The Effect of a Brief Mindfulness Training on Distress Tolerance and Stress Reactivity

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Poor distress tolerance (DT) is considered an underlying facet of anxiety, depression, and a number of other psychological disorders. Mindfulness may help to increase DT by fostering an attitude of acceptance or nonjudgment toward distressing experiences. Accordingly, the present study examined the effects of a brief mindfulness training on tolerance of different types of distress, and tested whether trait mindfulness moderates the effect of such training. Undergraduates ($n = 107$) naïve to mindfulness completed a measure of trait mindfulness and underwent a series of stress tasks (cold pressor, hyperventilation challenge, neutralization task) before and after completing a 15-minute mindfulness training or a no-instruction control in which participants listened to relaxing music. Participants in the mindfulness condition demonstrated greater task persistence on the hyperventilation task compared to the control group, as well as a decreased urge to neutralize the effects of writing an upsetting sentence. No effect on distress ratings during the tasks were found. Overall trait mindfulness did not significantly moderate task persistence, but those with lower scores on the *act with awareness* facet of mindfulness demonstrated greater relative benefit of mindfulness training on the hyperventilation challenge. Mediation analyses revealed significant indirect effects of mindfulness training on cold pressor task persistence and urges to neutralize through the use of the *nonjudge* and *nonreact* facets of mindfulness. These results suggest that a brief mindfulness training can increase DT without affecting the subjective experience of distress.

DISTRESS TOLERANCE (DT) IS defined as the capacity to withstand negative emotional or other aversive states (Leyro, Zvolensky & Bernstein, 2010). Individuals with low DT are believed to use more avoidance-oriented strategies and pursue negative reinforcement opportunities in the face of distress, which can lead to maladaptive forms of coping (Simons & Gaher, 2005). In accordance with such a theory, low DT has been found to be associated with a number of different symptoms of psychopathology and maladaptive health behaviors, including anxiety, depression, substance abuse, eating disorders, and borderline personality disorder (Allan, Macatee, Norr, & Schmidt, 2014; Anestis, Selby, Fink, & Joiner, 2007; Bernstein, Marshall, & Zvolensky, 2011; Gratz, Rosenthal, Tull, Lejuez & Gunderson, 2006; Richards, Daughters, Bornovalova, Brown & Lejuez, 2011). Research has also shown improvements in DT to be associated with successful treatment outcomes (Banducci, Connolly, Vujanovic, Alvarez, & Bonn-Miller, 2017; McHugh et al., 2014).

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Accordingly, understanding how to best enhance DT is an important direction for maximizing treatment efficacy.

One promising approach for increasing the capacity to tolerate distress is mindfulness training. Mindfulness involves deliberately focusing attention on the present moment while taking an attitude of openness and acceptance toward one's current experience instead of trying to change or control it (Bishop et al., 2004). Mindfulness may increase DT by causing emotional or other distressing experiences to be seen as less threatening and unpleasant, and by refocusing attention toward the current experience rather than negative reactions about current distress (Lotan, Tanay, & Bernstein, 2013). In support of this notion, individuals who are higher in trait mindfulness have been found to have greater scores on self-reported measures of DT (Hsu, Collins, & Marlatt, 2013; Luberto et al., 2014), as well as greater task persistence on behavioral measures of DT (Arch & Craske, 2010; Feldman, Dunn, Stemke, Bell, & Greeson, 2014).

Behavioral DT tasks typically involve asking participants to persist in a physically or mentally distressing task for as long as they are willing. This is in contrast to self-reported DT (e.g., Simons & Gaher, 2005), which asks respondents to rate how they *perceive* their ability to tolerate negative emotional states. Behavioral tasks are useful in that they allow for the measurement of a variety of different types of distress, such as pain, frustration, or interoceptive discomfort (see Leyro et al., 2010, for a review of behavioral DT tasks). In addition, they enable researchers to investigate the effects of brief experimental manipulations on task persistence as well as perceived distress.

In the context of mindfulness, a growing body of research has demonstrated that brief mindfulness training can influence behavior and stress reactivity on such tasks. For instance, a 1-day mindfulness training has been shown to significantly increase task persistence on a breath-holding challenge 3 months later (Lillis, Hayes, Bunting, & Masuda, 2009). In addition, mindfulness instructions following an anger induction in individuals with borderline personality disorder led to decreased anger and increased task persistence during a cognitively challenging arithmetic task (Sauer & Baer, 2012). Furthermore, mindfulness-based instructions have been shown to lead to greater task persistence and reduced distress ratings compared to spontaneous coping and distraction controls during the cold pressor task, in which participants submerge their hand in ice cold water for as long as they are willing (Liu, Wang, Chang, Chen, & Si, 2013; Masedo & Esteve, 2007).

In contrast to these findings, a study by Evans, Eisenlohr-Moul, Button, Baer, and Segerstrom (2014) found that ultra-brief mindfulness instructions with no opportunity to practice led to a decreased task persistence in the cold pressor compared to a spontaneous coping control. Furthermore, a recent study by Luberto and McLeish (2018) found that a brief mindfulness exercise did not have any effect on task persistence in the mirror-tracing task in a sample of daily smokers, and had just a marginally significant effect on subjective distress. Similarly, Paz, Zvielli, Goldstein, and Bernstein (2017) did not find a main effect of a brief mindfulness intervention on subjective distress during a hyperventilation challenge with nicotine-deprived smokers, though the intervention did eliminate the effect of low self-reported DT on distress during the task.

One possibility for these inconsistent findings is that the effect of mindfulness on DT may vary based on the specific task and the type of distress being tolerated. However, no single study has examined the effect of mindfulness across different tasks. Behavioral DT tasks have been shown to demonstrate some level of domain specificity (McHugh et al., 2011), and different types of distress may be more relevant for distinct psychological issues (Leyro et al., 2010). For example, the interoceptive distress involved in a hyperventilation challenge is associated with panic symptomology (Marshall et al., 2008), whereas tolerance of physical pain in the cold pressor task has been associated with negative mood and addiction abstinence (MacPherson, Stipelman, Duplinsky, Brown, & Lejuez, 2008).

Another type of task that measures DT is the neutralization task (Cougle, Purdon, Fitch, & Hawkins, 2013), which involves writing a sentence about and then imagining the occurrence of a negative event. This task offers a unique method of examining DT in that it assesses distress elicited by upsetting thoughts (i.e., a loved one being in a car crash) rather than challenging behavioral tasks, and it also examines urges to neutralize such thoughts. Neutralization behavior (e.g., crossing the written sentence out) and anxiety during this task have been shown to predict greater symptoms of obsessive-compulsive disorder, particularly obsessions, as well as self-reported DT (Cougle et al., 2013; Cougle, Timpano, Fitch, & Hawkins, 2011). Performance on the task has also been shown to be malleable in response to a two-session intervention targeting DT (Macatee & Cougle, 2015).

The primary aim of the present study was to examine whether a brief mindfulness intervention would improve task persistence and decrease

subjective distress on the cold pressor and hyper-ventilation challenge, as well as reduce urges to neutralize and neutralization behavior on the neutralization task. A secondary aim was to examine whether trait mindfulness, which captures an individual's disposition toward adopting a nonjudgmental and accepting stance toward his or her present experience, would impact the response to mindfulness training. A number of studies have shown that those higher in trait mindfulness benefit more from mindfulness interventions (Keng, Robins, Smoski, Dagenbach, & Leary, 2013; Laurent, Laurent, Nelson, Wright, & Sanchez, 2015; Reiner, Granot, Soffer, & Lipsitz, 2015; Shapiro, Brown, Thoresen, & Plante, 2011). For instance, Reiner et al. (2015) found that higher trait mindfulness led to greater improvement in heat pain sensitivity following a brief mindfulness training. However, results are not always consistent, as some studies have shown that lower trait mindfulness predicts better response to mindfulness interventions (Gawrysiak et al., 2018; Watier & Dubois, 2016), and others report no effect (Greeson et al., 2015).

In spite of the large number of studies examining trait mindfulness as a moderator of mindfulness-based interventions, extant research has yet to do so when using persistence on a distressing task as an outcome of DT. We predicted that in the current study, those higher in trait mindfulness would benefit more from mindfulness training compared to a no-instructions control on task persistence and subjective distress. Because distinct aspects of mindfulness have shown different effects on the impact of mindfulness interventions (Gawrysiak et al., 2018), we also conducted exploratory analyses examining each facet of the Five Facet Mindfulness Questionnaire separately to determine whether particular facets may be driving any moderator effects.

Materials and Methods

PARTICIPANTS

Participants (n = 107) were at least 18 years of age and were recruited from introductory undergraduate psychology classes. They received course credit for their participation. Exclusion criteria included (a) prior experience with mindfulness or meditation practice, (b) Reynaud's disease, current or past frostbite, open cuts, or sores in the hand to be submerged in cold water during the cold pressor task, (c) medical conditions such as cardiovascular disease, a history of seizures, asthma, sickle cell disease or trait, cerebrovascular disease, or a recent stroke or heart attack, as hyperventilation is contraindicated for individuals with such conditions,

(d) anxiolytic medication (e.g., Ativan, Xanax) taken in the 2 hours prior to the study.

PROCEDURE

Following informed consent, participants provided demographic information and filled out the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) and the Depression, Anxiety and Stress Scale (DASS; Lovibond & Lovibond, 1995). They were then connected to a respiration belt, which remained for the duration of the experiment. Next, participants read instructions from a paper packet that explained the basic nature of the tasks they were to complete. The instructions read: "For this part of the study, you are going to be led through some exercises that may be difficult or uncomfortable for you. The goal of each task is for you to stay with it for as long as you are willing. For each task, you can stop at any time you'd like, but the object is to see for how long you can go." Participants then completed the first round of DT tasks (cold pressor and the hyperventilation challenge), which were delivered in random order. Also included in the task set was the Computerized Mirror Tracing Persistence Task (Strong et al., 2003). However, this task was excluded from the analysis because of baseline differences in task persistence between the two experimental conditions. Of note, this difference was not significant in the entire sample, but only in the sample of 70 participants who did not reach the maximum time limit on the task, which was the criteria for inclusion in the task persistence analyses.

Prior to each task, participants rated their current subjective units of distress (SUDS; described below) on a paper form. Then they read the instructions for the task, and were reminded both on paper and through standardized experimenter instructions that while they could stop the task at any time, the goal was for them to see how long they could persist. After each task, participants rated the maximum SUDS they experienced during the task. They were then instructed to relax for a 2-minute recovery period prior to completing the next task. The experimenter communicated to participants from another room via intercom, and only entered the experiment room as necessary to set up the DT tasks.

Following the first round of DT tasks, participants listened to a 15-minute audio recording of either a mindfulness intervention or relaxing music (randomly assigned). Randomization of task order and condition was conducted using a computerized randomization algorithm prior to running the first participant. After the intervention, those in the mindfulness condition answered five multiple-choice questions to assess comprehension of the mindfulness training, and for

any questions that the participants answered incorrectly, the experimenter provided an explanation of the correct response. Participants then completed the second round of DT tasks, again in random order, with the addition of the neutralization task (explained below). The only other differences in the tasks post-intervention were (a) participants in the mindfulness condition were instructed to use the skills they learned previously to help with any feelings of distress elicited by the DT task, and (b) all participants completed a brief set of questions assessing the extent to which they used various mindfulness skills after each task.

DISTRESS TASKS

Cold Pressor

The cold pressor is a widely used task to safely measure sensitivity to and tolerance of pain (Tousignant-Laflamme, Pagé, Goffaux, & Marchand, 2008). For this task, participants were asked to put their dominant hand inside a cooler filled with an ice water bath that was between 0–2 degrees Celsius. Temperature was measured prior to each trial with a digital thermometer placed in the center of the bath. Participants were instructed to submerge their hand up to the wrist without touching the bottom of the container of water, and to keep their hand open for the duration of the task. They were told they should try to persist with the task for as long as they were willing, but they could stop at any time. Unbeknownst to the participants, the task had a maximum time of 180 seconds, a limit frequently used for safety reasons (e.g., Szuhany & Otto, 2015).

Hyperventilation Challenge

The hyperventilation challenge is a commonly used task designed to induce interoceptive distress by eliciting physiological sensations similar to anxiety (Zvolensky & Eifert, 2001). Participants were told to take full breaths through their mouth in time with an audio recording that instructed them when to breathe in and out. Consistent with prior literature (Bunaciu, Feldner, Babson, Zvolensky, & Eifert, 2012; Marshall et al., 2008), we used a breathing rate of 30 breaths per minute. Prior to beginning, the experimenter demonstrated the proper breathing technique, and participants practiced in time with the recording for 10 seconds. Participants were told to persist as long as they were willing, but that they could stop at any time. Once the task started, the experimenter monitored a live reading of the participants' tidal volume, or the amount of air inhaled as measured by expansion of the respiration belt, to determine that they were breathing in a consistent manner. If there was a noticeable reduction in tidal volume, the experimenter

reminded the participant to inhale and exhale deeply. Tidal volume throughout the task was also recorded to ensure that participants did not breathe differently after the mindfulness intervention, and this variable was included as a covariate in data analysis. Unbeknownst to the participants, the task ended automatically after 5 minutes.

Neutralization Task

The neutralization task is designed to test participants' urge to neutralize emotionally distressing thoughts (Cougle et al., 2013). For this task, participants were asked to think about a close friend or relative. They then wrote the following statement on a piece of paper ("___will be in a car accident"), filling in the blank with the name of person they called to mind. Next, they were asked to close their eyes and think about the situation for 30 seconds. Then they completed a rating of current distress, and reported how much of an urge they had to cancel out the effects of writing the sentence on a scale ranging from 0 (no urge at all) to 10 (extreme urge) (referred to as postrumination ratings). Upon completion of these questions, participants were told, "for the next minute you do not have to do anything, but if you wish to do something, it can be anything, and can involve the sheet of paper." After the minute passed, participants provided a rating of subjective distress and a neutralization urge rating (referred to as postneutralization ratings). They were also asked if they used any of the following strategies to cancel out or neutralize the effects of writing the sentence: (a) altered or destroyed the paper in any way, (b) visualized the accident, but with a less serious or a positive outcome, (c) carried out a superstitious act (e.g., did something they believed would bring good luck), (d) turned over or concealed the paper, or (e) used a religious strategy. To counteract the potential negative effects on participant mood, participants were then instructed to write down and think of a happy memory they have with the close friend or relative they chose before for 1 minute. Participants who reported intense emotional distress resulting from a traumatic memory of a car accident were excluded from this task, such a memory could amplify the distress caused by imagining a similar event during the task, thereby confounding results. This occurred with just two participants, both in the relaxation condition. Unlike the other tasks, the neutralization task was not administered prior to the intervention. Doing so may have compromised the validity of the second administration of the task by priming the use of neutralization behaviors due to prior questions about their use, as well as possible lack of compliance with rumination instructions for

participants who found thinking about the negative situation highly distressing the first time.

MINDFULNESS INTERVENTION

The mindfulness intervention used in this study was based on the principles of Mindfulness-Based Cognitive Therapy (Teasdale, Segal, & Williams, 2013). Initial versions of the intervention were tested with several clinicians with expertise in mindfulness, and feedback was incorporated in order to refine the procedures. Participants were given an explanation of the two key components of mindfulness: present-moment awareness and acceptance or nonjudgment. This was followed by an explanation of how judging one's experience often causes one to try and control or push away unpleasant experiences, but that such attempts at control often backfire. To illustrate this point, participants were guided through the workings of a Chinese finger trap, which is a finger-width tube made of straw that tightens around one's fingers if one inserts them in either end of the straw and attempts to pull them out. It was explained to participants that, paradoxically, the only way to release one's fingers is to push them in, which mirrors the way that taking an accepting attitude toward distressing experiences (as opposed to fighting or judging the experience) can release the hold that such distress has on one's current state. To illustrate this further, participants were guided through a 5-minute meditation exercise in which they were instructed to focus on their breathing. If extraneous thoughts, feelings, or physical sensations arose, they were guided to simply notice them in a nonjudgmental way, and refocus their attention on the breath. Participants were then instructed to practice taking such a nonjudgmental stance in a more challenging situation, specifically while held their breath for 20 to 30 seconds. The intervention concluded with an explanation of how, in the upcoming distress tasks, they should refrain from distracting themselves or trying to suppress unpleasant feelings during the tasks, and instead should observe those feelings with an attitude of curiosity and acceptance. The training was delivered through an audio recording, and lasted 15 minutes.

CONTROL PROCEDURES

Participants assigned to the control condition listened to relaxing music to account for time and any relaxing effects of the mindfulness meditation. The relaxing music consisted of the first 15 minutes of a YouTube video (audio only) playing soothing music (Meditation Relax Music, 2016). No instructions regarding the rest of the experiment were provided, participants were merely instructed to listen to the music and were monitored to ensure they stayed awake.

MEASURES

Subjective Units of Distress (SUDS)

The SUDS is a widely used rating scale that assesses an individual's level of distress from 0 (*no distress*) to 100 (*maximum distress*). Participants provided a SUDS rating immediately prior to each DT task regarding their current distress, and following the completion of each task regarding their maximum level of distress during the task. Values used for analysis represent change from pre-task to peak.

Five Factor Mindfulness Questionnaire (FFMQ)

The FFMQ (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006) is a 39-item self-report scale assessing various aspects of trait mindfulness. Items consist of statements describing various attributes of mindfulness and are rated on a 5-point Likert scale ranging from 1 (*never or very rarely true*) to 5 (*very often or always true*). The measure was derived from factor-analytic research of five independently developed mindfulness questionnaires, and consists of the following factors: *observe* (e.g., "I pay attention to sensations, such as the wind in my hair or sun in my face"), *describe* (e.g., "My natural tendency is to put my experiences in to words"), *act with awareness* (e.g., "I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted" — reverse scored), *nonjudge* (e.g., "I criticize myself for having irrational or inappropriate emotions" — reverse scored), and *nonreact* (e.g., "I perceive my feelings and emotions without having to react to them"). Cronbach's alpha for the five factors ranged from 0.67 to 0.91, and for the full scale was 0.86.

Depression, Anxiety, and Stress Scale (DASS)

The DASS (Lovibond & Lovibond, 1995) is a 21-item self-report scale in which participants rate the extent to which they experienced symptoms of depression, anxiety, and stress over the past week. The scale produces scores for each of the three symptom categories, and Cronbach's alpha in the present sample was between 0.75 and 0.88 for the three categories.

Mindfulness Use Questions

To assess the extent to which participants used mindfulness skills for the DT tasks postintervention, we developed a set of five questions conceptually based on the five facets of the FFMQ. Participants were asked to rate the extent to which the following statements applied to them during the prior task: "I tried to observe my thoughts, feelings or sensations during this task"

(*Observe*); "I tried to describe the thoughts, feelings and sensations I was experiencing to myself" (*Describe*); "I tried to distract myself from my thoughts, feelings and sensations" (*Act with Awareness*, reverse-scored); "I tried to take an accepting stance toward what I was experiencing" (*Nonjudge*); "When I experienced distressing thoughts or feelings, I tried to just notice them without reacting" (*Nonreact*). Questions were rated on a Likert scale from 1 (*Not at all*) to 5 (*A lot*). Internal consistency for the five items was diminished as a result of the reverse-scored item (Act with awareness), so the item was eliminated. With the remaining four items, Cronbach's alpha was 0.81.

Tidal Volume

Tidal volume was measured in order to ensure consistent breathing patterns during and between hyperventilation trials. Psychophysiological data was recorded with equipment made by James Long Company, Caroga Lake, NY and with the data-acquisition program Snap-master for Windows. The raw data were digitized at 1,000 samples per second, with a 4-channel A–D converter operating at a resolution of 16 bits and having an input range of −2.5 V to +2.5 V. Respiration was acquired using a latex rubber bellows strain gauge wrapped around the participant's chest to detect changes in thoracic girth during inhalation and exhalation. The respiration signal is dimensionless and uncalibrated, and thus is only usable as a ratio within subjects to assess changes in tidal volume within a single experimental session. The respiration signal was amplified and low-pass filtered at 10 hertz.

DATA ANALYSIS

To examine the impact of condition and the moderating effect of trait mindfulness on task persistence and subjective distress post-intervention, separate hierarchical multiple regressions for each task and outcome variable were conducted. Consistent with prior studies (Liu et al., 2013; Masedo & Esteve, 2007), participants who hit the maximum allotted time for each task at baseline were eliminated from analyses for that task. This was done in order to avoid artificially restricting improvements made from the first to second task, thereby increasing power to detect an effect of the intervention. Step one of each regression model included gender and either pre-intervention SUDS increase or task persistence for the relevant distress task. Gender was included as a covariate given previous literature suggesting differences in pain sensitivity and DT between men and women (Bunaciu et al., 2012). Step 2 of the analysis included condition and FFMQ as main

effects, while step 3 included their interaction. For the neutralization task, separate hierarchical linear regressions were run with postrumination and postneutralization (i.e., the 1-minute waiting periods) SUDS and neutralization urges as dependent variables, and condition as a predictor. In addition, a logistic regression was run examining the effect of condition on the likelihood of engaging in neutralization behavior. Similar to the analyses discussed above, gender was included as a covariate.

Power analyses using GPower indicated that when including relevant covariates in the model, a medium effect size ($f^2 = 0.15$) for the main effect of intervention would require a sample size of 68 to achieve 80% power with an alpha level of .05. In order to account for exclusion of participants who reached the maximum allotted time on the tasks and to increase power for moderator analyses, we recruited a sample of 107 participants.

To examine whether self-reported mindfulness use during each task mediated the effect of condition on post-intervention outcomes, we used a 5,000-sample bootstrap procedure to estimate bias-corrected 95% confidence intervals for the indirect effect (Hayes, 2013). Confidence intervals that do not overlap with zero indicate significant indirect effects. This method provides greater power and Type 1 error control compared to traditional mediation approaches, and does not rely on the assumption that the sampling distribution of the indirect effect is normal (Hayes, 2013). All mediation analyses included gender as a covariate, and pre-intervention task persistence was also controlled for in the analyses of the hyperventilation and cold pressor tasks.

Data were analyzed using SPSS Version 24.0 in Windows, and mediation analyses were conducted using the PROCESS macro for SPSS (Hayes, 2013). Assumptions of linear regression were tested, including normality, homoscedasticity and independence of residuals, absence of multicollinearity, and the presence of outliers. Data were determined to be suitable for linear regression. The squared semi-partial correlation coefficient (sr^2) was used as an indicator of effect size for predictors of interest.

For the hyperventilation challenge, data on tidal volume ratio from seven participants were missing as a result of equipment failure. To address this, we first used Little's missing completely at random test (Little, 1988) to determine that missingness of data was not related to any variables being examined in the study. We then used multiple imputation methods with fully conditional specification (van Buuren, 2007) to generate plausible values for the missing data. The model used to generate such values included the variables included in the regression

model, as well as baseline and pre- and post-intervention tidal volume and respiration rate, as we determined that such variables would serve as meaningful estimators of predicted tidal volume ratio values. Five iterations of complete data sets were generated, and the pooled data from these imputations were used in subsequent analyses involving tidal volume.

Results

PARTICIPANT CHARACTERISTICS

The sample was 66.4% female, and the mean age was 19.0 years ($SD = 1.4$). Participants were 57.0% Asian, 34.6% White, 4.7% biracial, and 3.7% African American. No difference was seen between participants randomized to the mindfulness ($n = 53$) or control ($n = 54$) conditions in gender, χ^2 (1) = 0.23, $p = 0.69$, $\varphi = 0.05$, race, χ^2 (3) = 2.24, $p = 0.52$, $\varphi = 0.15$, age, $t(104) = 1.54$, $p = 0.13$, $d = 0.30$. Table 1 also shows there was no difference between groups in baseline FFMQ, anxiety, stress or depression.

MANIPULATION AND RANDOMIZATION CHECKS

Table 1 also shows baseline variables related to task performance for the mindfulness and no instructions control groups. There were no significant differences between conditions in number of participants included (i.e., participants who did not reach maximum time during first task), baseline task persistence, or baseline SUDS increase for either the Cold Pressor or Hyperventilation tasks. Mean changes in SUDS from before each distress task to the peak were significantly different from zero, showing the tasks successfully induced distress (Cold Pressor: $M = 39.61$, $SD = 22.20$, $t[89] = 16.93$, $p < 0.001$, $d = 1.78$; Hyperventilation $M = 32.82$, $SD = 19.68$, $t[93] = 16.17$, $p < 0.001$, $d = 1.67$).

With regard to our mindfulness intervention, participants in the mindfulness condition demonstrated good comprehension of the training, answering a mean of 4.53 of 5 comprehension questions correctly ($SD = 0.85$). As can be seen in Table 1, mean scores for the mindfulness use questions were significantly higher in the mindfulness group for all three tasks. Self-reported mindfulness use significantly correlated with change in task persistence for the cold pressor ($r = 0.30$, $p = 0.004$) and hyperventilation ($r = 0.32$, $p = 0.02$). When examining just the mindfulness condition separately, the relationship remained significant for the cold pressor ($r = 0.33$, $p = 0.04$) but not hyperventilation

Table 1

Baseline Self-Report Means, Pre- and Post-Intervention Task Variables, and Post-Intervention Mindfulness Use for Mindfulness and Control Groups

Measure/Task	Condition		χ^2 or T
	Mindfulness	*Control*	
FFMQ Total	120.42 (14.70)	122.65 (15.16)	0.77
DASS Anxiety	3.68 (2.93)	4.16 (3.69)	0.75
DASS Depression	4.19 (3.96)	4.56 (3.83)	0.49
DASS Stress	6.66 (3.90)	6.92 (4.07)	0.74
Participants Included (Did not reach maximum time during first task)			
Cold Pressor	41 (77%)	49 (91%)	2.65
Hyperventilation	46 (87%)	48 (89%)	0.00
Mean Task Persistence in Seconds (SD)			
Cold Pressor Pre	47.05 (28.66)	48.12 (35.28)	0.16
Cold Pressor Post	59.13 (37.47)	49.49 (40.83)	-
Hyperventilation Pre	119.57 (65.86)	115.40 (62.97)	-0.79
Hyperventilation Post	159.96 (79.58)	107.35 (64.24)	-
Mean SUDS Increase During Task (SD)			
Cold Pressor Pre	39.39 (23.51)	39.80 (21.29)	0.09
Cold Pressor Post	38.17 (20.91)	39.08 (23.95)	-
Hyperventilation Pre	34.46 (17.80)	31.25 (21.40)	-0.31
Hyperventilation Post	29.57 (21.93)	33.02 (22.76)	-
Mean Mindfulness Use During Second Set of Distress Tasks (SD)			
Cold Pressor	4.05 (0.54)	2.94 (0.57)	-10.25**
Hyperventilation	3.91 (0.63)	2.82 (0.71)	-8.36**
Neutralization	3.67 (0.66)	3.00 (0.73)	-4.91**

Note. ** = $p < .01$; Difference in post-intervention variables across conditions not reported here, as the effect of condition was tested via regression, with results shown in the text and in Table 2. SUDS = subjective units of distress, range = 0-100; Mindfulness use was rated on a scale from 1 (not at all) to 5 (a lot).

(r = 0.17, p = 0.26). Mindfulness use among participants in the mindfulness condition was significantly associated with postrumination urge to neutralize (r = -0.34, p = 0.01), postneutralization urge (r = -0.34, p = .02), and postneutralization SUDS (r = -0.28, p = 0.046), but not postrumination SUDS (r = -0.17, p = 0.22). In addition, mindfulness use significantly predicted a lower likelihood of engaging in neutralization behavior (B = -0.23, SE = 0.12, p = 0.048, OR = 0.79).

TASK PERSISTENCE

Results of the hierarchical linear regression examining the effect of condition, FFMQ, and their interaction on task persistence for the cold pressor and hyperventilation challenge can be seen in Table 2. Graphical representation of mean task persistence for both tasks across groups and time points can be seen in Figure 1, with values reported in Table 1.

Cold Pressor
Seventeen participants were eliminated from the analysis because they reached the cutoff point (180 seconds) during the pre-intervention task, leaving 90 participants for the analysis. There was no difference in FFMQ, anxiety, depression, or stress scores between participants who were excluded from the analyses and those who did not (ps > 0.24). Results of the regression analysis can be seen in Table 2. Controlling for gender, pre-intervention task persistence, and trait mindfulness, the effect of condition on post-intervention task persistence did not reach significance (B = 10.09, SE = 5.98, p = 0.09, sr^2 = 0.017), though results were in the expected direction such that those in the mindfulness condition persisted longer than those in the control condition. The squared semi-partial correlation indicated that this effect was relatively small, with

condition accounting for an additional 1.6% of variance in post-intervention task persistence on the cold pressor. Neither the main effect of FFMQ or the condition by FFMQ interaction were significant.

Hyperventilation Challenge
Thirteen participants were eliminated from the analysis because they reached the cutoff point (300 seconds) during the pre-intervention task, leaving 94 participants for the analysis. Similar to the cold pressor, there was no difference in FFMQ, depression, anxiety or stress scores between participants excluded from the analyses and those were not (ps > 0.72), though a Fisher's Exact Test revealed that participants who persisted until the cutoff for the hyperventilation challenge at pre-intervention were significantly more likely to have done the same for the cold pressor (p = 0.032, OR = 4.32, 95% CI = 1.20 to 15.22).

Paired samples t-tests demonstrated that there were no significant differences in tidal volume during the hyperventilation challenge from pre- to post-intervention for either mindfulness, $t(46)$ = 1.45, p = 0.15, d = 0.22, or control, $t(48)$ = 1.04, p = 0.30, d = 0.16, participants. Furthermore, an independent samples t-test demonstrated that there was no difference in the ratio of tidal volume pre- to post-intervention between the mindfulness and control conditions, $t(92)$ = -1.48, p = 0.14, d = 0.31. Nonetheless, pre-post tidal volume ratio was included as a covariate for all analyses of the hyperventilation challenge.

Results of the hierarchical linear regression in Table 2 indicate that condition had a significant effect on task persistence after controlling for pre-intervention persistence, gender, tidal volume ratio, and FFMQ. Specifically, participants receiving mindfulness training persisted longer than those in

Table 2
Hierarchical Linear Regression Examining the Effect of Condition, Trait Mindfulness, and Their Interaction on Task Persistence

Outcome	Step	Predictors	ΔR^2	B	SE B	β
	1.	Persistence pre-intervention	.695**	.836	.094	.686**
		Gender		-10.67	6.61	-.125
	2.	Condition	.036*	10.09	5.98	.128[+]
		FFMQ		-.360	.205	-.134[+]
Cold Pressor Persistence (post-intervention)	3.	Condition x FFMQ	.008	-.494	.419	-.797
	1.	Persistence Pre-Intervention		.707	.102	.593**
		Gender	.349**	-16.20	13.23	-.078
		Tidal Volume Ratio		1.058	16.26	.053
Hyperventilation Persistence (post-intervention)	2.	Condition	.110**	50.99	12.12	.667**
		FFMQ		.158	.409	.002
	3.	Condition x FFMQ	.022[+]	-1.55	.806	-.020[+]

Note. [+] = p < .10, * = p < .05; ** = p < .01; Gender coded female = 0, male = 1; Condition coded 0 = control, 1 = mindfulness; FFMQ = Five Facet Mindfulness Questionnaire.
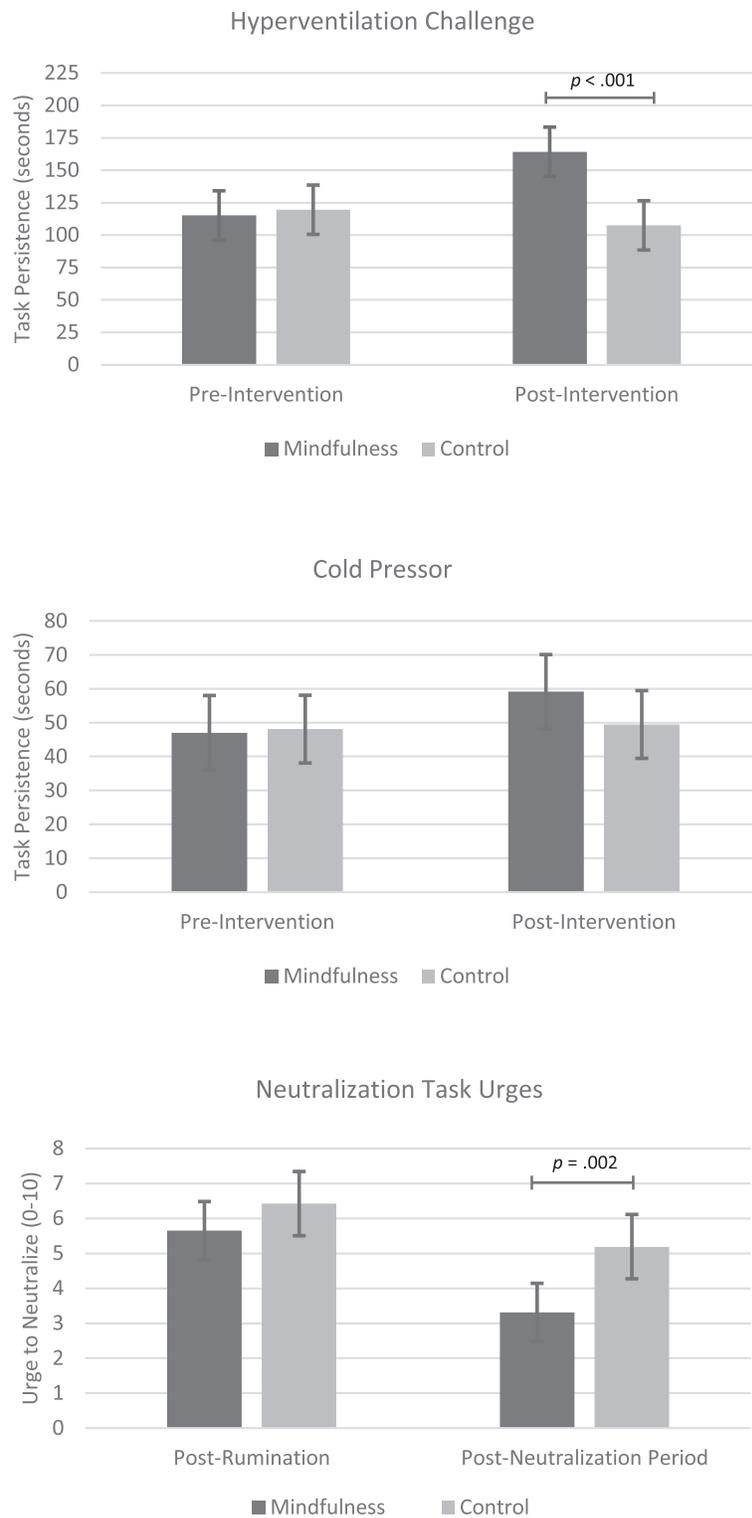
FIGURE 1   Group means for task persistence pre- and post-intervention for the hyperventilation challenge and cold pressor, and urge to neutralize after rumination and neutralization periods on the neutralization task. Error bars represent 95% confidence intervals. *p* values correspond to the Beta statistic in the regression models in Tables 2 and 3, representing the effect of condition on the each outcome controlling for gender and FFMQ (all tasks), baseline task performance (cold pressor and hyperventilation), and tidal volume ratio (hyperventilation only).

the control condition (B = 61.34, SE = 12.10, p < 0.001). The squared semi-partial correlation coefficient indicated that the effect of condition uniquely accounted 10.9% of variance in post-intervention task persistence during hyperventilation. There was no main effect of FFMQ, and the interaction between FFMQ and condition approached but did not reach significance (B = -1.55, SE = .81, p = 0.054). The direction of this effect was such that greater FFMQ resulted in a smaller effect of mindfulness training on task persistence compared to the no instructions control. The squared semi-partial correlation coefficient indicated that this effect accounted for 2.2% of unique variance in task persistence.

Separate exploratory analyses examining moderator effects of each FFMQ subscale revealed a significant effect of the interaction between condition and FFMQ-Act with Awareness (B = -4.58, SE = 2.30, p = 0.047), accounting for 2.3% of the variance in task persistence. There was a trend toward significance for the interaction of condition with FFMQ-Nonreact (B = -5.90, SE = 3.14, p = 0.06, sr^2 = 0.021) and FFMQ-Nonjudge (B = -3.67, SE = 1.90, p = 0.06, sr^2 = 0.022), whereas interactions with FFMQ-Observe (B = 3.80, SE = 3.03, p = 0.21, sr^2 = 0.00) and FFMQ-Describe (B = -.095, SE = 2.38, p = 0.97, sr^2 = 0.01) were not significant.

SUBJECTIVE DISTRESS

Results of the hierarchical linear regressions examining SUDS as the dependent variable were equivalent for both distress tasks. Specifically, no effect of condition was seen for cold pressor (B = -1.98, SE = 3.78, p = 0.91, sr^2 = 0.00) or hyperventilation (B = -5.07, SE = 4.15, p = 0.22, sr^2 = 0.00) when controlling for gender, pre-intervention distress, and,

in the case of hyperventilation, tidal volume ratio. Similar to the task persistence results, the main effect of FFMQ and the interaction of FFMQ and condition were nonsignificant for both the cold pressor (p > 0.30) and hyperventilation challenge (p > 0.50).

NEUTRALIZATION TASK

Means and standard deviations of SUDS ratings and urges to neutralize postrumination and post-neutralization for mindfulness and control groups are reported in Table 3. Also included are results of the main effects of condition and FFMQ in the regression models predicting each of the four continuous outcomes used in the task. No effect of condition was seen on SUDS change at either time point, or on postrumination neutralization urges. However, FFMQ significantly predicted postrumination and postneutralization SUDS, such that greater FFMQ was associated with a lower SUDS at both time points. In addition, there were significant main effects of condition and FFMQ on postneutralization urges to neutralize, such that greater FFMQ and being in the mindfulness condition predicted significantly weaker urges after the one minute neutralization period. Semi-partial correlation coefficients signified that condition uniquely accounted for 8.7% and FFMQ uniquely accounted for 4.6% of postneutralization urges. There were no significant interaction effects of FFMQ and condition (all p's > 0.10).

With regard to neutralization behavior, 75.2% of participants reported engaging in at least one of the prespecified neutralization behaviors. The most common behavior was to visualize the accident but with a more positive or neutral outcome, a strategy endorsed by 37.7% of the participants. This was followed by destroying or altering the

Table 3
Means and SDs of Neutralization Task Outcomes by Condition, and Prediction of Outcomes by Condition and Trait Mindfulness

Outcome	Mindfulness (SD)	Relaxation (SD)	Regression Analyses				
			Predictor	B	SE B	β	sr^2.
Post-rumination SUDS[a]	28.21 (21.97)	23.87 (23.01)	Condition	.727	4.39	.015	.001
			FFMQ	-.310	.144	-.188*	.032
Post-neutralization period SUDS[a]	6.54 (12.85)	4.81 (16.58)	Condition	-1.20	2.86	.061	.001
			FFMQ	-.213	0.94	-.171*	.028
Post-rumination urges[b]	5.65 (3.04)	6.42 (3.24)	Condition	-.773	.611	-.123	.015
			FFMQ	-.020	.021	-.094	.008
Post-neutralization period urges[b]	3.31 (2.91)	5.19 (3.44)	Condition	-1.96	.603	-.298**	.087
			FFMQ	-.048	.020	-.218*	.046

Note. * = p < .05; ** = p < .01; sr^2 = squared semi-partial correlation coefficient; [a] = Regression analyses reflect prediction of outcome controlling for pre-task SUDS and gender; [b] = Regression analyses reflect prediction of outcome controlling for gender; SUDS = subjective units of distress, range = 0-100; Urges scale range = 0-10; Condition coded 0 = control, 1 = mindfulness; FFMQ = Five Facet Mindfulness Questionnaire.

sentence (24.5%), turning over or concealing the paper (21.7%), carrying out a superstitious act (13.2%), and using a religious strategy (5.7%). Logistic regression results showed no effect of condition on the likelihood of engaging in neutralization behavior (OR = 1.22, 95% CI = 0.50 to 2.97, Wald = 0.19, $p > 0.10$).

MEDIATION ANALYSES

To examine whether self-reported mindfulness use accounts for effects of our mindfulness manipulation, we conducted mediation analyses on outcomes that either approached or reached significance (i.e., task persistence on the cold pressor and hyperventilation challenge, and postneutralization urges to neutralize). Given the preliminary nature of our mindfulness use questions, we also conducted exploratory mediation analyses of the individual items that correspond to the facets of mindfulness in the FFMQ, reporting results where significant.

For the cold pressor task, although the direct effect of condition on task persistence did not reach significance ($p = 0.09$, reported above), there was a significant indirect effect through self-reported mindfulness use during the task (B = 11.18, $SE =$ 4.64, 95% CI = 2.90 to 20.86). Exploratory mediation analyses with individual mindfulness use items revealed that this effect was the result of the *Nonreact* and *Nonjudge* items, as there was a significant indirect effect of condition on cold pressor task through *Nonreact* (B = 5.37, $SE =$ 2.66, 95% CI = 0.95 to 11.25) and *Nonjudge* (B = 6.63, $SE =$ 3.61, 95% CI = 0.42 to 14.63; see Figure 2). For the neutralization task, the indirect effect of condition on postneutralization urges to

neutralize through total mindfulness use during the task was not significant (B = -0.44, $SE =$ 0.34, 95% CI = -1.16 to 0.22). However, there was a similar pattern of results to the cold pressor in that the indirect effects through the individual *Nonreact* (B = -0.64, $SE =$ 0.30, 95% CI = -1.27 to -0.09) and *Nonjudge* (B = -1.02, $SE =$ 0.38, 95% CI = -1.85 to -0.35) items were significant (see Figure 2). No significant indirect effect of condition on hyperventilation task persistence through mindfulness use was found for the total scale (B = 2.08, $SE =$ 10.28, 95% CI = -17.07 to 24.35) or individual items.

Discussion

The goal of the present study was to examine the effect of a brief mindfulness training on task persistence and subjective distress in a series of DT tasks. We also sought to examine whether individuals who were higher in trait mindfulness would benefit more from such an intervention. Results showed that relative to a no-instructions control that included listening to relaxing music, mindfulness training significantly improved participants' persistence on the hyperventilation challenge but not the cold pressor. Furthermore, mindfulness training was associated with a decreased urge to neutralize the effects of writing a sentence about a loved one being in a car accident. The effect of mindfulness training on task persistence and decreased neutralization urges did not extend to subjective distress for any of the measures, though trait mindfulness did significantly predict reduced distress in response to the neutralization task.

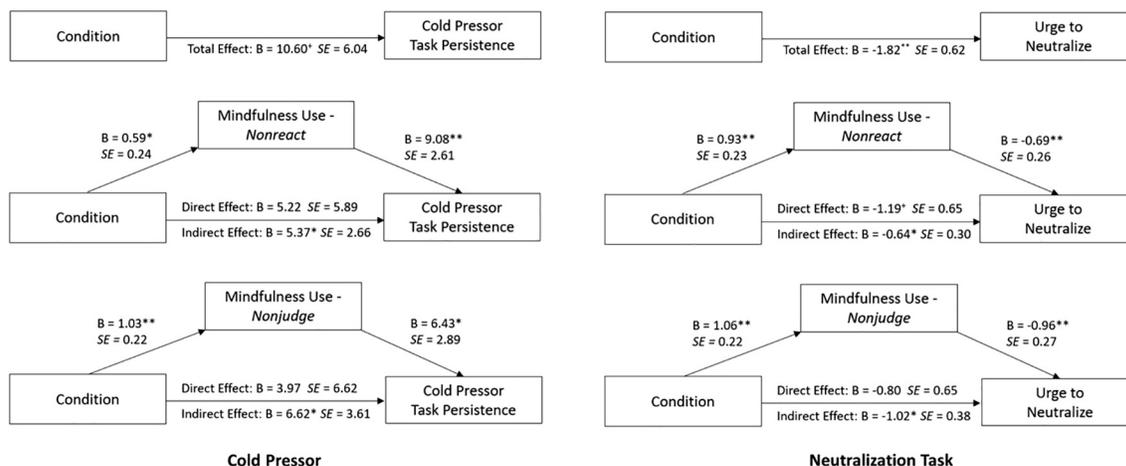This study built upon the previous literature by using several distress-tolerance-related outcomes

FIGURE 2 Mediation of the effect of condition on cold pressor task persistence (*left*) and urge to neutralize (*right*) through the *Nonreact* and *Nonjudge* mindfulness use items. Regression coefficients represent unstandardized values controlling for pre-intervention task persistence (cold pressor only) and gender. Condition coded 0 = control, 1 = mindfulness. $^+$ $p < 0.10$, * $p < 0.05$, $p < 0.01$.

that have not previously been examined in the context of a mindfulness intervention. Regarding the hyperventilation challenge, for instance, it has been demonstrated that trait mindfulness significantly predicts task persistence (Arch & Craske, 2010), and that a brief present-moment awareness training negates the impact of low self-reported DT on subjective distress (Paz et al., 2017). However, this is the first study to show that experimentally manipulating mindfulness improves behavioral DT. With regard to the neutralization task, Macatee and Cougle (2015) showed reductions in neutralization urges as a result of two 1-hour sessions that involved psychoeducation, progressive muscle relaxation, and imaginal emotion exposure. The present study showed similar effects on neutralization urges with a single 15-minute mindfulness intervention. Notably, the intervention used by Macatee and Cougle also encouraged participants to take an accepting stance toward distress, but given the number of other components of the intervention, it is difficult to know what the active ingredient may have been.

The effects of mindfulness on the hyperventilation challenge and neutralization task are clinically relevant given that performance on such tasks correlates with symptoms of psychopathology (Cougle et al., 2011; Cougle et al., 2013; Marshall et al., 2008), and because the nature of the tasks maps on quite closely to procedures used in exposure therapy. For instance, hyperventilation is frequently employed as an interoceptive exposure technique in the treatment of panic disorder. Intentionally eliciting sensations of physical distress associated with anxiety (e.g., increased heart rate, shortness of breath) allows patients to learn that such symptoms do not lead to the disastrous consequences that they expect. In obsessive-compulsive disorder, individuals often feel that having a thought about a negative outcome means that such an outcome will occur, and thereby attempt to neutralize the effects of the thought with compulsive behavior. Exposures are used so that patients can learn that compulsions are not necessary to prevent such negative outcomes. For both types of exposures, however, the willingness to tolerate distress is essential in order for the patient to adequately learn that their feared consequence will not occur. Given the impact of mindfulness on DT shown in the present study, mindfulness training may positively impact exposure therapy by helping individuals engage in more effective exposures. This idea is also supported by research showing mindfulness-based strategies during exposure are associated with declining distress levels (Brake et al., 2016), and that changes in mindful

nonreactivity mediate the effect of exposure therapy on health anxiety (Hedman, Hesser, Andersson, Axelsson, & Ljótsson, 2017). Beyond these two studies, however, there is little research directly examining how mindfulness may impact exposure (Treanor, 2011). The clinical applicability of such a question makes it an important direction for future investigation.

The present study also provides preliminary insight into the extent to which trait mindfulness moderates the effect of mindfulness training on interoceptive distress. Although the moderating effect of overall trait mindfulness on condition did not reach significance ($p = 0.05$), exploratory analyses revealed that the *Act with Awareness* facet of the FFMQ did significantly impact the effect of condition on task persistence in the hyperventilation challenge. Prior research examining the impact of trait mindfulness on improvements from mindfulness training has shown variable results (e.g., Greeson et al., 2015; Keng et al., 2015; Shapiro et al., 2011), but has largely focused on trait mindfulness as a unitary construct. We observed that individuals who tend to be less aware of their present-moment experiences and actions had the greatest improvements on task persistence following mindfulness training. Of note, moderator effects for the Nonjudgment and Nonreactivity facets fell just outside of significance (both p's = 0.06), but had similar effect sizes to Act with Awareness, and may be similarly relevant in identifying who is most likely to benefit from mindfulness training on the hyperventilation challenge. Although conclusions should be considered tentative at this point given the exploratory nature of the analyses, these findings warrant further research.

The fact that mindfulness training did not significantly impact distress levels on any of the tasks or task persistence in the cold pressor is contrary to our hypothesis and previous research using the cold pressor task (Liu et al., 2013; Masedo & Esteve, 2007). One important difference of the present study is that participants completed a series of distress tasks, whereas the studies of Masedo and Esteve and Liu et al. just used the cold pressor. Given the varying nature of the tasks, it may have been more difficult to successfully apply mindfulness strategies to all tasks, limiting their effects on distress ratings. This also could explain why effect sizes were strongest for the hyperventilation challenge. During the mindfulness training, participants were encouraged to practice taking a nonjudgmental attitude toward the sensations that arose when holding their breath, and also were encouraged to focus on the breath during a meditation. The instruction of mindfulness techniques in the context of breathing-related activities may have

made it easier to apply such techniques to hyperventilation, whereas participants were less successful at utilizing mindfulness for the cold pressor. The idea that unfamiliarity with applying mindfulness techniques to the distress experience in a particular task is supported by the results of Evans and colleagues (2014), who found that minimal instructions and no practice in the use of mindfulness strategies led to worse distress tolerance outcomes on the cold pressor compared to a control condition. It is also possible, however, that mindfulness has differential effects on increasing tolerance of the temperature-related pain involved in the cold pressor compared to the hyperventilation-induced interoceptive distress most closely associated with anxiety. Meta-analytic research, for instance, has shown that of the many outcomes that mindfulness interventions have been shown to improve, the largest effect sizes are seen on symptoms of anxiety, while the smallest are seen for pain (Khoury et al., 2013).

It should be noted that the differential effect of mindfulness training on task persistence and not self-reported distress in this study is consistent with the conceptualization of mindfulness as fostering an ability to respond differently to distress, even if the actual experience of distress cannot be directly altered (Bishop et al., 2004; Kabat-Zinn, 1990). This idea may be particularly applicable to novices to mindfulness training, which were used in this study, as research suggests that the effects of mindfulness differ with varying degrees of experience (Zeidan, 2014). It is possible that the small dose of mindfulness training was sufficient to improve participants' goal-directed behavior in the context of distress, but not to change their subjective evaluations of what they were experiencing.

An important question regarding the results of this study is whether the use of mindfulness skills was responsible for improved DT on the experimental tasks. Although our comparison condition controlled for practice effects on the cold pressor and hyperventilation tasks, as well as the effect of time and feelings of relaxation resulting from the mindfulness meditation, it did not involve explicit instructions for how to respond to distress during the second set of tasks. We elected for such a comparison condition so that participants would employ whichever regulation strategies they naturally use to handle distress. This allowed moderation analyses to test who benefits from mindfulness compared to natural coping, rather than an arbitrary strategy that participants might not normally employ.

A limitation of this design is that we cannot completely rule out the possibility that expectancy effects resulting from employing a strategy for responding to distress, rather than mindfulness skills

themselves, accounted for improvements seen in DT. Use of an active control condition such as reappraisal or suppression could have provided clarity regarding this issue. However, our manipulation checks suggest that participants successfully comprehended the key points of the mindfulness training, and those receiving the training endorsed greater use of mindfulness skills during the distress tasks compared to the control group. Most importantly, mindfulness use during the cold pressor and neutralization tasks, specifically the use of *Nonreact* and *Nonjudge* skills, significantly mediated the effect of condition on DT outcomes. This finding is consistent with the emphasis placed on acceptance in the mindfulness intervention. Although such results did not extend to hyperventilation outcomes and were based on a novel measure of mindfulness use that has not previously been validated, they suggest that effects seen in this study were at least partly a result of mindfulness strategies. Future research would benefit from further validation and refinement of such a brief assessment of mindfulness use, and exploration of the roles of the *Nonreact* and *Nonjudge* aspects of mindfulness as mechanisms for improvements in DT. This could be particularly fruitful in the context of research suggesting that the benefits of facets of mindfulness, like observing and acting with awareness, may depend on the presence of sufficient levels of nonjudgment and nonreactivity (Eisenlohr-Moul, Walsh, Charnigo, Lynam, & Baer, 2012; Peters, Eisenlohr-Moul, Upton, & Baer, 2013).

Other limitations to this study include that it was conducted with an unselected undergraduate sample. Whether these results generalize to other samples, particularly clinical populations, remains to be tested. Second, given the number of tasks that participants had to complete over the course of the experiment, there may have been an effect of fatigue on participants' behavior and subjective distress. Research has shown that performance on tasks requiring a substantial degree of self-control declines over time (Hagger, Wood, Stiff, & Chatzisarantis, 2010). We included a 2-minute rest interval between each task to reduce the effect of such self-control fatigue, but the combined effort exerted throughout the experiment may have decreased participants' willingness or ability to use strategies to help tolerate distress. A final limitation is that because we only asked about mindfulness use after distress tasks, we were unable to determine what other coping strategies participants were using, which would have been particularly relevant for understanding the spontaneous coping used by participants in the no-instructions control condition. Future research could ask participants to rate the extent to which they used range of possible coping strategies, including

mindfulness, to provide a more specific comparison of mindfulness to other methods of regulating distress. Future research could also benefit from testing the use of brief mindfulness interventions on tolerance of other forms of distress (e.g., social stress) using paradigms such as the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993) or the Maastricht Acute Stress Test (Smeets et al., 2012).

CONCLUSIONS

Despite the limitations listed above, the results of the present study suggest that a brief mindfulness training can improve willingness to tolerate distress in a laboratory setting. Specifically, mindfulness was found to be helpful for increasing tolerance of interoceptive distress on the hyperventilation challenge, and for the urge to neutralize the effects of writing and thinking about an upsetting future event. In addition, we found preliminary evidence that individuals who tend to be less aware of their present-moment experiences may benefit more from mindfulness training on the hyperventilation challenge. Future research should build upon such findings with clinical populations and examine whether mindfulness training has the potential to increase tolerance of distress in the context of therapeutic interventions.

Conflict of Interest Statement

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