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Abstract

It has been proposed that dispositional mindfulness and mindfulness meditation training helps individuals become more attentive and aware of their inner processes and behavior. Yet we know very little about how mindfulness training reduces stress and the underlying mechanisms for these effects. The present study investigated several mechanisms of mindfulness and stress reduction by conducting secondary data analyses on 3-day mindfulness training study that included a Trier Social Stress Test (TSST) stress reactivity session after the 3-day training. This previous study showed that brief mindfulness meditation training reduced psychological stress reactivity while increasing salivary cortisol to the TSST. In the present study, we coded behavioral emotion regulation responses (via recorded videos) to the TSST. We tested two competing accounts for how dispositional mindfulness and mindfulness training affect stress reactivity, comparing emotional reactivity (showing less negative affect) and emotional expression (showing less emotional suppression). Results supported the emotion expression account, a significant training condition × dispositional mindfulness interaction on anger to the TSST was observed ($\beta = 1.703$, $t(61) = 1.941$, $p = .057$). Specifically, participants higher in dispositional mindfulness, who had also received mindfulness training had the greatest response to the TSST. We also tested for other behavioral accounts, including anxiety, confidence, and overall speech rating, but did not find any significant effects for mindfulness training, dispositional mindfulness, and their interaction. We conclude that mindfulness meditation training fosters greater emotion-focused coping efforts through emotional expression, which can help buffer stress.

Mindfulness Meditation Training and Stress Reactivity: Behavioral Emotion Regulation Mechanisms

In recent years, much research has focused on the topic of mindfulness (Hochman, 2013). Mindfulness is defined as enhanced attention and awareness to one's present moment experience (Brown et al., 2007). The individual is aware (Grossman et al., 2011) of one's own thoughts, emotions, and body sensations, and what is happening in one's environment (Brown and Ryan, 2003). It has been proposed that mindfulness training helps individuals become more attentive and aware of their inner processes and behavior (Levitt et al., 2004) and fosters problem solving abilities allowing them to make better decisions (Ostafin and Kassman, 2012). This study aims to explore the mechanisms by which mindfulness meditation training reduces stress reactivity via changes in emotion regulation during the Trier Social Stress Test (TSST) (Kirschbaum et al., 1993).

Mindfulness training has been associated with a broad range of stress reduction effects. There is growing evidence that practicing mindfulness meditation can improve stress related disease outcomes (Kabat-Zinn, 1982; Bedard e al., 2003; Hofmann et al., 2010; Evans et al., 2008; Creswell et al., 2009). Studies indicate that an 8-week Mindfulness-Based Stress Reduction (MBSR) intervention has a beneficial effect for reducing stress reactivity (Hoge et al., 2013; Shapiro et al., 2011), reducing blood pressure reactivity to stress (Nyklíček et al., 2013), and decreasing the amount of pain sensitivity (Zeidan et al., 2010). Even brief mindfulness training is associated with reduced stress and pain reactivity. Brief mindfulness programs, usually three days of mindfulness meditation training, also show a reduction in stress reactivity (Creswell 2014), pain intensity associated with orbitofrontal cortex activation (Zeidan et al.,

2011), and negative mood (Zeidan et al., 2010). Also, evidence provides that self-reported dispositional mindfulness reduces psychological and physical stress reactivity to social stressors (Arche & Craske, 2010; Brown et al., 2012; Barnes et al., 2007; Skinner et al., 2008).

Despite this emerging evidence base, we know very little about how mindfulness training and dispositional mindfulness reduces stress. Thus, the present study investigated several purported mechanisms of mindfulness and stress reduction by conducting secondary data analyses on the Creswell et al. (2014) mindfulness training stress reactivity study. Specifically, this study had participants complete either three days of mindfulness meditation training (or an attention-matched control cognitive training). Immediately after the day 3 training, participants underwent the TSST. The results showed that brief mindfulness meditation training reduced psychological stress reactivity while increasing salivary cortisol reactivity to the TSST. The authors conclude that this may be due to the fact that mindfulness meditation training fosters greater active coping efforts, which reduces psychological stress appraisals but also increases cortisol reactivity (Creswell et al., 2014).

Previous reviews of the mindfulness literature suggest that mindfulness meditation reduces emotional reactivity. Mindfulness decreases the intensity of negative affect threatening stimuli (Arch & Craske, 2006; Creswell et al., 2007; Shapiro et al., 1998; Brown & Ryan, 2003). This may be due to the buffering of emotional reactivity through emotion regulation. Hence, emotion regulation may be an underlying mechanism for mindfulness training effects (Giese-Davis, et. al., 2012; Hayes & Feldman, 2006; Arch & Craske, 2006; Goldin & Gross, 2010; Chambers & Gullone, 2009). For example, Hayes and Feldman (2004) showed that mindfulness practice enhances emotional regulation by stabilizing emotions by either decreasing over-engagement with internal experiences like rumination, anxiety, or obsessions or decreasing

under-engagement like avoidance. Individuals high in mindfulness have also been shown to need less time to recover from negative emotional events (Kabat-Zinn, 1990). This facilitation of emotion regulation may be due to the fact that mindfulness fosters greater attention and acceptance of one's present experience, thus facilitating greater attention to one's feelings (Grossman & Van Dam, 2011; Brown & Ryan, 2003; Bishop et. al., 2004; Levit et. al., 2004).

Although previous accounts suggest that mindfulness may reduce negative affective reactivity, an alternative emotion regulation pathway has been offered (Britton et al., 2012; Goldin & Gross, 2010; Farb et al., 2007, Grant et al., 2011; Segal et al., 1999). Specifically, mindfulness may increase active emotion focused coping and emotional expression. This occurs when mindful individuals accept their current situation and accept their emotions instead of holding it back (Chambers et al., 2009). Indeed, previous studies show that suppressing emotions can increase sympathetic nervous system activity and poor coping outcomes. Previous studies dealing with cancer patients suggest that emotional suppression is maladaptive because it prohibits the acceptance of the present moment. Emotional suppression is associated with higher levels of self-reported distress (Classen, et. al., 1996), decreased positive emotions (Gross & Levenson, 1997), and a lower tolerance to pain (Elfant, et. al., 2008; Masedo & Esteve, 2007). When responding to social stressors, emotional expression facilitates more adaptability as it links mindfulness with fewer stress-related symptoms. This may be because mindfulness helps to tolerate anger states during anger-provoking stimuli (Weinstein et al., 2009; Chambers et al., 2009; Robins et al., 2012). Rather than avoiding this emotional effect, mindfulness enables one to notice the angered state and allows the individual to respond adaptively and overcome any behavioral problems that may arise (Baser, 2003; Wright, et. al., 2007). Thus, when an arising emotion occurs, individuals will begin to notice their thoughts and their current emotional state.

This may explain why Creswell's study showed an increased salivary cortisol response to the TSST for those in the mindfulness group while buffering psychological stress reactivity to a brief three-day mindfulness meditation training.

The present study tested these two competing emotion regulation accounts – does mindfulness training, dispositional mindfulness, or both, reduce emotional reactivity (show less negative affect) or increase emotional expression (reduce emotional suppression) under stress? Moreover, do these emotion effects mediate the effects of mindfulness training on altering psychological and neuroendocrine stress reactivity to the TSST? We tested these competing accounts with measures of coded anger and anxiety behaviors during the TSST. Specifically, the emotional reactivity account predicts an increase in emotional buffering and the emotional expression account predicts an increase in emotional expression [for fear and anxiety]. Moreover, we tested whether mindfulness training and dispositional mindfulness increased behavioral measures of confidence and speech quality during the TSST.

Method

Participants

Seventy-three (n=73) healthy male and female students (59% Male) from university campuses around Pittsburgh with an average age of 21.7 years old (SD = 2.91) participated in either a 3-day mindfulness meditation training or an attention training program. Participants identified themselves as Caucasian (33.3%), African American (4.5%), Asian American (31.8%), Latino (9.1%), and Others (21.2%). Participants were excluded from the study if they could not speak English, were not between the ages of 18 to 30 years of age, or used oral contraceptives like birth control. Three participants discontinued the study, three participants were excluded due

to outlier dispositional mindfulness scores, and one participant was excluded for being administered the wrong study condition. Thus, a total of 66 participants were analyzed.

Procedure

Participants were informed to partake in an attention training study consisting of three separate sessions for three consecutive days. For all three days, participants completed a variety of questionnaires regarding current mood and thoughts followed by an attention training exercise. Participants were randomly assigned to either a three-day mindfulness meditation training or a three-day analytic attention training for about 25 minutes each. After the audio training session, participants completed another questionnaire assessing their current mood and thoughts. The only difference from Day 1 and Day 2 was that on the second day, physiological sensors and a blood pressure cuff was applied upon their arrival. On the third day, four cortisol samples were also taken, and they completed a challenging social evaluative stress task (the TSST) following the mindfulness meditation or cognitive training session. For the challenging social evaluative stress task (TSST), participants first completed a 5-minute speech addressing why one would be a good administrative assistant for the psychology department followed by a 5-minute difficult calculation task (counting backwards from 2083 by 17's) in front of two evaluators who were trained to act in a cold and non-accepting manner during the whole performance task. For the present study, we collected videos of the participant's face during the TSST to examine how people's emotional responses are associated with stress response.

Dependent Measures

For all three days, participants filled out questionnaires about their current thoughts and feelings. During the second and third day of the attention study, physiological information was

collected. We hypothesized that mindfulness meditation reduced stress response through the use of several physiological measures, including heart rate, blood pressure, and cortisol levels.

To evaluate emotion processing effects, we developed a coding manual for assessing behaviors during the speech and math performance tasks of the TSST, which included measures of anger, anxiety, and confidence displays (see Behavioral Coding below). The overall quality of the speech was rated as well.

Interventions

Both attention training exercises were administered by having participants listen to audio files (via headphones) in the laboratory. The experimenter was blinded to the conditions by labeling conditions as either "1" or "2". All audio training sessions were 25 minutes each for three sessions. Details of the training interventions are provided in Creswell et al., 2014.

For the mindfulness meditation training exercise, participants learned how to foster attention and awareness to the present moment. The first session taught them focus around breathe awareness, and the second session progressed to a full body awareness. In the third session, participants practiced both breathe and body awareness along with emotional and thought awareness.

For the analytic attention control attention training, participants developed an analytical focus for effective problem-solving. For all three sessions, participants listened to a series of poetry and were told to analyze the poem. Participants were asked to notice the structure and imagery of the poems and later evolved to analyzing the deeper meaning and well as symbolism on the final session.

Behavioral Coding

There were a total of 64 videos that were content coded by three trained coders. Two videos were excluded because they did not contain any video files due to battery shortage or full memory card that occurred during the performance task. For each video, the coders made one scale rating for the speech task and another for the calculation task, which were then averaged together. All the coders were blind to the participants' conditions. Three coders completed the video coding and coded for the same behaviors. The coders were trained using a detailed behavioral coding manual, which provided instructions on the specific types of behaviors to look for and how to rate each video. They were trained to make ratings that were objective and unbiased. The behavioral coding was based on the frequency of the occurrences on a 7-point scale (1 = *not at all* to 7 = *most of the time*). The coders were trained to look for behaviors consisting of anger, anxiety, and confidence.

Several specific actions for the individual behaviors include:

1. Anxiety: lack of eye contact, shortness of breath, licking or biting lip, sweating, fidgeting, stuttering, bold and steady voice
2. Confidence: straight posture, strong and clear voice, consistent eye contact, not fidgeting
3. Anger: glaring, tightening of muscles, red face, huffing and sighing, rolling of eyes, shaking of head in disagreement, using sarcasm

An additional variable that we looked at was the overall speech quality of the participant. Coders made ratings based if the participant could be a good candidate for the administrative assistant position. Using the transcribed speeches, coders rated the content of the speech itself on a 7-point scale (1 = *not at all qualified* to 7 = *highly qualified*). Specific signs for a highly qualified speech include statements describing relevant skills and experiences (e.g. experience with data analysis, collaborating with faculty members, good organizational and leadership

abilities), minimal statements of irrelevance, and how convincing they provided the case ("I am very qualified for this position").

To improve inter-rater reliability, the coders were first trained how to code the videos by using practice videos and transcripts, and discrepancies were discussed verbally until agreement was reached. The final inter-rater reliability for all the videos showed high agreement for the speech task and calculation task for anxiety (89-93% agreement), confidence (88-89% agreement), anger (89-91% agreement), suggesting that the coding was highly reliable between all three coders. After finding a high percentage of agreement for all the coding categories, two of the three coders were randomly assigned to code each video. The two scores were then averaged for the behaviors, and this average was used for the final data analyses.

Results

In our previous study, Creswell and colleagues (2014) reported a significant training condition x dispositional mindfulness interaction (β= 1.89, $t(4) = 2.02$, $p = .048$) on psychological stress reactivity to the TSST with training expectancy (expectancies about the perceived benefits of the attention training) as a covariate. Specifically, participants who either received the mindfulness meditation training or who had high dispositional mindfulness (or who received the mindfulness meditation training and were high in dispositional mindfulness) showed lowered psychological stress reactivity, as shown in Figure 1. Additionally, this study also reported a significant interaction for training condition x dispositional mindfulness on area-under-the-curve (AUC) cortisol reactivity to the TSST (β=-1.85, $t(4) = -1.97$, $p = .05$) controlling for training expectancy. Figure 2 shows participants with low dispositional mindfulness, who had received mindfulness training, had the highest salivary cortisol response to the TSST. The present study considers behavioral emotion regulation mechanisms for this effect.

Preliminary Analyses

As described in Creswell et al (2014), preliminary analyses showed that randomization was effective for the mindfulness condition and the attention training control condition at baseline for age ($p = .96$), gender ($p = .18$), ethnicity ($p = .21$), prior exposure to meditation ($p = .57$), and day one dispositional mindfulness ($p = .18$). For the behavioral coding component, we examined the consistency across the two performance tasks for the coded variables. After, combining each variable into an average performance task measure, intra-class correlations showed a high degree of consistency across the speech task and the calculation task for each of the coded variables (anxiety $r = .88$; confidence $r = .66$; anger $r = .73$).

We tested two competing accounts for how mindfulness affects stress reactivity. The emotion buffering account predicts a decrease in emotional reactivity during the TSST, whereas the emotional expression account predicts increased emotional expression during the TSST. This was tested with two coded affective outcomes (anger and anxiety). These predictions were tested using multiple linear regression analyses with dispositional mindfulness, mindfulness training condition, and their interactions as predictor variables and training expectancy as a covariate.

First, we tested whether mindfulness training, dispositional mindfulness and their interaction with anger as the outcome variable. The mindfulness study condition yielded no significant main effect ($\beta = -1.27$, $t(61) = -1.478$, $p = .145$). No significant main effect for dispositional mindfulness was observed ($\beta = .025$, $t(61) = .158$, $p = .875$). However, there was a significant training condition × dispositional mindfulness interaction on anger to the TSST ($\beta = 1.703$, $t(61) = 1.941$, $p = .057$). Consistent with the emotional expression account, the interaction showed that participants higher in dispositional mindfulness, who also received mindfulness training, had the greatest anger response to the TSST (Figure 3).

We also tested the emotional reactivity vs. emotional expression accounts for behavioral anxiety during the TSST. We saw no significant main effect for the mindfulness training (β = -.501, $t(61) = -.523$, $p = .603$) and no significant main effect for dispositional mindfulness (β = .058, $t(61) = .330$, $p = .743$). Likewise, there was no significant interaction for training condition × dispositional mindfulness (β = .498, $t(61) = .517$, $p = .607$) suggesting that anxiety levels did not differ for those in the mindfulness training or those with higher dispositional mindfulness (or both mindfulness training and high dispositional mindfulness), shown in Figure 4.

Previous studies have not evaluated whether mindfulness alters behavioral measures of confidence during both tasks and whether mindfulness improves speech quality, but nonetheless we tested whether mindfulness might increase displays of confidence and speech quality during the TSST. We found no significant effects for both of these behavioral performance improvement variables. Specifically, for confidence, we did not find a main effect for mindfulness training (β = .241, $t(61) = .256$, $p = .799$), dispositional mindfulness (β = -.216, $t(61) = -1.256$, $p = .214$) (Figure 5). No significant interaction effect was observed as well (β = -.330, $t(61) = -.349$, $p = .729$). For speech quality, there was no significant main effect for training condition (β = .811, $t(62) = .852$, $p = .398$), no significant main effect for dispositional mindfulness (β = .166, $t(62) = .956$, $p = .343$), and no significant interaction effect (β = -.682, $t(62) = -.712$, $p = .480$), shown in Figure 6.

Mediation Analysis

Our initial analyses provided initial evidence for the emotion expression account, specifically, mindfulness increased behavioral expressions of anger during the TSST. We then conducted mediation analyses using methods described by Baron & Kenny (1986), but did not find any evidence that anger expression mediated the interactive effects of dispositional

mindfulness and mindfulness training on psychological ($\beta = 0.122$, $t(61) = 0.877$, $p = 0.384$) or cortisol ($\beta = -0.037$, $t(61) = -0.257$, $p = 0.798$) stress reactivity to the TSST originally observed in Creswell et al., (2014).

Discussion

Reviews of mindfulness literature indicate that the underlying mechanisms of stress effects are still unclear (Holzel et al., 2011). The present study revealed that emotional expression might be one potential emotion regulatory mechanism for mindfulness alters stress reactivity. Using multiple linear regression analyses, we found that anger expression was greatest among those high in dispositional mindfulness and also received mindfulness training to the TSST. The present finding is consistent with the growing literature showing that emotional expression can buffer stress (Davidson et al., 2003; Tang et al., 2007; Robins et al., 2012) and lead to a decrease in emotional suppression, which can improve psychological well-being (Chambers et al., 2009; Davidson et al., 2003; Pace, 2009; Barnes et al., 2007; Kabat-Zinn et al., 1998; Carlson et al., 2004; Kemeny et al., 2011). Chambers and colleagues (2009) explain that mindfulness can help improve emotion regulation skills by accepting their present emotions, including negative ones, rather than attempting to suppress them. Also, Robins and colleagues (2012) showed that MBSR led to decreases in anger suppression. There has been interest in understanding how people emotionally cope with stress through mindfulness, this present study offers novel insights into emotion processing under stress.

We did not observe an evidence for the reduced emotional reactivity account in this study. In fact, the mindfulness training and high dispositional mindfulness individuals had the greatest negative affectivity reactivity to the TSST. An important question that is raised is why mindfulness meditation training increases anger and cortisol reactivity to the TSST in the present

study. Instead of preventing negative emotions from occurring, mindfulness can help reduce the appraisal of a stressful event as threatening through active emotion-focused coping. Lazarus and Folkman (1984) explain that an active emotion-focused coping approach can lead to acceptance of their current situation. Acceptance of the current situation can help individuals reexamine their irrational thoughts. In other words, these individuals will not try to change their current emotion and feelings. Weinstein and colleagues (2009) found that those high in dispositional mindfulness used less avoidant strategies and made an effort to remain in the present moment. This could lead to a depletion of cognitive resources in attempting to make extra coping efforts, leading to greater cortisol reactivity and anger in response to the TSST. Indeed, other studies find a similar pattern, for example, several studies show that cognitive reappraisal reduces negative affectivity to the TSST while also increasing cortisol reactivity (Lam et al., 2009).

Anxiety was displayed during the TSST but did not have significant differences between the control condition ($M = 4.03$; $SD = 1.06$) and mindfulness training condition ($M = 3.93$; $SD = .930$). Although results revealed that participants had anxiety during the task, we did not find any differences suggesting that mindfulness produced more anxiety. This might have merely been because participants were under stressful engagement during the TSST, showing anxiety.

The present study also tested whether dispositional mindfulness and mindfulness training altered confidence and overall speech quality during the TSST. There were no significant differences between mindfulness meditation and the cognitive training groups. We initially hypothesized that those in the mindfulness meditation training group would have higher speech ratings because past studies have suggested that brief mindfulness meditation training can increase cognitive performance and benefit the working memory even under stressful situations (Jha et al., 2010; Weger et al., 2012; Kerr et al., 2011). One explanation that no significant

results emerged could be because all the participants had similar skills and abilities, since most were students attending Pittsburgh universities. Thus, mindfulness would not have resulted in better performance levels because this particular population sample would have had a decent amount of experiences to talk about during the speech task.

This research has several limitations. First, this may not have been an emotional expression coping response. Instead, mindful individuals could have shown more anger to the TSST because they were getting more worked up and not adaptively coping. Participants could have seen the TSST as a perceived threat or anticipation, which would trigger negative emotions beforehand (Lazarus and Folkman, 1984). This anticipatory stress would increase negative emotions, like anger, suggesting that prior anticipatory emotions may influence responses during the stress task (Smyth et al., 1998). Thus, another limitation of our study was that we did not measure emotional levels prior to the stress task.

Another possible limitation is that we did observe behavior at other time points except for during the TSST. This could have allowed us to see if the behaviors exhibited by the participants changed over time. Thus, it is unclear how mindfulness training can change stress reactivity over time.

Conclusion

The present study offers new insights on how mindfulness meditation training decreases stress reactivity. We provide initial evidence that mindfulness meditation training increases emotional expression to the TSST. This study helps to expand our understanding of promising underlying emotion regulation mechanisms of mindfulness and stress.

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Figure 1. Psychological stress perceptions during the TSST math and speech tasks as a function of dispositional mindfulness and mindfulness meditation (vs. control) training. To graphically depict the interaction pattern, low and high dispositional mindfulness groups were defined by a median split. Error bars reflect +/- 1 standard error. Reprinted from Creswell et al., 2014.

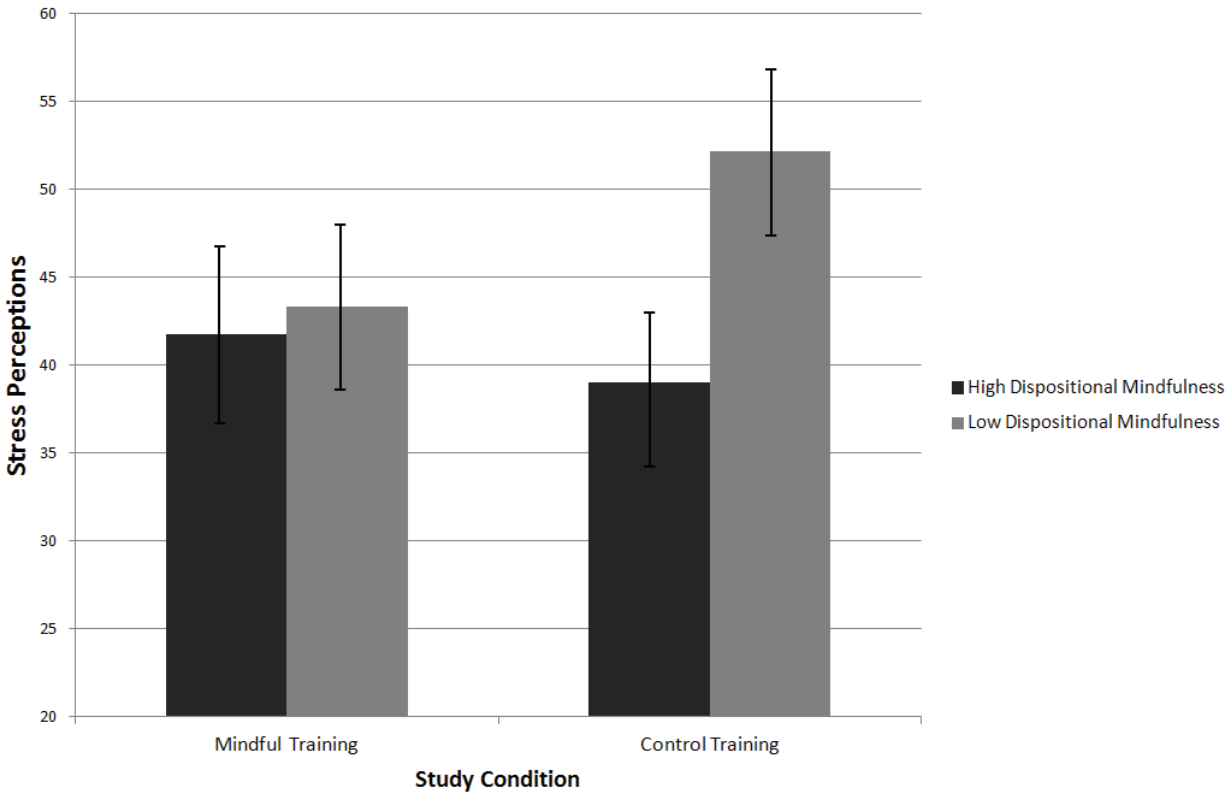

Figure 2. Salivary cortisol responses during the laboratory session as a function of dispositional mindfulness and mindfulness meditation (vs. control) training. To graphically depict the interaction pattern, low and high dispositional mindfulness groups were defined by a median split. Error bars reflect +/- 1 standard error. Reprinted from Creswell et al., 2014.

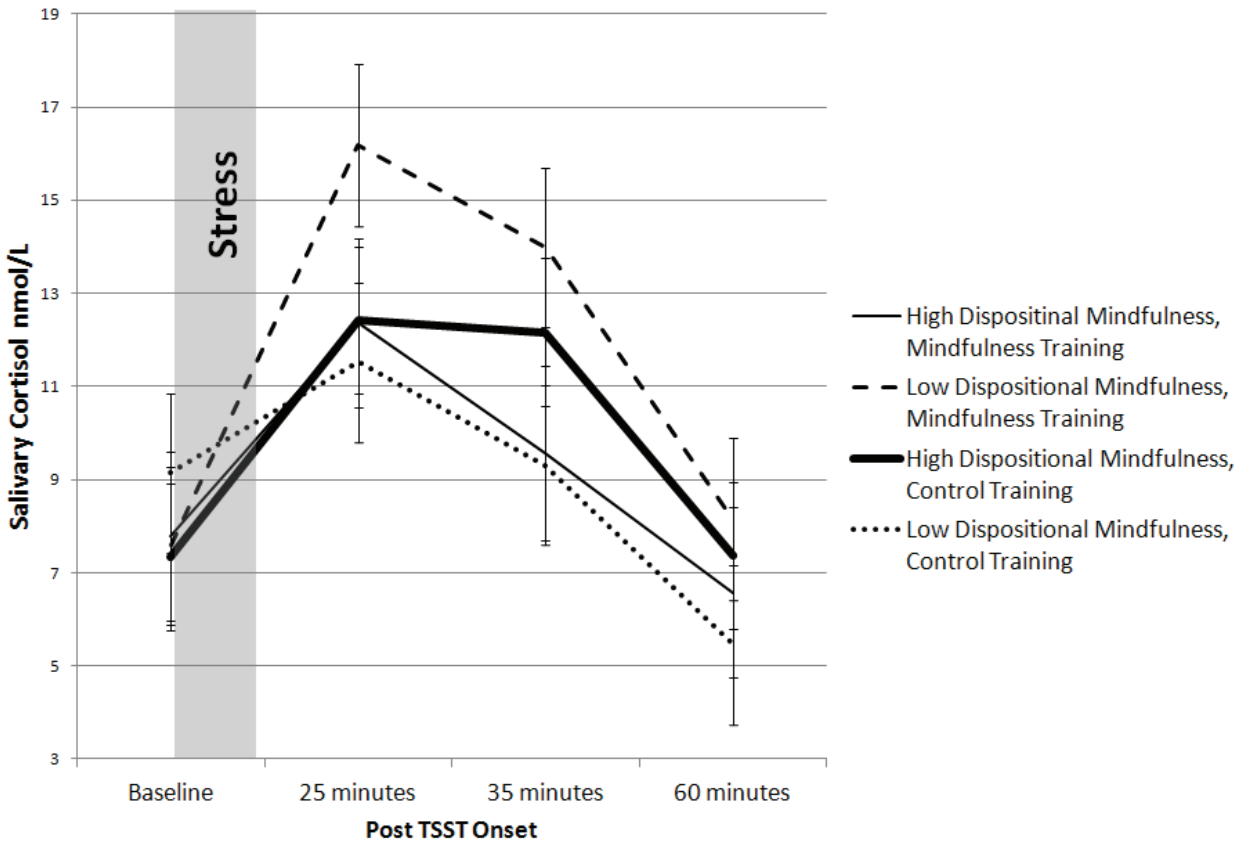

Figure 3. Anger responses during TSST as a function of dispositional mindfulness and mindfulness meditation (vs. control) training. To graphically depict the interaction pattern, low and high dispositional mindfulness groups were defined by a median split. Error bars reflect +/- 1 standard error.

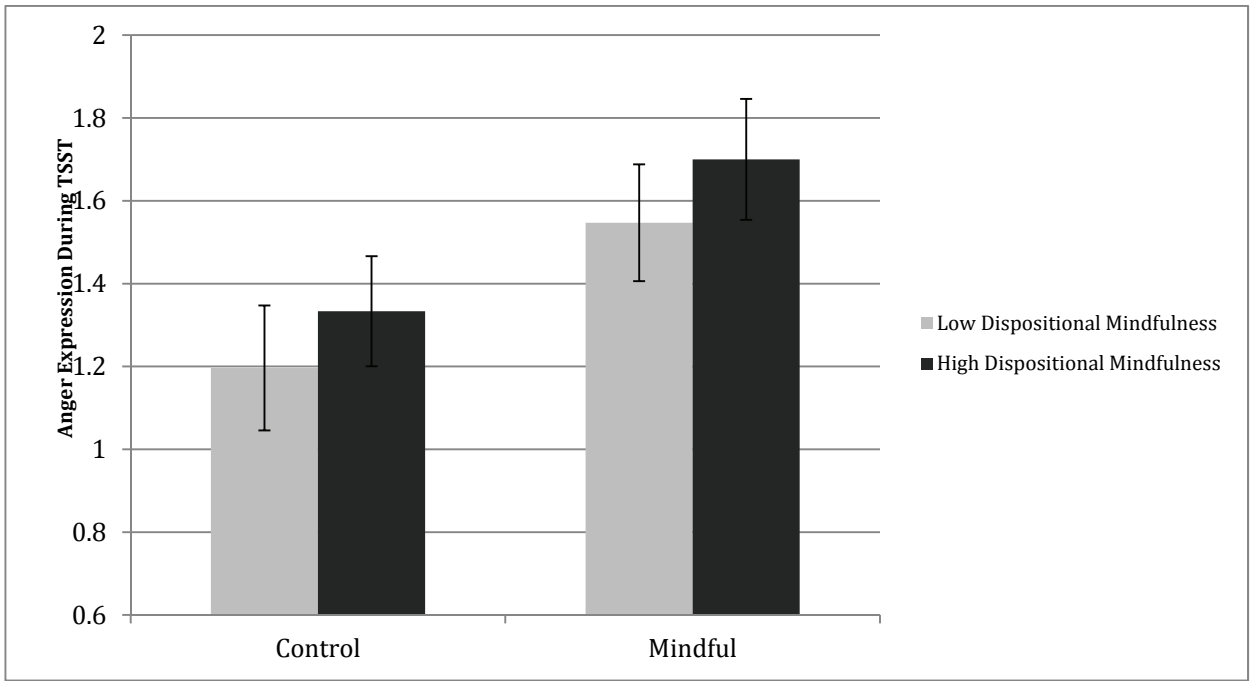

Figure 4. Anxiety responses during TSST as a function of dispositional mindfulness and mindfulness meditation (vs. control) training. To graphically depict the interaction pattern, low and high dispositional mindfulness groups were defined by a median split. Error bars reflect +/- 1 standard error.

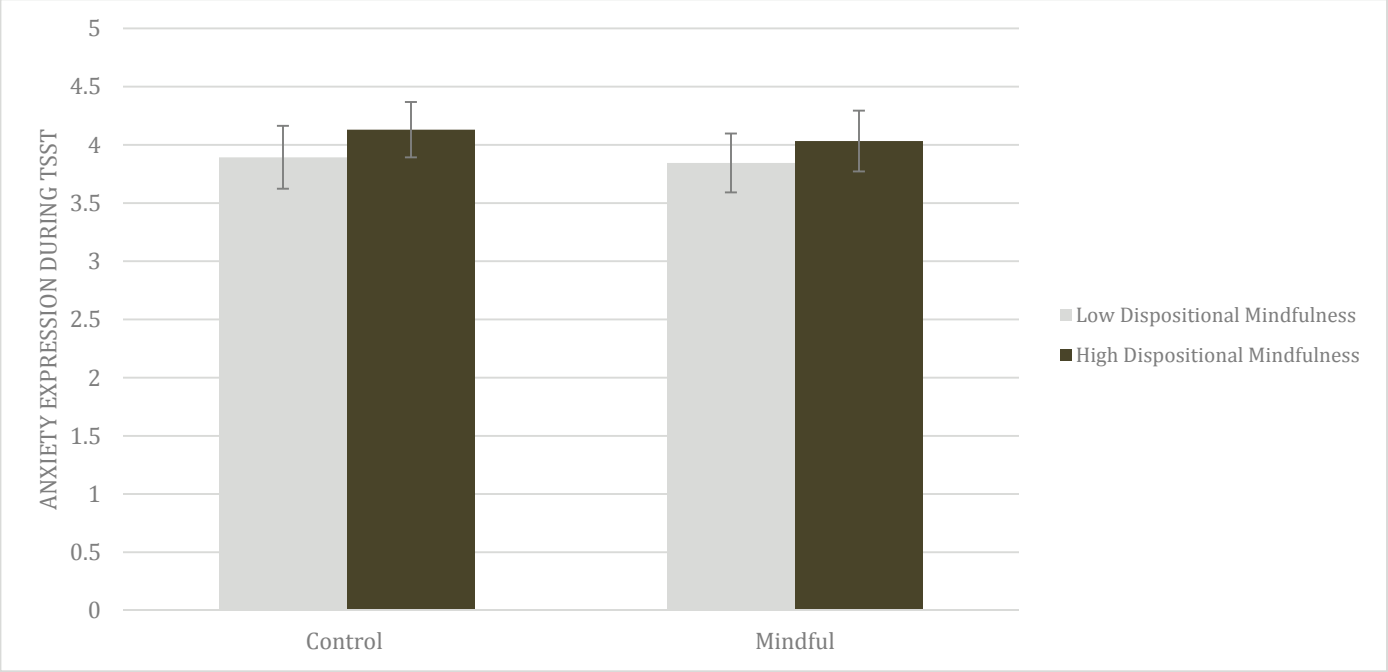

Figure 5. Confidence levels during TSST as a function of dispositional mindfulness and mindfulness meditation (vs. control) training. To graphically depict the interaction pattern, low and high dispositional mindfulness groups were defined by a median split. Error bars reflect +/- 1 standard error.

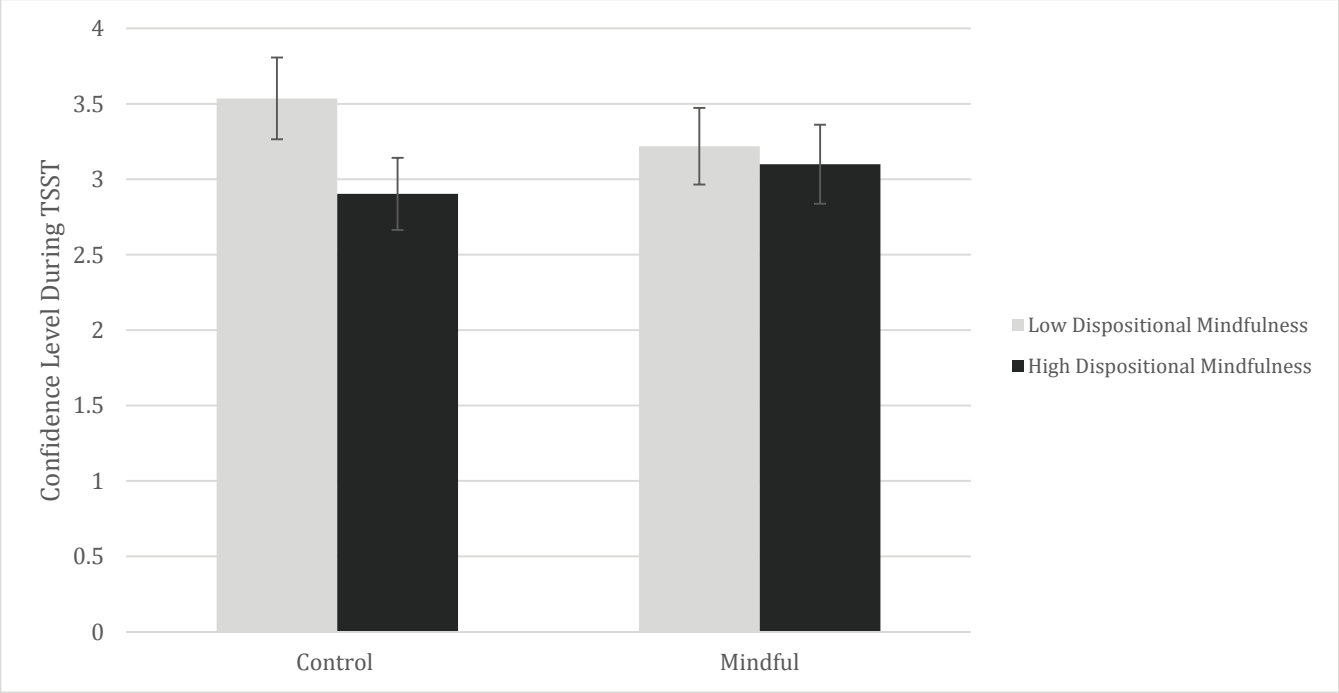

Figure 6. Speech ratings during TSST as a function of dispositional mindfulness and mindfulness meditation (vs. control) training. To graphically depict the interaction pattern, low and high dispositional mindfulness groups were defined by a median split. Error bars reflect +/- 1 standard error.