes. These distinct facets of trait mindfulness have demonstrated differential predictive validity across a variety of outcomes, including eating pathology (Adams et al., 2012), substance use (Eisenlohr-Moul, Walsh, Charnigo, Lynam, & Baer, 2012), and symptoms of depression and anxiety in both clinical (Desrosiers, Klemanski, & Nolen-Hoeksema, 2013) and non-clinical samples (Cash & Whittingham, 2010). For example, Desrosiers et al. (2013) found that the ability to describe internal and external experiences was inversely related to anxious arousal in adults presenting for treatment at a mood and anxiety disorders clinic, but the ability to notice and attend to these experiences was positively related to anxious arousal.

Much of the research to date on mindfulness consists of correlational research between trait mindfulness and psychological health, mindfulness-based clinical interventions, and laboratory research on the immediate effects of mindfulness induction exercises on stress and emotion regulation (for a review, see Keng, Smoski, & Robins, 2011). Despite the promising results of mindfulness-based interventions (e.g., Hofmann, Sawyer, Witt, & Oh, 2010; Khoury et al., 2013) and brief mindfulness induction exercises (e.g., Arch & Craske, 2006; Broderick, 2005), there has been little research conducted on the effects of trait or dispositional mindfulness beyond correlational research. Exceptions include Arch and Craske (2010), who found that trait mindfulness predicted less reactivity to a hyperventilation task in both anxious and non-anxious individuals. In another study of undergraduate students, trait mindfulness was found to predict lower cortisol responses and less subjective distress to a social evaluative threat (Brown, Weinstein, & Creswell, 2012). To our knowledge, there have been no studies to date exploring the effect of trait mindfulness on anxious responding during a more vigorous laboratory stressor, or while monitoring both subjective distress and autonomic reactivity.

One advantage of laboratory studies is that they allow for more control than clinical interventions or correlational studies, and as a result, are especially useful in the elucidation of causal relationships. Biological challenge paradigms, such as carbon dioxide (CO_2) inhalation, are frequently used in the study of anxiety, psychological risk factors for anxiety, and emotion regulation strategies (Amstadter, 2008; Cisler, Olatunji, Feldner, & Forsyth, 2010). Another methodological benefit of using biological challenge paradigms to study emotion regulation and related factors is that substantial research has been conducted on other variables that are predictive of anxious responding to CO_2 inhalation (e.g., anxiety sensitivity, fear of suffocation, trait anxiety, and distress tolerance), and these individual difference variables can then be included as covariates in regression models to allow for a more precise analysis of the relationships between predictor and dependent variables.

One of the most extensively studied forms of emotion regulation during biological challenges is suppression (i.e., attempting to prevent or inhibit the expression of an emotional experience or uncomfortable physical sensations), which tends to produce increased physiological arousal, greater autonomic instability, and more stress-related symptoms, despite the desire to down-regulate arousal (Campbell-Sills, Barlow, Brown, & Hofmann, 2006). Research exploring the effect of expressive suppression on physical pain suggests that suppression results in delayed recovery from pain and decreased pain tolerance, as well increased subjective reports of distress and pain intensity (Cioffi & Holloway, 1993; Masedo & Rosa Esteve, 2007; Moore et al., 2008). Indeed, individual differences observed in the duration of stress reactivity or cardiovascular recovery from a negative event have been linked to differences in an individual's ability to effectively regulate his or her emotions (Fredrickson et al., 2000; Tugade & Fredrickson, 2004). Reliance on suppression to cope with emotional distress is also associated with greater vulnerability for both the development of emotional disorders and the persistence of symptoms (Amstadter, 2008). However, prior studies utilizing laboratory stressors to explore factors contributing to emotion regulation have traditionally focused only on anxiety-related variables. As a result, little is known about factors that may promote adaptive emotion regulation or buffer against the negative effects of less effective emotion regulation strategies.

The purpose of the current study was to study the relationship between trait mindfulness and stress reactivity to instructions to suppress distress during CO_2 inhalation. In order to explore the unique contribution of the four factors of trait mindfulness, we controlled for anxiety-related variables that have demonstrated strong predictive validity for anxious responding in previous biological challenge paradigms using suppression. We chose suppression as an emotion regulation strategy for three key reasons. First, we wanted to control for individual differences in the habitual use of emotion regulation strategies since in the absence of explicit instruction on how to handle distress and uncomfortable physical sensations during the challenge, it is likely that participants would utilize a variety of strategies and introduce unnecessary confounds. Secondly, the effects of suppression on anxious responding during CO_2 challenges (i.e., elevated physiological arousal) are very well documented (e.g., Campbell-Sills et al., 2006; Feldner, Zvolensky, Eifert, & Spira, 2003; Feldner, Zvolensky, Stickle, Bonn-Miller, & Leen-Feldner, 2006; Karekla, Forsyth, & Kelly, 2004; Levitt, Brown, Orsillo, & Barlow, 2004; Spira, Zvolensky, Eifert, & Felnder, 2004). Lastly, suppression is an emotion regulation strategy acutely associated with negative affect, greater psychological distress, and slower recovery from pain (e.g., Aldao et al., 2010; Amstadter, 2008; Cioffi & Holloway, 1993; Moore et al., 2008) and has been shown to contribute to the onset and maintenance of emotional disorders (e.g., Amstadter, 2008). Therefore, evaluating the effects of trait mindfulness during a suppression manipulation is a more robust test of whether trait mindfulness protects or buffers against the negative consequences of maladaptive emotion regulation strategies.

We hypothesized that trait mindfulness would predict the subjective effects of the suppression instructions, such that participants higher in trait mindfulness would report less distress during inhalation of a 15% CO_2-enriched air mixture. Given the lack of prior research on how trait mindfulness influences autonomic responses to stress, our assessment of heart rate reactivity, as well as whether specific factors of trait mindfulness demonstrated differential relationships with stress reactivity, was exploratory in nature.

2. Method

2.1. Participants

Participants were recruited from a community sample and were told that they would be participating in a research study exploring how people use different emotion regulation strategies to deal with physical symptoms. The sample consisted of 48 healthy males, with an average age of 29.10 years old (range = 18–44; SD = 8.32). Based on our institutional review board's assessment of the potential risks of CO_2 inhalation to women in early stages of pregnancy, females were excluded from participation.

Approximately half of the sample (52%) identified as White, 27% as Black, 13% as Asian American, 4% as Hispanic, and 4% as Other. Prior to arrival at the laboratory, potential participants completed a brief screening assessment over the phone to determine initial eligibility and then underwent a medical screen conducted in person by study medical personnel to confirm study eligibility prior to participation. Exclusion criteria included presence of an Axis I psychiatric disorder, including a history of panic attacks, physical conditions that might pose a risk to the participant's safety (e.g., hypertension, asthma, history of cardiac disease), and identification as a current or heavy smoker within the past two years; psychiatric disorders were assessed using screening questions from the Structured Clinical Interview for DSM-IV (SCID I; First, Spitzer, Gibbon, & Williams, 1997). Two of the 50 participants who provided written, informed consent and completed the medical screen were deemed ineligible and excluded from participation.

2.2. Stressor

The stressor consisted of CO_2 inhalation, which results in a host of abrupt, temporary physical symptoms (e.g., tachycardia, breathlessness, sweating, dizziness) and emotional reactions (e.g., anxiety, nervousness, urge to escape, fear). Concentrations of CO_2-enriched air used in research with human subjects typically range from 2.2% to 65%, with higher concentrations of CO_2 producing more anxiety symptoms. The present study employed a CO_2 concentration of 15% based on previous studies that have successfully employed CO_2 concentrations below 20% as a proxy for anxiety symptoms (e.g., Bernstein, Zvolensky, Zvolensky, & Schmidt, 2009; Olatunji, Wolitzky-Taylor, Babson, & Feldner, 2009). The stressor entailed a 90-s challenge phase and a 90-s recovery phase that were administered continuously. A 90-s challenge phase has been used to elicit significant anxiogenic symptoms at similar levels of CO_2 concentration in non-clinical samples (e.g., Smits, Tart, Rosenfield, & Zvolensky, 2011).

During the challenge phase, an air-mixture enriched with a 15% CO_2 concentration was administered through a mouthpiece; participants were able to breathe room air through the mask until the CO_2 administration began. The mouthpiece, along with a nose clip to prevent participants from breathing through the nose, was worn during the 90-s challenge phase and removed immediately following the completion of the challenge phase. Participants were notified when the experimenter began the CO_2 administration and were also informed in advance that the CO_2 challenge phase would last for 90 s, unless they aborted the challenge prior to the 90-s mark. Prior to providing informed consent, participants were notified that breathing CO_2-enriched air might result in physical symptoms, such as increased heart rate, increasing breathing rate, sweating, nausea, lightheadedness, and headaches. All study procedures were reviewed and approved by Boston University's Institutional Review Board.

2.3. Predictor variables

2.3.1. Anxiety Sensitivity Index, Physical Concerns Subscale (ASI-Physical Concerns)

The ASI (Peterson & Reiss, 1992) is a 16-item self-report questionnaire that assesses fear related to physical symptoms of anxiety, as well as the concern that these symptoms will result in negative social, physical, or cognitive consequences. The ASI is one of the most commonly used measures of anxiety sensitivity and has demonstrated incremental validity above and beyond measures of state anxiety (McNally, 1996; Sandin, Chorot, & McNally, 2001). During biological challenge procedures conducted with community and clinical samples, anxiety sensitivity was found to be predictive of physiological symptoms (Perna, Romano, Caldirola, Cucchi, & Bellodi, 2003) and subjective anxiety (Shipherd, Beck, & Ohtake, 2001), and appeared to moderate the effects of maladaptive emotion regulation strategies on anxious arousal and heart rate reactivity (Kashdan, Zvolensky, & McLeish, 2008). Prior studies suggest that the physical concerns subscale of the ASI is the greatest predictor of anxious responding during physiological challenges (Brown, Smits, Powers, & Telch, 2003; Carter, Suchday, & Gore, 2001; Feldner, Zvolensky, et al., 2006).

2.3.2. Suffocation Fear Scale (SFS)

The SFS (Rachman & Taylor, 1994) is a 16-item self-report questionnaire that rates responses on a 5-point Likert scale and has been shown to predict anxious responding during biological challenges (McNally & Eke, 1996; Shipherd et al., 2001). Participants are asked to rate how anxious they would feel in a variety of situations (e.g., swimming while wearing a nose plug). A history of suffocation or suffocation fear has been linked to greater CO_2 reactivity and panic symptoms in both healthy (McNally & Eke, 1996) and clinically anxious samples (Rassovsky, Kushner, Schwarze, & Wangensteen, 2000).

2.3.3. Distress tolerance

The length of time that participants engaged in a cold pressor task without aborting the task was recorded as a behavioral indicator of distress tolerance; unbeknownst to participants, there was a 10-min time limit on the task. Behavioral indicators of distress tolerance have been frequently utilized to predict anxious responding during a subsequent stressor in similar experimental paradigms (McHugh et al., 2011). Low levels of distress tolerance, or a diminished ability to withstand negative emotional states or aversive physical sensations, has been found to be significantly related to the presence of anxiety psychopathology, as well as the severity of anxiety symptoms (Leyro, Zvolensky, & Bernstein, 2010; Schmidt, Richey, Cromer, & Buckner, 2007). Low distress tolerance has further been shown to predict lower pain endurance, slower rate of recovery during a cold pressor task, and the presence of physiological symptoms of panic during a biological challenge (Bonn-Miller, Zvolensky, & Bernstein, 2009; Feldner, Hekmat, et al., 2006).

2.3.4. State-Trait Anxiety Inventory, Trait Version (STAI-T)

The STAI-T (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) is a 20-item self-report measure that assesses more stable, trait-level anxiety using a 4-point Likert scale. The STAI-T captures individual differences in reactions to stressors and is the most widely used self-report measure of anxiety. Although trait anxiety appears to show a stronger association with anxious responding in women than in men (Monkul et al., 2010), it has demonstrated strong correlations with measures of anxiety sensitivity (e.g., Koszycki & Bradwejn, 2001; Zvolensky, Feldner, Eifert, & Stewart, 2001) and thus may be an important covariate to include in regression equations predicting anxious responding to biological challenges.

2.3.5. Kentucky Inventory of Mindfulness Skills (KIMS)

The KIMS (Baer et al., 2004) is a 39-item self-report questionnaire designed to assess habitual use of four mindfulness skills: *observing* (12 items; able to observe and attend to bodily or sensory sensations, thoughts, and emotions), *describing* (8 items; ability to provide descriptions of observed phenomenon), *acting with awareness* (10 items; ability to restrict attention to the present moment), and *accepting without judgment* (9 items; ability to adopt a nonjudgmental attitude toward experiences). Participants are instructed to respond based on their own opinion of what is generally true for them using a 5-point Likert scale. The KIMS has demonstrated good internal consistency, and the factor structure of the four scales has been empirically validated (Baer et al., 2004; Baum et al., 2010). The KIMS has also shown incremental validity beyond anxiety sensitivity, distress tolerance, and negative affectivity in the prediction of multiple facets of emotion dysregulation associated with anxiety psychopathology (Salters-Pedneault, Roemer, Tull, Rucker, & Mennin, 2006; Vujanovic, Bonn-Miller, Bernstein, McKee, & Zvolensky, 2010).

The KIMS was chosen over other measures because it captures the multidimensional factor structure of trait mindfulness, whereas other measures of trait or dispositional mindfulness, such as the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), are one-dimensional and only capture present-focused awareness. Baer et al. (2006) recently developed another self-report measure of trait mindfulness, the Five Factor Mindfulness Questionnaire (FFMQ), which includes the four factors of trait mindfulness indexed by the KIMS, as well as a fifth factor – *nonreactivity to inner experience*. However, the FFMQ remains in need of "extensive additional validation in a range of samples," and so the use of the KIMS, which assesses all facets of mindfulness save nonreactivity, is still promoted at this time (Baer et al., 2006, p. 43).

2.4. Dependent variables

2.4.1. Heart rate

Heart rate was monitored continuously; laboratory software computed average values of specific time intervals defined by the experimental protocol. All heart rate data were also visually inspected to ensure accuracy of the software's computations. The equipment was provided by James Long Company, Caroga Lake, New York and the data acquisition program consisted of Snap-Master, which was run on a Windows-based computer system. Raw data values were digitized at a rate of 512 samples per second using a 31-channel A/D converter with an input range of −2.5 V to +2.5 V and 12-bit resolution. The high-pass filter (HPF) and low-pass filter (LPF) were set at .1 Hz and 1000 Hz, respectively.

Heart rate reactivity has reliably demonstrated a strong relationship with anxiety and panic (Bernston & Cacioppo, 2004; Bystritsky, Craske, Maidenberg, Vapnik, & Shapiro, 2000), and may even serve as an early marker for developmental risk (Monk et al., 2004). Consistent with previous CO_2 challenge studies (e.g., Feldner, Zvolensky, et al., 2006; Kutz, Marshall, Bernstein, Zvolensky, 2010; Levitt et al., 2004; Richey, Schmidt, Hofmann, & Timpano, 2010; Schmidt et al., 2007; Telch, Harrington, Smits, & Powers, 2011) and suppression studies (e.g., Campbell-Sills et al., 2006; Gross & Levenson, 1993; Hofmann, Heering, Sawyer, & Asnaani, 2009), we measured heart rate as an autonomic indicator of anxiety.

2.4.2. Subjective Units of Distress Scale (SUDS)

The SUDS (Wolpe, 1958) is a single-item self-reported measure of distress that rates discomfort on an 11-point Likert scale (0 = no discomfort, 10 = worst discomfort ever experienced). SUDS ratings are used frequently in research to provide a quick, quantitative assessment of anxiety during a specific point in time. For the present study, participants were asked immediately following the 90-s challenge phase to indicate the amount of discomfort they were experiencing in the present moment; symptoms of CO_2 inhalation typically become more distressing as the duration of inhalation increases, and so subjective distress was likely to be most intense at the 90-s mark.

2.4.3. State-Trait Anxiety Inventory, Brief State Version (STAI-B)

The STAI-B (Spielberger et al., 1983) is an 8-item self-report measure that assesses anxiety in the present moment using a 4-point Likert scale. The STAI-B has been shown to be sensitive to changes in transitory anxiety induced by stressful experimental procedures or naturally occurring stressors (Spielberger et al., 1983). Participants were administered the STAI-B at baseline and again after the recovery phase of the CO_2 challenge task.

2.4.4. Diagnostic Symptoms Questionnaire (DSQ)

The DSQ (Sanderson, Rapee, & Barlow, 1989) is a 16-item self-report measure that assesses the somatic and cognitive symptoms associated with panic, as well as the overall sensation of panic or fear. For each panic-related symptom endorsed, participants rate the symptom intensity on a 9-point Likert scale. The DSQ has been shown to capture a symptom profile specific to the experience of panic (Rapee, Sanderson, McCauley, & Di Nardo, 1992). Participants completed the DSQ after completion of the recovery phase of the CO_2 challenge task.

2.5. Procedure

After providing written informed consent and completing the medical screen, participants filled out a battery of self-report questionnaires that included the predictor variables. Participants were then brought into the experimental room and given an overview of the study procedures while a research assistant applied the autonomic sensors. In order to maximize procedural consistency, instructions were pre-recorded and played over a speaker system; participants were provided with a written copy of the instructions as well. Participants first underwent a baseline period where two minutes of autonomic data were collected after an eight-minute stabilization period. All participants were then instructed to engage in suppression by distracting themselves, controlling their emotions, and acting as if nothing was happening to them. Prior to the challenge task, participants were given an opportunity to practice the suppression strategy by engaging in a cold pressor task. As part of this task, participants were instructed to submerge their right hand in a container of ice water chilled to four degrees. Participants were instructed to use the suppression strategy to cope with any discomfort that arose during the cold pressor task.

After completion of a dichotomous manipulation check questionnaire, participants' responses were reviewed for adherence to the strategy by the experimenter and corrective feedback was provided to participants as needed; the majority of participants (75%) reported perfect adherence to the suppression strategy during the practice exercise. The participants then engaged in the CO_2 challenge task, with instructions to continue using the suppression strategy. After completion of the CO_2 challenge task and measures of subjective distress, participants were debriefed regarding the experimental procedure and compensated for participation.

2.6. Data analysis

We tested a hierarchal regression model to determine whether factors of trait mindfulness predicted anxious responding during the CO_2 stressor after controlling for anxiety sensitivity related to physical concerns (measured with the physical concerns subscale of the ASI), fear of suffocation (measured with the SFS), distress tolerance (measured by length of the cold pressor task, up to 10 min), and trait anxiety (measured with the STAI-T). We entered the ASI physical concerns subscale, SFS, behavioral indicator of distress tolerance, and the STAI-T in the first step of the model. In the second step, the four factors of trait mindfulness were entered

(KIMS *observing*, *describing*, *awareness*, and *acceptance* scales) to provide a more conservative evaluation of the contribution of trait mindfulness beyond the influence of other empirically derived predictor variables. All predictor variables were grand-mean centered and force-entered stepwise into the regression hierarchy. Multicollinearity analyses suggested that the conditions of the model were met (VIF < 5, tolerance $> .10$), with only two predictor variables demonstrating variance inflation factors greater than 2.00. A power analysis suggests that for each step of the hierarchical regression, the sample size ($N = 48$) was sufficiently large (89% test power) to detect a large effect size (f^2 effect size $= .35$) of a multiple regression with four predictors per step at $p < .05$.

In order to control for the differences at baseline, we calculated individual change scores for heart rate by subtracting the resting heart rate value in beats per minute at baseline (mean = 71.52; SD = 9.84) from the heart rate values recorded during the challenge (mean = 74.51; SD = 10.89) and recovery (mean = 85.98; SD = 24.46) phases of the stressor. Difference scores were also computed by subtracting heart rate during the challenge phase from heart rate during recovery to explore the temporal sequence of heart rate change. Individual change scores in subjective state distress were calculated for the STAI-B by subtracting STAI-B scores at baseline (mean = 16.50; SD = 2.01) from STAI-B scores after the stressor (mean = 21.11; SD = 6.00). The calculated difference score and change scores for heart rate and the STAI-B were included as the dependent variables in all subsequent analyses.

Although participants were instructed to abstain from caffeinated beverages for at least 12 h prior to study participation, approximately 15% of the sample ($n = 7$) reported caffeine use. However, the number of caffeinated drinks consumed prior to the study was low (mean = .17; SD = .43) and occurred at least 3 h prior to participation. Bivariate correlations computed between the number of caffeinated drinks consumed and duration of time since last caffeinated drink, heart rate reactivity, and subjective distress were non-significant.

Information on the frequency (i.e., number of days), duration (i.e., average minutes each day), and intensity (i.e., vigorous, moderate, walking) of physical activity over the past week was also collected using the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003). Metabolic equivalent minutes were computed based on intensity of physical activity, and then summed to provide a continuous measure of physical activity over the past week. Bivariate correlations computed between metabolic minutes of physical exercise and subjective distress were non-significant; heart rate reactivity during the recovery phase was significant, $r = -.33$, $p < .05$. However, when entered as a predictor in our hierarchal regression model, physical activity was not a significant predictor of heart rate reactivity during the recovery phase and thus was not included in our subsequent regression models.

3. Results

3.1. Suppression manipulation check

In order to examine whether participants followed the suppression instructions, we administered a 9-item self-report questionnaire after the CO_2 challenge task to assess the degree to which participants utilized suppression (3 items), reappraisal (3 items), or mindfulness-based (3 items) strategies to cope with their distress. Response options ranged from 0 (strongly disagree) to 8 (strongly agree). Cronbach's alpha values indicated that the internal consistency was acceptable for each of the three scales: suppression (*alpha* = .80), reappraisal (*alpha* = .70), and mindfulness (*alpha* = .72).

Participants reported the use of the suppression technique during the CO_2 challenge significantly more than the mindfulness, $t\,(1, 47) = 9.45$, $p < .0001$, or reappraisal techniques, $t\,(1, 47) = 8.79$, $p < .0001$. Bivariate correlations computed for trait mindfulness and the suppression manipulation check were non-significant, suggesting that variability in trait mindfulness and adherence to the suppression technique were unrelated.

3.2. Descriptive statistics

Table 1 presents the means and standard deviations for the predictor and dependent variables. Table 2 lists the zero-order correlations among the predictor and dependent variables.

3.3. Heart rate

The results of the hierarchal regressions models predicting heart rate reactivity are presented in Table 3. Neither anxiety sensitivity related to physical concerns, fear of suffocation, distress tolerance, or trait anxiety (entered in step 1), nor the trait mindfulness factors (entered in step 2) contributed significantly to increases in heart rate during the CO_2 inhalation challenge phase compared to resting heart rate at baseline. However, during the stressor recovery phase, the addition of the trait mindfulness factors in step 2 explained a significant 27% of model variance after accounting for the anxiety-related variables in step 1. In particular, the *describing* factor of the KIMS emerged as a unique predictor of heart rate change, with participants who reported greater skill at describing thoughts, feelings, and sensations demonstrating significantly less elevation in heart rate during the recovery phase of the CO_2 stressor compared to heart rate at baseline, $B = -1.70$, SE $= .58$, $sr^2 = .20$, $p < .01$.

When examining the sequential change in heart rate from the challenge phase to the end of the recovery phase, the anxiety-related variables entered in step 1 did not account for a significant portion of model variance. Trait mindfulness factors (entered in step 2) accounted for a significant portion (26%) of model variance above and beyond anxiety sensitivity related to physical concerns, fear of suffocation, distress tolerance, and trait anxiety. Specifically, participants who scored high on the *describing* factor of the KIMS

Table 1
Means and standard deviations for uncentered predictor variables and dependent variables.

	Mean	SD
Predictor variables		
STAI-T	31.85	9.53
SFS	6.67	7.85
ASI-Physical Concerns	4.60	4.94
Distress Tolerance	338.53	272.13
KIMS-Observing	37.02	9.90
KIMS-Describing	29.48	6.79
KIMS-Awareness	32.29	6.48
KIMS-Accepting	34.60	6.78
Dependent variables		
HR: Baseline	71.52	9.84
HR: Challenge	74.51	10.89
HR: Recovery	85.99	24.46
STAI-B: Baseline	16.50	2.01
STAI-B: Challenge	21.12	6.00
SUDS	8.02	1.63
DSQ	29.10	19.07

Abbreviations: STAI-T = State-Trait Anxiety Inventory, Trait Version; SFS = Suffocation Fear Scale; ASI = Anxiety Sensitivity Index; KIMS = Kentucky Inventory of Mindfulness Skills; HR = heart rate; STAI-B = State-Trait Anxiety Inventory, Brief State Version; SUDS = Subjective Units of Distress Scale; DSQ = Diagnostic Symptom Questionnaire.

Table 2
Zero-order correlations between predictor and dependent variables.

Variable	1	2	3	4	5	6	7	8	9a	9b	9c	10a	10b	11	12
1. STAI-T	1														
2. SFS	.01	1													
3. ASI-Physical Concerns	.51**	.01	1												
4. Distress Tolerance	−.24	−.07	−.35*	1											
5. KIMS-Observing	−.03	−.09	.07	.01	1										
6. KIMS-Describing	−.46**	−.23	−.38**	.05	.21	1									
7. KIMS-Awareness	−.54**	.02	−.36*	.17	−.16	.28	1								
8. KIMS-Accepting	−.62**	−.15	−.44**	.31	−.24	.32*	.36*	1							
9. HR															
a. Baseline	−.07	.02	−.45**	.12	−.11	−.07	−.07	.13	1						
b. Challenge	−.02	.19	−.25	.14	.09	−.09	−.18	.06	.73**	1					
c. Recovery	.05	−.02	−.27	.22	−.04	−.35*	−.06	.10	.50**	.52**	1				
10. STAI-B															
a. Baseline	.04	.15	.28	.07	.11	−.15	.24	−.32*	−.06	.12	.11	1			
b. Challenge	.16	.30*	.21	.03	.11	−.23	−.36*	−.16	−.23	.10	.06	−.11	1		
11. SUDS	.05	.21	−.02	.23	.18	−.22	−.08	.01	.04	.12	.25	.10	.56**	1	
12. DSQ	.22	.24	.16	.13	.20	−.35*	−.34*	−.14	−.24	.08	.34*	.13	.65**	.52**	1

Notes: *$p < .05$,**$p < .01$, two-tailed. While several predictor variables were significantly correlated, multicollinearity analyses did not indicate any issues with multicollinearity (tolerance > .1, VIF < 5). STAI-T = State-Trait Anxiety Inventory, Trait Version; SFS = Suffocation Fear Scale; ASI = Anxiety Sensitivity Index; KIMS = Kentucky Inventory of Mindfulness Skills; HR = heart rate; STAI-B = State-Trait Anxiety Inventory, Brief State Version; SUDS = Subjective Units of Distress Scale; DSQ = Diagnostic Symptom Questionnaire.

demonstrated less heart rate elevation from the CO_2 challenge phase to the recovery phase, $B = -1.76$, SE = .56, $sr^2 = .23$, $p < .01$.

3.4. Subjective distress

Table 4 presents a summary of the hierarchal regression models predicting subjective distress (SUDS), changes from baseline in level of state anxiety (STAI-B), and self-reported experience and intensity of panic-related symptoms (DSQ). For subjective distress (SUDS) experienced during the stressor, none of the hypothesized predictor variables accounted for a significant portion of model variance.

For the hierarchal regression predicting changes in state anxiety (STAI-B) from baseline to immediately following the CO_2 stressor, the anxiety-related variables entered in step 1 did not predict significant model variance. The four trait mindfulness factors entered in step 2 explained an additional 19% of variance that did not reach statistical significance ($p < .12$). However, the *awareness* factor of the KIMS was a significant and unique predictor of changes in state anxiety from baseline to the challenge phase, with greater ability to fully engage in an activity and restrict attention to the present moment predicting less anxious responding during the CO_2 stressor, $B = -.41$, SE = .18, $sr^2 = .12$, $p < .05$.

For participants' self-reported experience and intensity of panic-related symptoms (DSQ) during the 90-s CO_2 challenge phase, entering the four factors of trait mindfulness in step 2 accounted for an additional 21% of model variance, which approached statistical significance ($p < .06$). The *observing* factor of the KIMS emerged as a significant predictor of panic symptoms experienced during the CO_2 stressor, such that participants who reported that they generally attend to bodily or sensory sensations, thoughts, and emotions reported more symptoms of panic and greater intensity of symptoms, $B = .71$, SE = .33, $sr^2 = .09$, $p < .05$.

4. Discussion

Mindfulness-based strategies have been found to be effective at reducing subjective distress and avoidance behaviors (Eifert & Heffner, 2003; Hofmann et al., 2010), but there has been limited exploration of the effect of mindfulness on physiological arousal to stress. In a previous study using a CO_2 challenge task, instructions to suppress challenge-induced emotional responses resulted in increased heart rate reactivity during the recovery phase (Feldner, Hekmat, et al., 2006), which is consistent with other studies that have demonstrated higher pain levels and delayed recovery from pain with the use of suppression (e.g., Masedo & Rosa Esteve, 2007).

The results of our study showed that trait mindfulness, and the *describing* factor in particular, attenuated heart rate reactivity to the CO_2 challenge, such that participants higher in trait mindfulness exhibited less heart rate reactivity during the recovery phase as

Table 3
Hierarchical multiple regression equation predicting heart rate reactivity.

Predictor	Change in HR from Baseline to challenge			Change in HR from baseline to recovery			Difference in HR from challenge to recovery		
	B	*t*-Value	ΔR^2	*B*	*t*-Value	ΔR^2	*B*	*t*-Value	ΔR^2
Step 1			.15			.09			.10
STAI-T	−.08	−.43		.63	1.27		.70	1.47	
SFS	.20	1.18		−.13	−.27		−.33	−.72	
ASI-Physical Concerns	.47	1.40		−.77	−.82		−1.24	−1.36	
Distress Tolerance	.01	1.48		.02	1.22		.01	.72	
Step 2			.11			.27*			.26*
KIMS-Observing	.24	1.66		.70	1.90		.46	1.30	
KIMS-Describing	.06	.28		−1.70	−2.94**		−1.76	−3.17**	
KIMS-Awareness	−.09	−.40		.53	.91		.62	1.11	
KIMS-Accepting	.27	.82		1.43	1.72		1.16	1.45	

Notes: *$p < .05$; **$p < .01$. HR = heart rate; *B* = unstandardized beta weight; ΔR^2 = change in R^2 statistic; STAI-T = State-Trait Anxiety Inventory, Trait Version; SFS = Suffocation Fear Scale; ASI = Anxiety Sensitivity Index; KIMS = Kentucky Inventory of Mindfulness Skills.

Table 4
Hierarchical multiple regression equation predicting subjective distress.

Predictor	Subjective distress (SUDS)			Change in state anxiety from baseline to challenge (STAI-B)			Panic symptoms (DSQ)		
	B	*t*-Value	ΔR^2	*B*	*t*-Value	ΔR^2	*B*	*t*-Value	ΔR^2
Step 1			.11			.06			.12
STAI-T	.02	.57		.07	.54		.38	1.05	
SFS	.05	1.61		.18	1.35		.59	1.53	
ASI-Physical Concerns	.00	.07		.04	.15		.32	.45	
Distress Tolerance	.00	1.31		.00	.37		.00	.36	
Step 2			.14			.19			.21
KIMS-Observing	.05	1.81		.13	1.12		.71	2.14*	
KIMS-Describing	−.07	−1.68		−.09	−.52		−.95	−1.94	
KIMS-Awareness	−.01	−.29		−.41	−2.22**		−.65	−1.24	
KIMS-Accepting	.08	1.49		.32	1.43		.88	1.39	

Notes: *$p < .05$; **$p < .01$. B = unstandardized beta weight; ΔR^2 = change in R^2 statistic; SUDS = Subjective Units of Distress Scale; STAI-B: State-Trait Anxiety Inventory, Brief State Version; DSQ = Diagnostic Symptom Questionnaire; State-Trait Anxiety Inventory, Trait Version; SFS = Suffocation Fear Scale; ASI = Anxiety Sensitivity Index; KIMS = Kentucky Inventory of Mindfulness Skills.

compared to both resting heart rate at baseline and heart rate during acute CO_2 inhalation. Although the addition of trait mindfulness factors did not significantly contribute to the overall regression model predicting subjective distress, the specific skill of staying fully engaged in the present moment (*acting with awareness*) significantly predicted less subjective anxiety during the challenge phase of the CO_2 stressor, and the specific skill of attending to bodily or sensory sensations, thoughts, or emotions (*observing*) predicted more symptoms of panic and greater intensity of symptoms.

It is possible that the *describing* factor (i.e., the ability to apply verbal descriptors to experiences) is a particularly salient marker of an individual's tendency to engage in other factors of trait mindfulness, such as observing emotional or sensory experiences and maintaining a present-focused awareness (arguably prerequisites for describing the experience). On the other hand, the *observing* factor of trait mindfulness was positively related to the experience of panic-related symptoms during the CO_2 challenge, which suggests that simply attending to internal and external sensations does not necessarily confer any benefit for adaptive emotion regulation. Similar relationships between the *observing* factor of trait mindfulness and negative psychological outcomes have been reported in other studies, including a study of eating pathology in female smokers that found that the *observing* factor predicted more severe anorexic symptoms, while the *describing* factor predicted less symptomatology (Adams et al., 2012). These findings suggest that simply observing symptoms or physical sensations is not sufficient to provide a buffer against stress reactivity. While the ability to observe emotional experiences does appear to be meaningfully related to other factors of trait mindfulness (i.e., *describing, acting with awareness,* and *accepting*), it may offer limited value as a unique predictor of positive outcomes due to strong associations with indicators of ineffective emotion regulation, such as trait rumination or hypervigilance to threat detection.

Although specific factors of trait mindfulness emerged as unique predictors of stress reactivity as assessed by both self-reported distress and heart rate, different factors of trait mindfulness were associated with subjective versus physiological stress – autonomic reactivity was attenuated by the *observing* factor, whereas subjective distress was negatively associated with the *acting with awareness* factor. Emotion theories suggest that an individual's behavioral, physiological, and experiential responses to emotions should reflect coherence over time, but empirical investigations demonstrate weak correlations between experiential and physiological response symptoms (for a review, see Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Indeed, studies comparing subjective and cardiovascular effects of emotion regulation strategies often report discrepancies between experiential and physiological response systems. Therefore, it is not surprising that factors of trait mindfulness might exhibit distinct relationships across different response systems.

Our study showed that none of the anxiety-related variables (anxiety sensitivity related to physical concerns, fear of suffocation, distress tolerance, trait anxiety) predicted anxious responding during the stressor as assessed by subjective report or autonomic responses. Although the effects of CO_2 are most pronounced amongst panic disorder patients, measurable physiological and psychological effects have also been observed in normal, non-anxious volunteers. A comparison with other studies showed that the sample in the present study reported a comparable level of anxiety sensitivity related to physical concerns (mean = 4.60; SD = 4.94) as the levels reported by other non-clinical samples in similar studies (e.g., Arch & Craske, 2010), suggesting that our findings are not due to unusually low levels of this particularly salient predictor variable. It is possible, however, that some of our findings are the result of gender-specific effects, as a previous study examining the role of anxiety sensitivity in responding to a CO_2 challenge found that trait anxiety was only predictive of CO_2-induced panic in females (Monkul et al., 2010). Therefore, it may be important to examine gender as a possible moderator variable in future studies.

A potential limitation is the statistical test power of our analyses, given the sample size and number of predictors, although a power analysis conducted did suggest that the sample size was sufficiently large to test our hierarchal multiple regression model. It is noteworthy that significant effects did emerge, but it is also possible that the analyses were underpowered to fully detect effects (i.e., greater risk for Type II error), or that the variance accounted for in our regression model would be greater in a larger sample. Another limitation is the assessment of trait mindfulness, which relied exclusively on self-report and thus was limited by participants' ability to reflect and accurately assess their habitual use of skills associated with trait mindfulness. Adherence to the suppression strategy was also assessed via self-report, and consequently limited by participants' insight into their use of emotion regulation strategies. However, the purpose of the manipulation was to amplify the distress and physiological arousal naturally experienced during CO_2 inhalation through the paradoxical effect of suppression. Therefore, even if the manipulation did not function as intended, participants still demonstrated significant autonomic and subjective distress (e.g., participants rated distress during CO_2 inhalation, on average, as 8.02 on a 0 to 10 distress scale, where 10 was worst discomfort ever experienced) that was significantly related to factors of trait mindfulness.

We chose to use a behavioral indicator of distress tolerance (i.e., cold pressor task); all other predictor variables were assessed via self-report. Although behavioral measures of distress tolerance are traditionally viewed as more ecologically valid, particularly for biological challenges, and less vulnerable to participant bias, the use of different methodology to assess our predictor variables is another possible limitation. As stated earlier, our institutional review board required us to restrict the sample to healthy males in the interest of minimizing risk to female participants who may be in the early stages of pregnancy and thus unaware of potential risks. There is also data to suggest that anxious responding, including heart rate reactivity, in females can be either amplified or dampened depending on the current stage of the menstrual cycle (Ossewaarde et al., 2010), which may have confounded results in the present study if female participants were included. Therefore, our study results are limited to non-clinical, male adults. However, even in healthy controls, individual differences in trait mindfulness have been found to predict risk factors for depression and anxiety, such as trait rumination and negative bias (Paul, Stanton, Greeson, Smoski, & Wang, 2012), suggesting that trait mindfulness might exert a similar or possibly even augmented effect in a clinical sample. Although women typically report utilizing more emotion regulation strategies than men, both sexes appear to engage in suppression to a similar extent (e.g., Nolen-Hoeksema, 2012; Nolen-Hoeksema & Aldao, 2011). Levels of trait or dispositional mindfulness also do not appear to differ between the sexes (Modinos, Ormel, & Aleman, 2010), which provides some support for the possible generalizability of the current study's findings to women.

It is worth noting that although the Western conceptualization of mindfulness originated in the Buddhist tradition, differences do exist between the two conceptualizations. In particular, Western conceptualizations of mindfulness are independent of a specific code of ethics and prioritize awareness of both internal and external experiences, while Buddhist teachings tend to emphasize introspective awareness (Keng et al., 2011). However, the discussion of mindfulness in the present study is consistent with the self-report measures designed to assign mindfulness and the clinical research conducted to date, which largely reflect Western conceptualizations of mindfulness. Despite these limitations, our study highlights the predictive value of trait mindfulness for anxious responding during a highly fear-inducing stressor and while engaging in an emotion regulation strategy associated with greater stress reactivity. Although it is feasible that the differential relationships observed for factors of trait mindfulness and subjective versus autonomic measures of distress are due to underpowered analyses, it is also possible that these results reflect distinct mechanisms of action for each of the factors, which is an important area for future research. An additional strength of the current study is that each participant received training and instruction in the use of suppression to manage the distress experienced during the CO_2 challenge, as previous studies of trait mindfulness have failed to control for individual differences in participants' habitual use of emotion regulation strategies. Furthermore, we believe that evaluating the effect of trait mindfulness on stress reactivity while engaging in suppression provides a more stringent test of our hypothesis that trait mindfulness would attenuate anxious responding to symptoms experienced during the CO_2 challenge.

The current study was also able contribute to the existing literature on mindfulness by exploring whether specific dimensions of trait mindfulness uniquely predicted responses. In order to maximize the efficacy of mindfulness-based approaches, it is essential that we know *which* factors of trait mindfulness are particularly important so we can develop more finely targeted trainings and interventions. For example, existing mindfulness-based therapies focus largely on becoming an observer of internal and external sensations. Yet research to date on the unique relationships between facets of mindfulness and psychological outcomes suggest that the ability to notice and observe these experiences is often predictive of *more* symptomatology in the absence of the other mindfulness skills. Results from both this study and prior studies of trait mindfulness argue for a greater emphasis in mindfulness-based interventions on the ability to describe one's experiences, which is a skill that receives little, if any, explicit attention in existing mindfulness protocols. Given that higher levels of the *describing* factor of trait mindfulness were associated with less autonomic arousal during recovery from CO_2 inhalation in the current study, an emphasis on the ability to describe internal experiences may be particularly effective for patients with panic disorder.

The results of our study have important theoretical and practical implications, and suggest that trait mindfulness may be an important moderator that needs to be considered in emotion and psychophysiological challenge studies. Our study is one of the first to date to demonstrate the effect of trait mindfulness on heart rate reactivity, specifically that the *describing* factor of trait mindfulness significantly and inversely predicted heart rate change during recovery from an acute stressor. It appears that high levels of trait mindfulness buffered against the effect of an emotion regulation strategy traditionally associated with greater distress and slower recovery from pain, and thus efforts to enhance trait mindfulness may be especially effective for facilitating recovery from other sources of physical stress, such as panic attacks or even medical procedures.

An important area for future research is to investigate whether trait mindfulness can be enhanced by mindfulness trainings or other interventions. Given the accumulating evidence that trait mindfulness may serve as a positive resource for promoting adaptive emotion regulation and reducing vulnerability for the development of emotional disorders, interventions aimed at enhancing trait mindfulness in healthy individuals may be a powerful prevention tool. Additional studies should also explore how mindfulness-based interventions interact with trait mindfulness as possible predictors of treatment response, as well as which factors of mindfulness are most important for achieving successful treatment outcomes.

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