



SHORT COMMUNICATION

# Trait mindfulness modulates neuroendocrine and affective responses to social evaluative threat

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Received 23 November 2011; received in revised form 6 April 2012; accepted 9 April 2012

## KEYWORDS

Mindfulness;  
Stress buffering  
hypothesis;  
Social evaluative threat;  
Trier Social Stress Test

## Summary

**Background:** Individual differences in mindfulness have been associated with numerous self-report indicators of stress, but research has not examined how mindfulness may buffer neuroendocrine and psychological stress responses under controlled laboratory conditions. The present study investigated the role of trait mindfulness in buffering cortisol and affective responses to a social evaluative stress challenge versus a control task.

**Methods:** Participants completed measures of trait mindfulness, perceived stress, anxiety, and fear of negative evaluation before being randomized to complete the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) or a control task. At points throughout the session, participants provided five saliva samples to assess cortisol response patterns, and completed four self-report measures of anxiety and negative affect to assess psychological responses.

**Results:** In accord with hypotheses, higher trait mindfulness predicted lower cortisol responses to the TSST, relative to the control task, as well as lower anxiety and negative affect. These relations remained significant when controlling for the role of other variables that predicted cortisol and affective responses.

**Conclusions:** The findings suggest that trait mindfulness modulates cortisol and affective responses to an acute social stressor. Further research is needed to understand the neural pathways through which mindfulness impacts these responses.

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Accumulating evidence has linked mindfulness interventions with improved health-relevant outcomes in at-risk patient populations, including lower diurnal cortisol levels among individuals with cancer (Carlson et al., 2007). Yet little is

known about the underlying mechanisms linking mindfulness with health improvements. One prominent explanation for the effects is the stress–buffering hypothesis (e.g., Cohen and Edwards, 1989). Largely studied in a social support context, this hypothesis also offers that psychological resiliency factors, like mindfulness, offer protection against the pathogenic effects of stressful events but will not confer additional health benefits in the absence of stress. Correlational studies have shown that mindful individuals report fewer stress symptoms (e.g., Brown and Ryan, 2003), but

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no studies have directly tested the stress–buffering role of mindfulness under controlled laboratory conditions.

Mindfulness concerns a sustained, receptive attention to what is taking place in the present (Brown and Ryan, 2003). The present study tested whether individual differences in mindfulness moderate neuroendocrine and psychological responses to social evaluative threat in the Trier Social Stress Task (TSST; Kirschbaum et al., 1993). Social evaluative stress reliably impacts health-relevant biological responses, including hypothalamic–pituitary–adrenal (HPA) axis activation (Dickerson and Kemeny, 2004). In testing the mindfulness stress–buffering hypothesis, we predicted that those higher in mindfulness would show lower salivary cortisol and psychological stress responses to the TSST, relative to a control task. Several stress regulatory traits have been inversely associated with mindfulness, including perceived stress, generalized anxiety, negative affectivity, and social anxiety (Brown and Ryan, 2003). Social anxiety has also been associated with TSST responses (Dickerson and Kemeny, 2004). Thus secondary analyses tested whether dispositional mindfulness is associated with TSST responses while controlling for these four traits.

## 1. Methods

### 1.1. Participants

Participants were 44 undergraduate students ( $n = 36$  female) at a Northeastern university who earned research participation credit. Their average age was 19.68 years ( $SD = 1.36$ ). Most (77.3%) were Caucasian; the remainder were Asian (9.1%), African American (2.3%), Native American (2.3%) or another race/ethnicity (9.1%). Participants were excluded if they self-reported health conditions (e.g., high blood pressure), health habits (e.g., regular cigarette or illicit drug use), or prescription drug use (e.g., antidepressants) that could affect their stress responsiveness. Participants were asked not to engage in strenuous exercise, drink alcohol, or smoke on the day of their appointment, and to not consume dairy products, caffeine, or eat within 1 h of the laboratory session (Kudielka et al., 2009).

### 1.2. Procedure

Prior to the laboratory session, participants completed a questionnaire battery (see Section 1.3 below). To control for diurnal cortisol variation, all laboratory sessions were completed on weekdays between 2 pm and 7 pm. Baseline salivary cortisol and self-reported state negative affectivity and state anxiety were first collected 5–10 min after laboratory arrival. Participants were then randomly assigned to either the TSST or a control task condition. Following standard TSST procedures, participants in this condition spent 5 min mentally preparing a 5-min speech before delivering it to a panel of two critical peer evaluators. Participants then performed a mathematical subtraction task before the same critical evaluators. Control condition participants performed the same tasks alone into a tape recorder (i.e., without social evaluation). At standardized intervals over the next 45 min, saliva samples and affect measures were collected while participants rested (see Section 1.4 below). A full debriefing followed the final data collection.

## 1.3. Dispositional measures

### 1.3.1. Mindfulness

The 15-item Mindful Attention Awareness Scale (MAAS; Brown and Ryan, 2003) assessed the frequency of open attentiveness to and awareness of present events and experiences using a 6-point Likert scale (*almost always* to *almost never*). An example item is, “I find myself preoccupied with the future or the past.” Higher scores indicate higher mindfulness (sample  $\alpha = .95$ ).

### 1.3.2. Perceived stress

The 10-item version of the Perceived Stress Scale (PSS; Cohen et al., 1983) assessed the extent to which life situations are appraised as stressful ( $\alpha = .84$ ).

### 1.3.3. Anxiety

The 9-item Profile of Mood States anxiety subscale (POMS; McNair et al., 1971) assessed anxiety over the past week ( $\alpha = .93$ ), while the Taylor Manifest Anxiety Scale (TMAS; Taylor, 1953) measured anxiety symptoms in general ( $\alpha = .88$ ).

### 1.3.4. Negative affectivity

The Positive Affectivity Negative Affectivity Schedule (PANAS; Watson et al., 1988) assessed affective arousal over the past week ( $\alpha = .88$ ).

### 1.3.5. Fear of negative evaluation

The 12-item Fear of Negative Evaluation Scale (FNE; Leary, 1983) measured a form of social anxiety particularly relevant to the TSST environment ( $\alpha = .93$ ).

## 1.4. State measures

### 1.4.1. Salivary cortisol

Saliva samples were collected five times during the 90-min lab session to assess peak cortisol reactivity and recovery (Dickerson and Kemeny, 2004). Samples were collected via 2-min sublingual placement of synthetic Salivettes (Salimetrics, State College, PA) at baseline, immediately after the speech task (10 min from task onset), and 10, 20, and 35 min after the tasks (20, 30, and 45 min from task onset). After the session, samples were stored at  $-20^{\circ}\text{C}$  until entire-sample assay. Samples were then thawed and centrifuged for 15 min at  $1500 \times g$  at  $10^{\circ}\text{C}$ . Cortisol was assayed using the Salimetrics competitive immunoassay method. Inter-assay coefficient of variation (CV) was 6.69–6.88%, intra-assay CV was 3.88–7.12%, and the sensitivity was  $<0.007 \mu\text{g/dL}$ .

### 1.4.2. Anxiety

The POMS anxiety subscale assessed anxiety “currently” at baseline ( $\alpha = .88$ ), and at 10, 20, and 35 min after the tasks (20, 30, and 45 min from task onset).

### 1.4.3. Negative affectivity

The NA portion of the PANAS assessed negative affectivity “right now” (baseline  $\alpha = .87$ ) on the same assessment schedule as with POMS anxiety. Items on both scales had a unique random order at each assessment.

## 1.5. Statistical analyses

Analyses of the full repeated cortisol and affect outcomes were conducted using restricted maximum likelihood mixed models. Condition and individual difference measures were tested as main effects and in interaction with each other and with time (the latter as linear and curvilinear slopes). Participant gender, contraceptive use, session day waking time, session time, and number of previous night sleep hours were covaried in preliminary analyses. Due to positive skewness, cortisol values were log-transformed and state PANAS NA scores were square-root transformed.

## 2. Results

### 2.1. Preliminary analyses

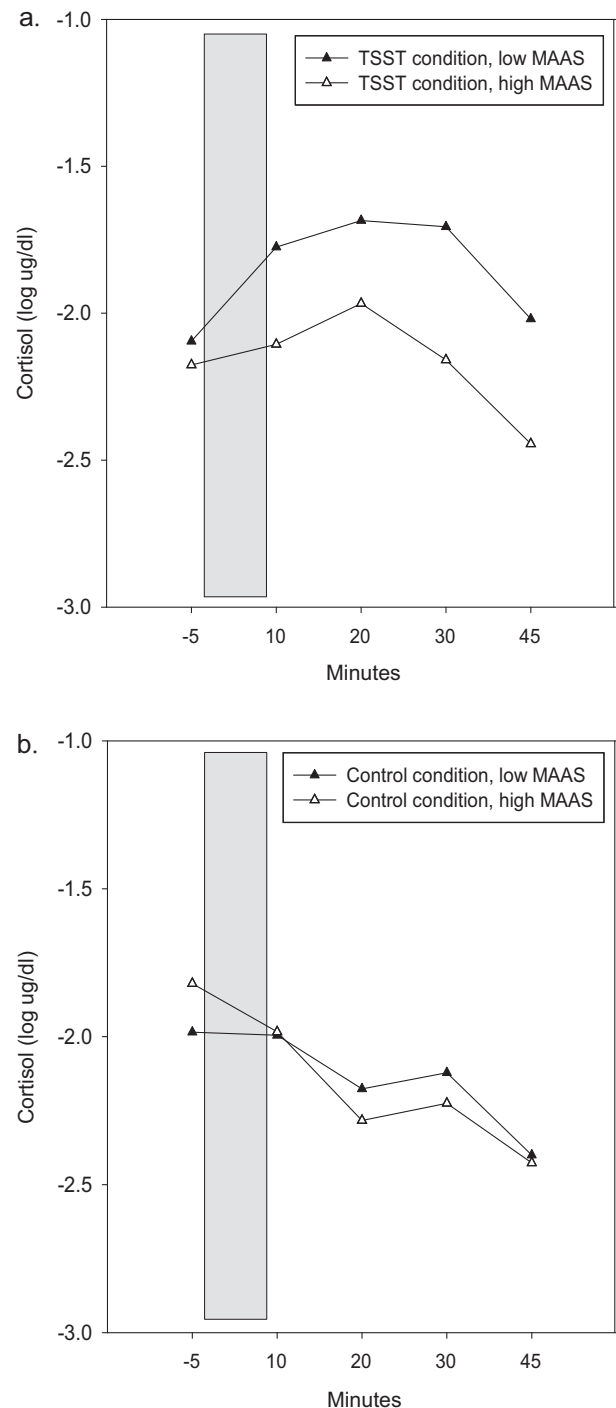
We first tested whether the TSST produced significant changes in cortisol and affective responses, relative to the control task. Mixed models revealed time<sup>2</sup> × condition interactions on all responses, such that significant curvilinear change (rise and fall) was observed in cortisol [ $F(1,168) = 5.12, p = .03$ ], PANAS NA [ $F(1,191) = 27.99, p < .0001$ ], and POMS anxiety [ $F(1,186) = 31.43, p < .0001$ ] in the TSST condition only. Thus, the TSST produced significant stress-related neuroendocrine and affective responses. Among the participant covariates, later session times predicted lower cortisol responses [ $F(1,41) = 9.31, p = .004$ ] and males reported higher NA [ $F(1,63) = 11.90, p = .001$ ] and anxiety [ $F(1,62) = 9.77, p = .003$ ]. These covariates were included in subsequent analyses of the relevant outcomes.

### 2.2. Primary analyses

The primary analyses examined whether mindfulness moderated the three response curves observed in the TSST relative to the control condition. In a mixed model predicting salivary cortisol response, a time<sup>2</sup> × condition × MAAS mindfulness interaction was observed [ $F(1,166) = 5.12, p = .02$ ], such that participants higher in mindfulness showed reduced cortisol responding in the social evaluative TSST condition (see Fig. 1a); mindfulness was not associated with cortisol responding in the control TSST condition (Fig. 1b). The same three-way interaction was observed in the models predicting NA [ $F(1,187) = 3.83, p = .05$ ; Fig. 2a and b] and marginally, anxiety [ $F(1,182) = 3.66, p = .06$ ; Fig. 2c and d]; higher mindfulness predicted lower affective responses.

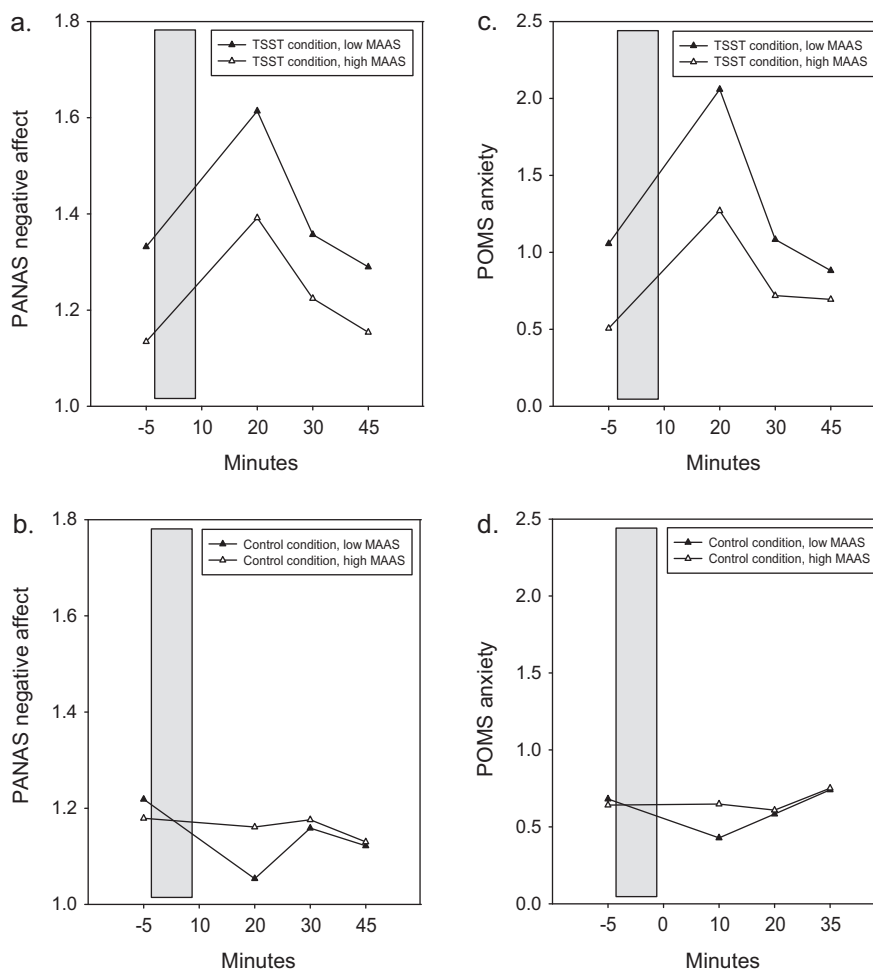
### 2.3. Secondary analyses

Among the non-mindfulness dispositional measures and the baseline affect measures, separate mixed model analyses showed that only dispositional fear of negative evaluation predicted cortisol responses [ $F(1,40) = 4.24, p = .05$ ]; those with lower scores showed elevated cortisol across conditions. However, controlling for this variable did not alter the already reported significant relation between mindfulness and cortisol responses ( $p = .03$ ). In the prediction of psychological responses, higher perceived stress [ $F(1,61) = 8.04, p = .006$ ], trait POMS anxiety [ $F(1,61) = 5.65, p = .02$ ], and trait manifest anxiety [ $F(1,61) = 8.10, p = .006$ ] predicted



**Figure 1** Mean salivary cortisol responses to the Trier Social Stress Test (a) and the control task (b) according to high and low mindfulness. *Notes.* Shaded bars indicate tasks period. MAAS = Mindful Attention Awareness Scale. MAAS scores were split at the median for graphical purposes; analyses were conducted using continuous scores.

higher state anxiety across conditions. In predicting NA responses over time, only main effects for perceived stress [ $F(1,62) = 7.42, p = .008$ ] and manifest anxiety [ $F(1,62) = 5.03, p = .03$ ] were found; those with higher trait scores reported higher NA across conditions. Controlling for



**Figure 2** Mean negative affect and anxiety responses to the Trier Social Stress Test (a and c, respectively) and the control task (b and d, respectively) according to high and low mindfulness. *Notes.* Shaded bars indicate tasks period. MAAS = Mindful Attention Awareness Scale; PANAS = Positive Affect Negative Affect Schedule; POMS = Profile of Mood States. MAAS scores were split at the median for graphical purposes; analyses were conducted using continuous scores.

these main effects did not substantially alter the time<sup>2</sup> × condition × mindfulness interaction in models predicting POMS anxiety ( $p = .05$ ) and NA ( $p = .05$ ).

Fig. 2a and c shows that mindfulness was related to anxiety and NA even at baseline. To confirm that the reported mindfulness – TSST affective response relations were not primarily determined by these baseline relations, a final set of analyses controlling for baseline affective responses showed a time × condition × mindfulness interaction in predicting anxiety ( $p = .05$ ) and a time<sup>2</sup> × condition × mindfulness interaction in predicting NA ( $p = .05$ ). The other dispositional measures showed no main or interaction effects in parallel models (all  $p > .17$ ).

### 3. Discussion

Consistent with the mindfulness stress–buffering hypothesis, this experiment found that cortisol responses to a social evaluative threat task was moderated by dispositional mindfulness, such that more mindful individuals showed an

attenuated cortisol response to the Trier Social Stress Test relative to a control task. Attenuations of emotional response – negative affect and anxiety – were also found among those higher in mindfulness. Several psychological traits in the general domain of stress, anxiety, and negative affect predicted cortisol and emotional responses, but the significantly lower cortisol and emotional responses among more mindful persons remained after controlling for these trait predictors.

This research suggests that mindfulness can buffer stress responding, and extends previous, self-report-based research by showing that mindfulness buffers neuroendocrine and affective responses to social evaluative stress. Interestingly, the lower negative affective responses to social evaluative threat among more mindful individuals was apparent even at baseline (see Fig. 2); however mindfulness predicted lower TSST affective responses after controlling for baseline affect, consistent with our buffering hypothesis.

Our findings compliment recent results showing lower autonomic stress reactivity to the TSST among participants receiving a mindfulness-integrated intervention (Kemeny

et al., 2011). Dispositional mindfulness has been associated with lower amygdala activation in response to socio-emotional threat (Creswell et al., 2007), and the amygdala is linked to the HPA axis via projections to the hypothalamus (Sullivan et al., 2004). Thus, mindfulness may impact stress-related cortisol secretion through attenuated amygdala response to threat. The present work provides initial indication for a neuroendocrine-mediated stress buffering mechanism linking mindfulness to improved physical health in stress-related disorders.

### 3.1. Limitations and future directions

A power analysis based on a large effect size for TSST cortisol increase ( $d = .92$ ; Dickerson and Kemeny, 2004), and the present multilevel modeling approach, indicated that the reported sample size was appropriate. But the comparatively small sample may have limited the potential for observing significant predictions among some control variables. However the stress buffering effects held when controlling for these study variables. Second, future research should control for rumination and other social anxiety indicators to rule out alternative interpretations of the findings, as both traits have been associated with both mindfulness (Brown and Ryan, 2003) and TSST cortisol responses (e.g., Zoccola et al., 2010). Third, replication in larger, non-college adult samples is needed before definitive conclusions can be drawn about mindfulness and social threat responses.

## 4. Conclusions

Neuroendocrine and other responses to psychosocial stress may be influenced in part by stable trait factors (Kudielka et al., 2009). The present findings support the importance of individual differences in stress-relevant contexts, and may be important for understanding long-term effects of mindfulness on responses to naturally occurring social stressors. Since acute social evaluative threats such as the TSST elicit physiological responses that can have deleterious health consequences when activated chronically, better understanding the protective role of mindfulness could translate into health benefits.

### Role of the funding source

This study was supported by award number UL1RR031990 from the National Center for Research Resources and NIH Roadmap for Medical Research, National Institutes of Health. The content of the manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the National Center for Research Resources, National Cancer Institute, or the National Institutes of Health.

The study sponsors had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the paper for publication.

## Conflict of interest

None declared.

## Acknowledgments

We thank Christopher Niemiec for assistance in collecting the data and Shirley Helm for conducting the cortisol assays. This study was supported by award number UL1RR031990 from the National Center for Research Resources and NIH Roadmap for Medical Research, National Institutes of Health.

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