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ORIGINAL PAPER

Why It Pays to be Mindful: Trait Mindfulness Predicts Physiological Recovery from Emotional Stress and Greater Differentiation among Negative Emotions

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Abstract Although mindfulness has been generally linked to superior emotional functioning, several areas remain unclear. In extending prior work, the current report evaluated the link between trait mindfulness and physiological patterns of recovery from negative emotion and investigated possible associations between trait mindfulness and emotion differentiation. After completing a trait mindfulness measure, 80 healthy volunteers were block-randomized (matched on gender and relatively high versus relatively low trait mindfulness) to complete either emotional (EN) or neutral (NE) writing tasks first. In the EN order, participants wrote about an upsetting experience and, in the NE order, about the events of an average day. In partial support of expectation, relatively more mindful men showed greater physiological reactivity to an emotional task followed by superior recovery, but only in the EN order; supplementary analyses suggest that greater non-reactivity scores among males may be involved in the physiological regulation of emotional stress. As expected, relatively more versus relatively less mindful participants also differentiated more among discrete negative emotions but, again, only in the EN order. Taken together, findings offer preliminary evidence that the more differentiated emotional responding associated with aspects of trait mindfulness may facilitate more adaptive responding under stress and contribute to superior mental and physical health.

Keywords Mindfulness · Emotion · Recovery · Differentiation · Non-reactivity · Regulation · Health

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Introduction

Mindfulness training appears to benefit both psychological and physical health. Mindfulness-based interventions reduce anxiety and depression in clinical populations (Hofmann et al. 2010) and stress in healthy individuals (Chiesa and Serretti 2009), with controlled research showing reduced pain and increased physical function (Morone et al. 2008; Plews–Ogan et al. 2005) and improved health outcomes in patients with cancer (Hoffman et al. 2012), cardiovascular disease (Hughes et al. 2010; Manikonda et al. 2008), and irritable bowel syndrome (Gaylord et al. 2011; Kearney et al. 2011; Gaylord et al. 2011).

Less clear is how mindfulness "works" to promote adaptive functioning (see Baer 2010; Hölzel et al. 2011 for recent reviews). One promising possibility is that mindfulness is associated with superior self-regulation, particularly emotional regulation. In theory, because mindfulness increases awareness and the non-reactive acceptance of experience (Hayes and Feldman 2004), it is likely to facilitate superior regulation. Maintaining present-moment, non-judgmental awareness during experience is thought to reduce arousal during and/or facilitate recovery from, negative emotional experiences such that mindful individuals "let go" of events more easily, thereby avoiding protracted arousal (Kabat-Zinn 1990).

Although several authors have examined the mechanisms of mindfulness within the context of emotion regulation

(Chambers et al. 2009; Gratz and Tull 2010; Garland 2011), direct empirical examinations of both emotional reactivity and recovery profiles are few. Most studies investigating links between mindfulness and emotion regulation suggest that mindfulness reduces *reactivity* to stressful or emotional experiences. Relative to controls, participants randomized to either mindfulness-based interventions or brief mindfulness inductions show less emotional reactivity to stressors, at least as evidenced by lower self-reported negative affect (Arch and Craske 2006; Erisman and Roemer 2010), reduced emotional interference in cognitive tasks (Ortner et al. 2007), and reduced sympathetic/vagal ratio (a measure of heart rate variability (HRV); Brewer et al. 2009). Findings from neuroimaging studies also imply that mindfulness reduces emotional reactivity. Reduced reactivity in both limbic and prefrontal cortex areas is seen in long-term versus novice meditators (Gard et al. 2012; Grant et al. 2011; Taylor et al. 2011) and (in uncontrolled studies) among those recently completing mindfulness training (Goldin et al. 2012; Westbrook et al. 2013).

However, it remains unclear whether reduced reactivity is mirrored in improvements in the *recovery* from emotional experiences. It has been suggested that there is less variability in emotional reactivity than there is in recovery *after* exposure to a stressor is terminated (Davidson et al. 2003). Prima facie, this distinction creates the possibility that aspects of mindfulness may be more closely tied to recovery from, rather than reactivity to, stressful experience. Mindfulness training is thought to help individuals approach difficult emotions with an attitude of non-judgment rather than trying to avoid or alter them (Teasdale et al. 2000). This "stance" may permit a more natural (and time limited) emotional trajectory to unfold. By turning *towards* present experience rather than away from it, more mindful people may therefore still react to events but let go of emotional responses more rapidly than less mindful people, thus facilitating a quicker recovery.

Few studies have directly examined links between mindfulness and patterns of emotional *recovery*. Those that do exist are inconsistent and often limited by a focus on specific clinical populations. In one study, participants randomized to a brief mindfulness intervention reported less negative affect than controls after watching an affectively mixed film clip but did not differ following recovery from it (Erisman and Roemer 2010). In another recent study, participants with a history of chronic depression were randomized to 8 weeks of Mindfulness-Based Cognitive Therapy (MBCT; Segal et al. 2002) or a wait-list control; the MBCT participants reported less anxiety following recovery from a standardized laboratory-based social evaluative stressor stressor (Britton et al. 2012). Importantly, however, there were no differences in anxiety *during* the stressor, leading the authors to conclude that the effect of mindfulness training may be specific to the chronicity (i.e., recovery from emotion), rather than a generalized blunting of the intensity of responses.

Data regarding acceptance (Hayes 2004; a construct closely related to mindfulness) are similarly mixed. Studies comparing acceptance with strategies such as suppression or evaluation suggest links between acceptance and greater subjective (Campbell-Sills et al. 2006) or physiological recovery (Dunn et al. 2009; Low et al. 2008), others an association between acceptance and greater negative affect following recovery (Dunn et al. 2009), and others no association at all (Campbell-Sills et al. 2006). In sum, the small and discrepant literature in relation to the association between dispositional mindfulness and recovery suggests the need for further experimental work examining recovery as well as reactivity trajectories in non-clinical samples.

A second area in need of empirical development regards the specific emotion-regulatory tendencies that may be enhanced by mindfulness and contribute to decreased reactivity and/or enhanced recovery following emotional stress. One characteristic that may improve with greater mindfulness is emotion differentiation. Emotion differentiation refers to the tendency to distinguish like-valenced emotions as separate and discrete from one another (i.e., on a felt level, events are not simply experienced as "bad" but are described using discrete emotion terms: irritability versus sadness versus shame; Barrett et al. 2001; Lindquist and Barrett 2008). Research suggests that lower differentiation is associated with poorer health (Lane et al. 2002). While stressors tend to reduce differentiation to a single good–bad continuum (for a review, see Reich et al. 2003), personality differences may moderate this tendency. In one experience-sampling study, individual differences in perceived stress and neuroticism were associated with lower differentiation while dispositional resilience predicted greater differentiation (Ong and Bergeman 2004).

Theoretical and preliminary empirical work suggest mindfulness may enhance emotion differentiation. As noted, mindfulness training aims to develop the capacity to deliberately and non-judgmentally attend to difficult experiences (Teasdale et al. 2000). Trait mindfulness is positively associated with measures of awareness such as emotional intelligence, including clarity and labelling abilities (Baer et al. 2004; Brown and Ryan 2003; Schutte and Malouff 2011), but negatively related to alexithymic tendencies (Baer et al. 2004). The tendency to clearly and non-judgmentally attend to emotional experience may mean that more mindful individuals are better able to differentiate among discrete aspects of an overarching experience while the style of less mindful individuals may mean they tend towards experiencing their emotions as predominately pleasant or unpleasant.

To date, only one study has directly examined the link between mindfulness and differentiation. In this experience-sampling study, higher levels of trait mindfulness were related to greater emotion differentiation for both negative and positive emotions (Hill and Updegraff 2012). Mediational models suggested that mindfulness reduced emotional reactivity

partly by increasing the ability to differentiate among the discrete aspects of experience. Such data are, however, limited insofar as it is possible that the more versus less mindful persons differentially self-select into events which lend themselves to more versus less differentiation. The nascent literature in this area further suggests the value of extending current knowledge by assessing the links between trait mindfulness and emotion differentiation under controlled conditions.

Given the gaps identified in the literatures above, the current study was designed to examine two issues, specifically (1) the links between trait mindfulness and *recovery* from negative experience, as distinct from reduced emotional reactivity and (2) whether mindfulness is associated with greater emotion differentiation, defined as the experience of multiple discrete emotional states during emotional stress. An empirically based understanding of both *where* in the emotion-regulatory process mindfulness is most important, and the specific processes associated with mindfulness that may influence emotional reactivity and recovery may assist the refinement of interventions to help the development of health-promoting regulatory profiles. Consistent with the above literatures, it was expected that relative to those relatively low in trait mindfulness, relatively more mindful participants would show equal or greater physiological reactivity to the emotional task as evidenced by increased HR and decreased HRV, and superior recovery, as evidenced by decreased HR and increased HRV. We also expected that trait mindfulness would be associated with greater negative and positive emotion differentiation.

Of final note, whether mindfulness would be associated with greater differentiation under conditions of greater stress or among females versus males were treated as exploratory issues. There were two reasons for exploring potential associations between gender and emotional reactivity and recovery and/or emotion differentiation. First, men and women have normatively different emotion and regulatory styles. Relative to men, women tend to experience and express less anger (Diehl et al. 1996) and greater fear and sadness (Madden et al. 2000). Compared with women, men are less motivated by interpersonal considerations (Timmers et al. 1998) and more likely to withdraw from conflictive interactions (Levenson et al. 1994).

Second, evidence from mindfulness research suggests gender differences in the specific mindfulness facets that might be differentially relevant to the reactivity versus recovery aspects of emotionality. Studies using the Five Factor Mindfulness Questionnaire (FFMQ) (Baer et al. 2006), distinguish among five facets of mindfulness (observe, acting with awareness, describe, non-judgment, and non-reactivity) (Deng et al. 2011; Heeren et al. 2011; Veehof et al. 2011). Men tend to score higher on the *non-reactivity* facet of the FFMQ, while women score higher on *observe* (Bränström et al. 2011; Gilbert and Waltz 2010; Josefsson et al. 2011). Such differences create the possibility that gender differences in specific mindfulness skills may influence the manner in which men and women respond to emotional stress.

Method

Participants

The University of Auckland Human Participants ethics Committee provided ethical approval for the study. Following approval, participants responded to flyers distributed in a city hospital, E-mail, and word of mouth advertisement. Participants fluent in English and aged 18+ years were eligible. Eighty individuals (n =40 males) completed demographic and psychological questionnaires at baseline before a laboratory session. Consistent with previous studies (Garland 2011; Lange et al. 2012; Reynolds, Consedine, and McCambridge 2013), participants were dichotomized into relatively high and low mindfulness groups using a trait mindfulness measure.

Procedure

Laboratory sessions were conducted across 9 months between January and September 2011. Participants attended sessions individually with one of two trained research assistants. Participants were fitted with a Polar RX800CX heart rate monitoring chest band, and their heart rate and HRV were recorded continuously on the Polar watch throughout the session. Before writing, participants completed a baseline measure of positive and negative affect and then sat at rest for a 3-min period. Participants were block randomized (matched on gender and relatively high versus low trait mindfulness) to complete either emotional (EN) or (NE) neutral writing tasks first. For the emotional task, participants wrote about a highly stressful or very upsetting experience that still caused them some distress while in the neutral task they wrote about the events of an average day. For each task, participants wrote for 7 min followed by a 5-min recovery period. Mean positive and negative affect were measured at baseline, immediately after each writing task, and after a recovery period. Mean HR and HRV data for these same time-points were calculated.

Measures

Heart Rate and Heart Rate Variability High-frequency heart rate variability (HF-HRV) was chosen as an index of physiological reactivity and recovery as it is a measure of the increase and decrease in heart rate that occurs with inhalation and exhalation, respectively, and is reliably associated with parasympathetic nervous system activity via the vagus nerve

(Berntson et al. 1997). Rapid changes in HF-HRV are associated with psychological conditions. In healthy individuals, acute withdrawal of vagal efferent activity occurs in response to stressful situations (Berntson et al. 1993) and induction of negative affect (Lane et al. 2009), resulting in rapid increases in heart rate and decreases in HRV (Berntson et al. 1993). Rapid increases in HF-HRV generally occur in response to relaxation exercises (Sakakibara et al. 1994; Sarang and Telles 2006) and meditation (Lehrer et al. 1999; Peressutti et al. 2010). Blunted HF-HRV reactivity (smaller acute decreases) in response to stressful events, on the other hand, has been found in individuals with depression (Rottenberg et al. 2007) and post-traumatic stress disorder (Cohen et al. 2003) and may reflect deficits in self-regulation (Thayer et al. 2009). HRV data processing was carried out using the KUBIOS HRV program. Prior to conducting primary analyses of HF-HRV, HF values were transformed using a natural logarithm to normalize the distribution of scores. A larger HF value indicates greater HRV and greater parasympathetic predominance.

Physical Activity Status Scale (Heil et al. 1995) Because baseline cardiovascular fitness is linked to both resting heart rate and heart rate variability metrics (Britton et al. 2007), participants' self-reported fitness was assessed using a single-item, self-report measure upon which each participant rated his or her activity habits over the past month on a scale ranging from 0 to 10. A rating of 0–1 indicates very low activity while the highest rating of 10 represents a weekly total of running more than 25 miles or exercising aerobically (e.g., tennis) for more than 12 h.

FFMQ (Baer et al. 2006) Trait mindfulness was measured with the FFMQ. The FFMQ comprises 39 items designed to measure five skills thought to be associated with mindfulness: observing, describing, acting with awareness, accepting without judgment, and non-reactivity. Items are scored on a five-point scale, and a higher total score indicates greater dispositional mindfulness. The questionnaire has been shown to have good psychometric properties (Baer et al. 2008; Goodall et al. 2012; Van Dam et al. 2009) and reliability (Cronbach's alpha) for the full scale in this study was 0.87. Cronbach's alpha for the individual subscales ranged between 0.81 and 0.92. The median total FFMQ score (131) was used to divide the subjects into relatively higher and lower mindfulness groups for analysis and is comparable to mean FFMQ scores of between 126 and 138 reported in similar studies using healthy population-based samples (Baer et al. 2011; Bränström et al. 2011; Van Dam et al. 2009).

Emotion Differentiation Emotion differentiation was computed using items from the Positive and Negative Affect Scale (Tellegen et al. 1988). Participants were asked to rate the extent to which they experienced affective states (e.g., interested, strong, irritated) during each writing session and recovery period using a five-point scale from 1, "very slightly or not at all" to 5, "very much." The correlations among participants' reports of *interested*, *excited*, *strong*, *enthusiastic*, *proud*, *alert*, *inspired*, *determined*, *attentive*, and *active* were used to index positive emotion differentiation while between items *distressed*, *upset*, *guilty*, *scared*, *hostile*, *irritable*, *ashamed*, *nervous*, *jittery*, and *afraid* indexed negative emotion differentiation. As in prior studies (Hill and Updegraff 2012; Tugade and Fredrickson 2004), average intraclass correlations (ICCs) with absolute agreement between emotion terms were calculated. To test mindfulness-differentiation links, separate ICCs were calculated for positive and negative emotion differentiation among relatively more and less mindful participants at each of the five timepoints. Further ICCs were calculated for different data groupings in the course of analysis (see "Results"). In line with previous research (Barrett et al. 2001; Hill and Updegraff 2012), higher correlations indicate that different emotion terms are being used to describe felt experience in the same way (i.e., lower differentiation), whereas lower correlations indicate that different emotion terms are being used to describe aspects of felt experience in distinct ways (i.e., higher differentiation).

Results

Effects of Mindfulness on Physiological Reactivity and Recovery

To examine the effects of trait mindfulness on reactivity and recovery trajectories, we ran two, parallel 2 (task order)×2 (gender)×2 (relatively high/low mindfulness)×5 (phase) mixed-model ANCOVAs on the HR and HRV metrics, in which phase was a within-subject factor, task order, gender, and mindfulness between-subject factors and self-reported exercise levels a covariate. Gender was included in the model given evidence of gender differences in emotion (Manstead 1998), and participant's average weekly exercise levels were also controlled, as fitness is known to be associated with greater HF-HRV (Britton et al. 2007). For the HR model, there was a trend towards a main effect of phase, Wilks $\lambda = 0.89$, F (4,68)=2.21, $p = 0.07$, with HR being greater during both writing task phases. There was also a main effect of task order on HR, F (1,71)=5.02, $p = 0.03$, $\eta^2 = 0.07$. HR was greater when completing the neutral task first.

In contrast to expectation, there were no differences in HR as a function of trait mindfulness F (1,71)=0.92, $p = 0.34$, and gender was also non-significant F (1,71)=1.02, $p = 0.32$. However, the effect of phase on HR was qualified by an interaction between phase and mindfulness, Wilks $\lambda = 0.86$,

F (4,66)=2.66, p=0.04, η^2=0.14. Inspection of the interaction plot suggested that, while HR was generally lower among relatively more mindful participants, this difference was smaller during emotional recovery and larger during the neutral writing tasks. There was also a two-way interaction between phase and task order, Wilks λ=0.75, F (4,68)=5.68, p=0.001, η^2=0.25. This interaction suggested that HR differences across the tasks (i.e., EN or NE) were larger during neutral and neutral recovery phases.

The parallel HRV (log HF) model was less complex. There were no main effects associated with phase, mindfulness, task order, or sex in the model, suggesting that HF-HRV did not vary as a function of mindfulness itself. However, there was a significant four-way interaction between phase, mindfulness, sex, and task order on HF-HRV, Wilks λ, 0.77, F (8,134)= 2.25, p=0.02, η^2=0.12. To deconstruct this effect, we conducted parallel mixed-model ANCOVAs separately for males and females. Although the female model showed no effects on HF-HRV, the male model showed a three-way interaction between task order, mindfulness, and phase, Wilks λ=0.57, F (4,32)=5.95, p=0.001, η^2=0.43 (see Fig. 1a and b). Examination of the interaction plot for men showed that, when they completed the emotional writing task first, the HF-HRV of relatively more (versus relatively less) mindful men initially decreased suggesting reactivity to the task but then increased during the neutral task, providing some support for the enhanced recovery expected among relatively more mindful participants. However, there was relatively little variation in HF-HRV among the relatively more mindful men across tasks if the neutral writing task was completed first. In this order, relatively less mindful men unexpectedly showed greater variability in HF-HRV.

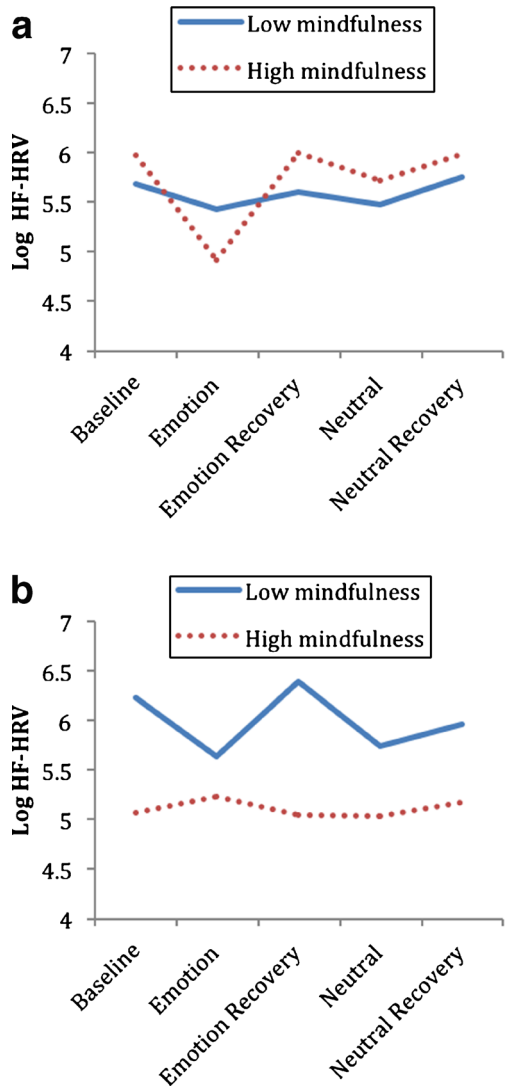

Fig. 1 **a** Mean HRV (log HF) of more and less mindful males in the EN order. **b** Mean HRV (log HF) of more and less mindful males in the NE order

Gender Differences in Mindfulness Facets and the Links Between Mindfulness and HRV

To examine whether gender differences in specific mindfulness facets (rather than the aggregate) might account for the gender interactions in the HF-HRV models, a MANCOVA controlling for age was used to test for the effects of gender and mindfulness (relatively high/low) on the five specific facets of the FFMQ. Age was included as a covariate, given preliminary evidence of a relationship between age and mindfulness (Baer et al. 2008). Results showed significant effects of gender and mindfulness on both observe and non-react (see Table 1). Consistent with prior work (Bränström et al. 2011; Gilbert and Waltz 2010; Josefsson et al. 2011), males had higher non-reactivity scores while females scored higher than males on the observe facet.

Effects of Mindfulness on Emotion Differentiation

To test the link between trait mindfulness and emotion differentiation, we began with univariate contrasts as a function of mindfulness, gender, and order. ICCs between the emotions comprising the positive and negative differentiation indices relatively more and less mindful participants at each timepoint were calculated first. Individual ICCs were then averaged to represent mean positive and negative differentiation by relatively more and less mindful participants across tasks. A paired contrast of the ICCs representing mean differentiation for relatively more and less mindful participants was conducted, using the Fisher r-to-z transformation and α = 0.05. Given the effects of gender and order found on physiological responding above and prior evidence of gender differences in emotion regulation (Madden et al. 2000; Timmers et al. 1998), the independent effects of gender and order on differentiation were then examined. For ease of presentation, all ICCs representing mean negative emotion differentiation

Table 1 Means and standard deviations of sample mindfulness facets as a function of high versus low mindfulness and gender

	Mindfulness and gender grouping				*F* value		
	Male participants		Female participants				
	Low mindful ($n=19$)	High mindful ($n=21$)	Low mindful ($n=20$)	High mindful ($n=20$)	Gender (G)	Mindfulness (M)	G×M
Total mindfulness	114.73 (9.22)	145.37 (12.60)	118.76 (7.24)	142.61 (8.53)	0.29	139.79**	2.20 (0.14)
Observe	2.96 (0.66)	3.64 (0.66)	3.22 (0.52)	3.90 (0.48)	5.87*	28.48**	2.84 (0.10)
Describe	3.21 (0.55)	3.68 (0.51)	2.71 (0.49)	3.47 (0.47)	0.13	9.82**	0.04 (0.85)
Aware	3.08 (0.73)	3.31 (0.89)	2.97 (0.43)	3.33 (0.56)	0.07	3.79	0.17 (0.69)
Non-judge	2.81 (0.62)	3.23 (1.23)	3.24 (0.68)	3.47 (0.81)	2.76	2.88	0.23 (0.63)
Non-react	3.07 (0.43)	3.79 (0.49)	2.68 (0.43)	3.51 (0.44)	9.29**	55.29**	0.51 (0.48)

Standard deviations appear in parentheses

*$p<0.05$, **$p<0.01$

are reported in Table 2. Because there were no main effects of mindfulness, gender, or order on positive emotion differentiation, these ICCs are not reported.

As can be seen in Table 2, analyses provided some evidence consistent with expectations in terms of negative emotion differentiation. First, there was a strong trend towards greater negative differentiation by relatively more mindful participants across tasks ($z=1.56$, $p=0.06$). However, analyses showed no main effect of gender on negative ($z=-0.95$ $p=0.34$, two-tailed) or positive emotion differentiation ($z=-0.03$, $p=0.76$, two-tailed). Additionally, participants differentiated less in the EN than in the NE order across tasks ($z=1.65$, $p=0.05$). Prior work suggests that emotion differentiation may decrease under conditions of stress (Reich et al. 2003), and it may be that completing the emotion task first had "carry-over" effects during subsequent neutral tasks and thus greater polarization of emotions than occurred when the neutral task was completed first.

Finally, the interactive effects of mindfulness, gender, and order on negative differentiation only were examined. Separate ICCs among the emotions comprising the negative differentiation index for relatively more and less mindful males and relatively more and less mindful females in each of the NE and EN orders across the five different time-points were calculated (see Table 2). In the EN order, relatively more mindful women differentiated more among their negative emotions across tasks ($z=2.22$, $p=0.01$). In the same order, relatively more mindful men also tended towards greater differentiation, ($z=1.4$, $p=0.07$). Conversely, in the NE order, relatively more mindful males did not differentiate than relatively less mindful males ($z=0.8$, $p=0.2$) and nor was differentiation greater in relatively more versus less mindful females ($z=0.44$, $p=0.3$). Because it might be argued that differentiation is not entirely independent of the underlying level of negative affectivity, mean levels of negative emotion across tasks were calculated to aid interpretation of effects. No differences were found between relatively more and less mindful participants in average levels of negative emotion in this phase of analysis or any subsequent phase. Differentiation thus appeared to be independent of actual levels of negative affect.

Discussion

The present study investigated links between mindfulness and reactivity to, and recovery from, emotional stress as well as on emotion differentiation. Although there were no overall differences in HR and HF-HRV between relatively more and less mindful persons, interactions suggested lower heart rate in relatively more mindful participants, particularly during neutral tasks and greater HF-HRV in relatively more mindful men when they completed an emotion task first. Such findings offer some support for the prediction that relative to less mindful participants, more mindful participants would show a pattern of equal or greater reactivity to an emotional task followed by superior recovery. Similarly, although emotion differentiation did not vary as a function of mindfulness alone, interactions showed greater negative emotion differentiation among the relatively more mindful when they completed the emotion task first. Again, these results were partially consistent with the prediction that more mindful persons should report a more differentiated emotional state. Below, we revisit these findings in greater detail, concentrating on their contributions to extant literatures, possible reasons for the qualified nature of results, and their implications.

Mindfulness—Reactivity Versus Recovery Differences in Physiology

A pattern of greater initial reactivity followed by superior recovery among more mindful men when they completed

Table 2 Intra-class correlations showing main and interactive effects of mindfulness, gender, and order on negative emotion differentiation

Interactive effects

	Males						Females					
	NE			EN			NE			EN		
	HM	LM	*r-z*	HM	LM	*r-z*	HM	LM	*r-z*	HM	LM	*r-z*
Negative ED												
Baseline	0.90	−0.36		0.63	0.75		0.49	0.35		0.11	0.94	
Neutral	0.53	0.18		0.35	0.84		0.51	0.04		−0.56	0.92	
Neutral recovery	0.05	0.15		−0.20	0.76		0.14	0.03		0.11	0.89	
Emotion	0.75	0.86		0.27	0.89		0.97	0.76		0.78	0.79	
Emotion recovery	0.96	0.76		0.52	0.75		0.96	0.86		0.45	0.93	
Mean negative ED	0.64a	0.32b	$z=0.08, p=0.2$	0.31c	0.80d	$z=1.4, p=0.07$	0.61e	0.41f	$z=0.44, p=0.3$	0.18g	0.89h	$z=2.22, p=0.01$*
	(0.37)	(0.50)		(0.32)	(0.06)		(0.35)	(0.39)		(0.50)	(0.06)	
Main effects												
HM versus LM mean[a]	0.76 (0.42)	0.56 (0.14)	$z=1.56, p=0.06$									
Males versus females mean[b]	0.61 (0.38)	0.73 (0.17)	$z=0.95, p=0.17$									
NE versus EN mean[c]	0.58 (0.35)	0.78 (0.05)	$z=1.65, p=0.05$									

Standard deviations appear in parentheses

[a] The mean of high mindfulness subgroups (i.e., a, c, e, and g) was compared with the mean of low mindfulness subgroups (i.e., b, d, f, and h)

[b] The mean of male subgroups (i.e., a, b, c, and d) was compared with the mean of female subgroups (i.e., e, f, g, and h)

[c] The mean of NE subgroups (i.e., a, b, e, and f) was compared with the mean of EN subgroups c, d, g, and h)

*$p<0.05$

the emotion task first is consistent with previous studies in which psychologically healthy individuals have demonstrated acute decreases in HRV in response to stress (Berntson et al. 1997; Lane et al. 2009; Thayer et al. 2009) and acute increases in HRV during activities associated with recovery, such as relaxation and meditation (Peressutti et al. 2010; Sarang and Telles 2006). Although the link between mindfulness and reduced reactivity is well documented (Arch and Craske 2006; Brewer et al. 2009; Gard et al. 2012; Grant et al. 2011; Ortner et al. 2007; Taylor et al. 2011), few studies have tested for mindfulness-associated effects on recovery. To the best of our knowledge, the present study is the first to utilize a non-expert sample and to include recovery periods and a physiological measure to directly examine links between dispositional mindfulness on physiological recovery as well as reactivity profiles. Thus, our first contribution lies in offering a more fine-grained picture of the autonomic responses associated with trait mindfulness following emotional stress: Rather than dampening the emotional response, mindfulness appears to facilitate recovery following initial reactivity to stressors. Physiological findings thus provide objective, albeit qualified, evidence consistent with suggestions that mindfulness training may moderate chronicity, rather than generally blunt the intensity of emotional responses (Britton et al. 2012).

However, it remains unclear why greater overall HRV was observed in relatively more mindful males but not in relatively more mindful females when they completed the emotion task first. One possible explanation for gender differences in the physiological responses of relatively more and less mindful participants may be the differential contribution of mindfulness facets *observe* and *non-reactivity* to total mindfulness scores. Although there was no gender difference in total mindfulness scores, greater non-reactivity among men may have moderated physiological responses to emotional stress while higher observing scores among women may have exacerbated them. Prior work has linked greater observing scores with greater reactivity in anxious individuals (Ehlers and Breuer 1992, 1996), and self-focused attention can be maladaptive (Harvey 2004; Mor and Winquist 2002). Thus, compared with relatively more mindful men, women may have come into greater contact with negative emotion and experienced greater physiological arousal. Conversely, their relatively less developed non-reactivity may have limited their ability to attenuate emotional reactivity and recover physiologically once the stressor passed.

Also unclear is why relatively more mindful males demonstrated the hypothesized physiological profile in the EN but not the NE order. One possibility is that, when relatively more mindful males completed the neutral task first, low task demand may have led or allowed them to "practice" mindfulness informally (which seems plausible as participants knew the experiment was about mindfulness) enhancing state mindfulness at the start of the emotional task relative to those without a comparable "practice period" who completed the emotional task first. Being momentarily mindful is more likely among persons higher in this trait, and data suggest that state mindfulness exerts stronger effects on day-to-day well-being than trait mindfulness (Brown and Ryan 2003). Therefore, although speculative (we did not measure state mindfulness), the interactive effects of state mindfulness together with their superior capacity for non-reactivity among relatively more mindful men may have shifted their response tendencies further along the spectrum of mindful emotion regulation from enhanced recovery following emotional stress to diminished reactivity to it in the first place. Recent neuroimaging evidence suggests that long-term meditators may develop a more stable reduced reactivity to emotionally salient stimuli (Chiesa et al. 2012) and raises the possibility that *where* mindfulness operates in the emotion-regulatory process (i.e. during reactivity to and/or recovery from emotional stress) depends on both the level *and* state of mindfulness concerned. Future research should investigate this hypothesis and the temporal development of mindfulness skills more generally.

Although further work is needed to show *causal* links between the mindfulness skill of non-reactivity and enhanced physiological recovery following emotional stress, results from this study are among the first to suggest that non-reactivity may be an integral component of mindfulness in this regard. Findings may thus imply that a particular emphasis on cultivating non-reactivity skills is needed for women to receive the full physiological benefits of mindfulness training. Finally, these data may offer empirically informed guidance for mindfulness teachers, trainers, and practitioners as to the expected trajectory of change in emotional experience (i.e., that practice may not influence response intensity but should shorten duration). Such an understanding may enhance participants' commitment to mindfulness training and help reduce attrition during the early stages of mindfulness training (Dobkin et al. 2012).

Mindfulness—Greater Differentiation of Negative Emotions

The greater negative emotion differentiation reported by relatively more (compared with relatively less) mindful participants in the present study is consistent with recent data from an experience-sampling study (Hill and Updegraff 2012). The experimental paradigm used in the current study builds on these earlier findings by suggesting that this link is not due to more mindful participants self-selecting into less stressful contexts that facilitate the experience of more differentiated emotions. The greater differentiation among relatively more mindful participants is also consistent with links between greater differentiation and adaptive personality characteristics such as emotional flexibility (Potter et al. 2000; Terracciano et al. 2003, 3) and resilience (Tugade and Fredrickson 2004). Finally, the more differentiated nature of relatively mindful

participants' negative emotions together with the superior physiological recovery of relatively more mindful men in the EN order may suggest that experiencing less polarized negative emotion states attenuates physiological reactivity at times of emotional stress. Such an interpretation is consistent with the finding that greater emotion differentiation mediates the relationship between higher mindfulness and reduced self-reported emotional reactivity (Hill and Updegraff 2012). However, further work is needed to establish causal links between greater differentiation and physiological recovery as the structure of our data did not permit mediational analysis.

The greater negative differentiation of relatively more mindful participants in the EN but *not* the NE order was unexpected and appears somewhat inconsistent with the profile of diminished autonomic reactivity in relatively more mindful men in the NE order. Although counterintuitive, it is possible that the same mindfulness "practice effect" noted above may have contributed to similar differentiation by relatively more and less mindful participants in the NE order. Consistent with the general mindfulness tenet to fully experience, rather than evade negative feelings (Teasdale et al. 2000), one might expect that in this study's relatively more mindful (but not expert) participants, practicing mindfulness during the neutral tasks may have resulted in their greater engagement with negative emotions during the NE than the EN order. Such engagement may have led them to report levels of differentiation comparable to those reported by relatively less mindful participants in the NE order. However, given that non-reactivity confers the capacity to keep the mind calm and balanced when distressing thoughts and feelings are present (Baer et al. 2006), relatively more mindful men may have been able to decouple physiological and subjective responses in the NE order. Although plausible, such an argument remains speculative, and further experimental studies are needed to examine whether mindfulness, particularly the non-reactivity aspect of mindfulness, promotes "decoupling" among the components of emotional responding.

Study Limitations

Although these findings offer novel contributions regarding possible mechanisms underpinning the relationship between mindfulness and emotion regulation, they have some obvious limitations. In addition to those noted above, writing about personally stressful events may be more benign than other laboratory stressors and thus may not have been sufficiently emotionally evocative to elicit the full extent of differences in the way those relatively high and low in trait mindfulness respond to emotional stress. However, as the expressive writing paradigm is personally salient in nature, its use in the present study strengthens the ecological validity and generalizeability of findings. Although the sample used was relatively meditation-naive, it would have been desirable to examine the potential relevance of participants' previous meditation experience. It is also possible that the use of a non-expert sample to represent relatively high mindful individuals in the present study failed to maximize between-groups differences. However, this consideration had to be balanced against our aim of examining the effects of dispositional mindfulness on emotional reactivity and recovery in a normal population, to date a relatively unexplored area.

Furthermore, the method chosen to group participants into relatively high and low mindfulness groups by dichotomizing their total mindfulness scores was somewhat arbitrary. Previous studies employing the same grouping method (Garland 2011; Lange et al. 2012; Reynolds et al. 2013) and reporting mean total mindfulness (FFMQ) scores comparable to the mean in the current study (Baer et al. 2011; Bränström et al. 2011; Van Dam et al. 2009) nonetheless strengthen confidence as to the validity of the grouping method used.

Participants were not blinded to the mindfulness aspect of the study and nor were they given instructions about whether to apply mindful emotion regulation while completing the writing tasks. It is therefore possible that demand characteristics and/or increased state mindfulness arising from participants' practice during tasks influenced some responses. As we did not measure socially desirable responding or state mindfulness, it was not possible to eliminate the possible impact of such variables. Finally, this study's findings do not permit the drawing of causative links between high trait mindfulness, greater negative emotion differentiation, and enhanced physiological recovery from emotional stress. Despite these shortcomings, our results give rise to some interesting and testable hypotheses in relation to the effects of state and/or trait mindfulness on emotion-generative and regulation processes and their links to emotional wellbeing and health.

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