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Self-Regulatory Deficits Associated with Unpracticed Mindfulness Strategies for Coping with Acute Pain

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Abstract

Training in mindfulness is a well-supported therapeutic strategy for pain conditions, though short-term mindfulness training for acute pain is not always effective. To explore the possibility that initial attempts at mindfulness in people without previous training may drain self-regulatory resources, the current study used a student sample ($N=63$) to test the hypothesis that brief instruction in mindfulness would lead to reduced pain tolerance on a cold pressor task (CPT), compared to more familiar strategies for coping with acute pain. We also investigated whether high heart rate variability (HRV), a physiological indicator of self-regulatory capacity, would predict pain tolerance. Higher HRV predicted greater pain tolerance only in the control group, suggesting that applying unfamiliar mindfulness strategies while attempting to tolerate pain more rapidly sapped self-regulatory strength.

Keywords

mindfulness; self-regulation; heart rate variability; pain

Overriding the tendency to avoid or escape physical pain is a salient example of self-regulation, the capacity to alter the way one thinks, feels, or behaves (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven & Baumeister, 2000). Mindfulness also involves self-regulation; in this case, the maintenance of controlled but open and non-judgmental attention (Baer et al., 2008; Bishop et al., 2004; Masicampo & Baumeister, 2007). Studies suggest that long-term mindfulness training can improve other aspects of self-regulation, such as rumination (Chamber, Lo, & Allen, 2008) and emotion regulation (Erisman & Roemer, 2010; Goldin & Gross, 2010). Although there is some evidence that weeks or months of training in mindfulness improves self-regulation with regard to pain tolerance (Kingston, Chadwick, Meron, & Skinner, 2007), the effects of initial attempts to be mindful on pain tolerance have not been examined. The possibility that the initial phases of mindfulness training may be highly demanding of self-regulatory resources, and therefore may reduce the ability to effectively self-regulate in other domains, has significant theoretical and clinical implications.

Mindfulness and Pain

Mindfulness-based interventions that involve prolonged training have been used successfully in the treatment of chronic pain conditions to improve quality of life, psychological distress, and pain-related activity interference (Kabat-Zinn, 1982; Kabat-Zinn, Lipworth, & Burney, 1985; Grossman, Tiefenthaler-Gilmer, Raysz, & Kesper, 2007; Morone, Greco, & Weiner, 2008). However, there is less evidence regarding the shorter-term delivery of mindful approaches to coping with acute pain. On one hand, the beneficial effects of mindfulness on self-regulation and coping observed in therapeutic settings may generalize to short-term pain tolerance. Supporting this possibility, six 1-hour mindfulness training sessions with asymptomatic participants over three weeks produced improved pain tolerance as measured by cold pressor task (CPT) duration, the amount of time one can hold one's hand in a container of very cold water, relative to a guided visual imagery control group (Kingston et al., 2007). In another study, as little as 30 minutes of mindfulness training per day over three consecutive days resulted in reduced pain sensitivity to electrical shocks, leading the authors to conclude that mindfulness meditation training, however brief, may benefit pain control by reducing anxiety and improving attentional focus in the moment (Zeidan, Gordon, Merchant, & Goolkasian, 2010). Other studies have explored the role of interventions based on Acceptance and Commitment Therapy (ACT), a multi-component approach that combines mindful acceptance of one's inner experiences with commitment to valued behavior (Hayes, Strosahl, & Wilson, 1999). These studies tend to support the claim that compared to cognitive control or avoidance, brief ACT-based interventions improve acute pain tolerance (Hayes et al., 1999; Masedo & Esteve, 2007; Gutierrez, Luciano, Rodriguez, & Fink, 2004). Finally, a body of literature examining the effects of different cognitive approaches to acute pain suggests improved pain tolerance resulting from instructions to focus on the sensory aspects of pain rather than the emotional aspects of pain or distraction (e.g. Suls & Fletcher, 1985), similar to the mindful approach of observing rather than avoiding unpleasant sensory experiences.

On the other hand, there is some evidence that when participants are given instructions but little time to practice a mindfulness-based approach, there is no effect on pain tolerance. For example, McMullen and colleagues (2008) reported that brief instructions in acceptance of pain had no effect on tolerance of electric shocks, whereas significant effects were seen for a longer training period that included several experiential exercises and metaphors designed to encourage acceptance of pain and behavioral commitment to tolerating it. However, the multi-component, ACT-based approach used in this study makes it difficult to ascertain the effects of mindfulness per se on pain tolerance.

Because the exercise of mindfulness involves the regulation of attention and cognition, the self-regulatory demand of being mindful may not improve pain tolerance and may contribute to self-regulatory fatigue and poorer pain tolerance for novice practitioners. Ample evidence supports the strength model of self-regulation, which claims that there is a limited, fatigable, and common reservoir of self-regulatory resources such that exertion on one self-regulatory task (e.g., emotion inhibition, resisting temptation, interpersonal cooperation, persistence) causes impairment on a subsequent but unrelated act of self-regulation (for a review, see Hagger, Wood, Stiff, & Chatzisarantis, 2010).

In summary, although some studies have examined the effects of approaches that are similar to mindfulness, the impact of brief instructions in mindfulness on acute pain tolerance has not been tested. Theoretically, initial attempts to be mindful seem to require self-regulatory effort that may detract from its benefit for novice practitioners coping with acute pain. Therefore, when mindfulness is unfamiliar, the self-regulatory demands associated with its application may result in self-regulatory fatigue. With practice, however, such strategies are likely to become more automatic, require less self-regulatory effort, and yield more benefit (Bargh & Chartrand, 1999).

Self-regulation and Heart Rate Variability

Some individuals have a greater capacity for self-regulation than others, and this capacity may be reflected in the autonomic parameter of heart rate variability (HRV; Segerstrom & Solberg Nes, 2007). HRV is the variability in intervals between successive heartbeats and is thought to reflect the level of autonomic flexibility and inhibitory control that allows an individual to respond adaptively to internal and external demands (Porges, 2001; Thayer & Lane, 2000). In particular, parasympathetically mediated HRV reflects the degree of inhibitory control over the heart that slows down the heart rate and increases HRV (Berntson et al., 1997; Task Force, 1996). There are a variety of methods for calculating HRV, which tend to be highly correlated and are thought to index predominantly parasympathetic vagal control of the heart (Berntson et al., 1997; Task Force, 1996). These measures of parasympathetically mediated HRV are associated with respiratory sinus arrhythmia (RSA; Berntson et al., 1997), the increase and decrease in heart rate caused by the respiratory cycle, but also reflect activity of an interrelated group of neural structures involved in self-regulatory and executive functions (Thayer & Lane, 2000).

A growing body of research supports the link between baseline HRV and the capacity for self-regulation across a number of domains similar to pain tolerance, including emotional control and persistence. For example, experimental studies suggest that higher baseline HRV predicts improved persistence on a difficult task (Segerstrom & Solberg Nes, 2007; Solberg Nes, Carlson, Crofford, de Leeuw, & Segerstrom, 2010), better emotion regulation among rejection-sensitive individuals exposed to interpersonal conflicts (Gyurak & Ayduk, 2008), and less emotional distress among children watching an upsetting film (Fabes, Eisenberg, & Eisenbud, 1993). Higher baseline HRV is also correlated with better impulse control among male children and adolescents (Allen, Matthews, & Kenyon, 2000), while lower levels of baseline HRV are associated with deficits in emotional and behavioral control associated with anxiety (Thayer, Friedman, & Borkovec, 1996) and depression (Rechlin, Weis, Spitzer, & Kaschka, 1994).

The Present Study

For difficult or stressful tasks such as tolerating acute pain, unpracticed attempts to be mindful may tax self-regulatory resources. The strength model of self-regulation suggests that asking participants to engage in two simultaneous self-regulatory tasks—practicing unfamiliar mindfulness skills while tolerating acute pain—might tax self-regulatory resources more rapidly and produce less pain tolerance than allowing participants to use

more familiar strategies for managing acute pain. Although some studies have examined brief acceptance-based interventions or multiple sessions of mindfulness training prior to an acute pain challenge, no studies have examined the effects of brief mindfulness instructions on pain tolerance or the role that HRV may play.

Therefore, the present study tested two hypotheses regarding the relationships among unfamiliar mindfulness strategies, HRV, and pain tolerance. First, we predicted that, due to the presence of simultaneous self-regulatory demands, short-term instructions in unfamiliar mindfulness strategies would decrease pain tolerance relative to a condition in which participants use familiar strategies for coping with acute pain. Second, consistent with previous findings on the relationship between HRV and self-regulatory capacity, we predicted that higher levels of baseline HRV would predict greater pain tolerance. In addition, the relationship between a priori self-regulatory strength as reflected in baseline HRV and the effects of simultaneous self-regulatory demands was examined by testing the interaction between mindfulness instructions and HRV.

Method

Participants

Participants were 63 psychology students who participated for partial course credit; this comprised a subset of participants who had ECG data from a larger study ($n = 121$). There were no significant differences on demographic variables or CPT tolerance times between those with and without ECG data. Ethnically, the sample was 74% Caucasian, 2% African American, 3% Asian American, and 19% “other.” The sample was 46% female and the average reported age was 18.98 ($SD = 1.62$). We did not measure participants’ prior experience with mindfulness training, though previous research has found that the vast majority of students have little or no experience with mindfulness or other meditation techniques (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). The study was approved by the University of Kentucky Institutional Review Board.

Procedure

Upon arriving at the laboratory, participants provided informed consent and were seated in a comfortable chair in a quiet room. Participants were prescreened and excluded for the presence of diabetes, seizures, high blood pressure, low blood pressure, chronic pain, panic attacks, Reynaud’s disease, or cardiovascular disease. Electrodes were attached to collect a 10-minute baseline ECG, and participants were allowed to rest and adapt to the equipment while filling out questionnaires. During the final few minutes of this baseline period, participants received instructions on a computer about the strategy they would be asked to use during the pain tolerance task. Participants were randomly assigned to one of two mindfulness groups (*observe-only* or *observe, describe, and accept*) or a control group. All instructions to participants were standardized and provided in written form on the computer screen and aurally through headphones.

The *observe-only* group ($n = 26$) received instructions on how to bring awareness to the present moment (e.g., “Focus on the experience as it is happening”), while the *observe*,

describe and accept group ($n = 21$; 39) received these instructions in addition to instructions to describe (e.g., “Try to label the experience, using a single word or short phrase”) and be non-judgmental (e.g., “Be open to the experience without criticism or judgments”). These instructions were based on instructions provided to participants in mindfulness-based stress reduction programs (Kabat-Zinn, 1990). Participants in the control group ($n = 16$) were instructed to use any coping strategy that came naturally to them during the pain task. The different mindfulness groups were initially constructed to explore the potential impact of different facets of mindfulness on pain tolerance.

In order to reduce demand characteristics, participants in each group were given a rationale regarding how the assigned technique would improve the ability to cope with pain. To ensure participants understood their assigned coping strategy, they were asked to answer two questions based on the rationale given, and were required to give correct responses before continuing to the CPT. Immediately following each CPT, participants were asked to rate on a visual analog scale (0 to 100) the extent to which they used observing, describing, accepting, distracting, ignoring, and suppressing strategies during the CPT.

The tank contained water maintained at an average temperature of .27 C and continuously circulated by an electric pump¹. A mesh screen prevented the ice from directly coming into contact with the participant’s hand. When ready, the participant was asked to completely submerge his or her left hand up to the wrist and leave it in the tank for as long as possible. Following this first CPT, participants received a brief reminder of the coping strategy they had been assigned to use and were then asked to engage in a second CPT. The correlation between the two CPTs on pain tolerance was $r = .88$.

Measures

Pain Tolerance—Tolerance was measured as the total time in seconds that the participant’s hand was completely submerged in the water, averaged across the two CPTs. Average tolerance was 113.68 seconds ($SD = 105.16$) with a range of 18 to 723 seconds. Since this variable was positively skewed, we applied a log10 transformation to the data.

Heart Rate Variability—A Biopac Systems (Goleta, CA) ECG100B amplifier was used to collect and record ECG information with leads attached to the chest in a modified Lead II configuration (Martin, 2004). The ECG was sampled at 500 samples/s and continuously recorded using Biopac Acqknowledge 3.7 software. Mindware (Gahanna, OH) HRV 2.51 software was used to visually inspect and edit data in accordance with the guidelines described by the Task Force of the European Society and Cardiology and the North American Society of Pacing and Electrophysiology (1996). This software provides spectral analysis of the data, yielding log HF HRV power (.15 – .4 Hz) as a measure of vagally mediated HRV. The mean HF HRV across the 10 minutes preceding the first CPT, during which participants were filling out questionnaires and listening to instructions, was used to create the baseline HRV variable for each individual. Completing questionnaires and

¹The water temperature was maintained at a colder temperature than that in many other CPT experiments in an effort to provide a more stringent test of the coping techniques and to prevent a pain tolerance ceiling effect, a common problem in CPT research that can result in the need to exclude as many as half of all participants (e.g. Hayes et al., 1999; Masedo & Esteve, 2007).

listening to instructions constitutes activity that is not truly “basal” or “resting.” However, asking participants to engage in 10 minutes of an unexciting and non-complex task has been shown to yield an equally if not more reliable baseline measure of HRV and other cardiovascular variables compared to resting baselines that ask participants to sit quietly (Jennings, Kamarck, Stewart, Eddy, & Johnson, 1992). There were no differences between groups in baseline HRV. Average baseline HRV was 5.96 (SD = .88) with a range of 4.23 to 7.96.

Data analysis

Due to the small number of subjects in each group, there was less than desirable power to detect the expected small to moderate effect size. Therefore, to improve power and because there were no differences between the two mindfulness instruction groups on pain tolerance or in the HRV-pain tolerance relationship, they were combined for analyses. All statistical tests were performed with two-tailed $\alpha = .05$. To test the prediction that higher levels of baseline HRV would predict greater CPT tolerance, we examined the zero-order correlation between the two variables. Our prediction regarding the negative effect of unfamiliar attempts to cope mindfully on CPT tolerance was examined using an independent samples *t*-test. Despite the uneven sample sizes, the variances were not significantly different between groups ($F = 2.50, p = .12$). According to simulation studies, independent samples *t*-tests are robust against violations of normality and equal sample sizes when the variances are not significantly different (Gibbons & Chakraborti, 1991; Rasch, Teuscher, & Guiard, 2007). In order to examine the hypothesis regarding the interaction between baseline HRV and group assignment to predict CPT tolerance, we used hierarchical linear regression. Baseline HRV and group assignment were entered in the first step, and the interaction between baseline HRV and group assignment was entered in the second step (see Table 2 for model summary). HRV was mean-centered in regression analysis to reduce multicollinearity and facilitate interpretation (Aiken & West, 1991).

Results

Table 1 displays descriptive variables between groups, while Table 2 shows the zero-order correlations for the primary study variables. As shown in Table 1, ratings of strategies used during the CPT indicated that those who were instructed to cope mindfully indeed used more observing and describing and less distraction, ignoring, and suppression than those who did not receive mindfulness instructions. The mindful instructions also resulted in marginally more accepting than no instructions ($t(61) = 1.89, p = .07$). As shown in Table 2, the correlation between baseline HRV and group assignment was non-significant: $r = .04, p = .79$. Furthermore, a repeated measures ANOVA with time in minutes during the 10-minute baseline as the within subjects measure, and group assignment as the between-subjects measure revealed that there was no effect of group ($F(9,53) = .78, p = .38$) time ($F(9,53) = .99, p = .44$), or the interaction between group and time: $F(9, 53) = .86, p = .56$. Taken together, these results suggest that group assignment did not affect baseline HRV. There were no differences between groups in subjective pain ratings ($t(61) = .22, p = .83$). Hypothesis 1 predicted that mindful strategies would reduce pain tolerance. Confirming this hypothesis, those who received instructions to cope with pain mindfully showed

significantly less CPT tolerance compared to the control group ($t(61) = 2.15, p = .04, d = .46$). Hypothesis 2 predicted that baseline HRV would be positively associated with pain tolerance. Confirming this hypothesis, higher levels of baseline HRV were positively correlated with improved CPT tolerance ($r = .30, p = .02$; 95% CI = .06 – .51).

Both of these effects were qualified by an interaction between baseline HRV and group (mindful vs. control) on pain tolerance ($\beta = -.39, t(61) = -1.99, p = .05$). Table 3 shows the results from the hierarchical regression analysis, while Figure 1 shows the interaction between HRV and group. We tested the significance of the correlations between HRV and CPT tolerance for each group. The correlation in the control group was positive and significant ($r = .63, p < .01$; 95% CI = .20 – .86) such that higher HRV was associated with greater CPT tolerance. However, the correlation in the mindfulness group was not significant ($r = .16, ns$; 95% CI = $-.09 - .39$); therefore, the positive relationship between baseline HRV and CPT tolerance was eliminated by the mindfulness instructions.

Discussion

Training in mindfulness, the exertion of non-elaborative and non-judgmental attention, has beneficial effects for chronic pain conditions (Kabat-Zinn et al., 1985; Grossman, et al., 2007; Morone et al., 2008). However, initial attempts to be mindful, at least in the absence of significant opportunities for practice, may fatigue self-regulatory resources, especially when facing a stressful or challenging task. Therefore, the present study tested whether initial attempts to be mindful would have a negative effect on acute pain tolerance. The results supported this hypothesis, consistent with the strength model of self-regulation, though in a slightly different form than what has been articulated in the past (Baumeister et al., 1998). Specifically, the results provide evidence for the idea that simultaneous self-regulatory demands, in addition to sequential ones, can produce decrements in performance.

It may be that the instructions to be mindful of the pain ironically led to more effort and less pain acceptance in the mindfulness group if they perceived the need to perform some kind of pain control that did not come naturally to them. Conversely, the instructions to participants in the control group to rely on their own resources and strategies may have actually increased acceptance, which would be consistent with the finding that post-task ratings of acceptance were only marginally greater in the mindful group.

The normal association between higher baseline HRV and self-regulatory capacity was uncoupled in the mindfulness group. One distinct possibility is that simultaneous self-regulatory demands overwhelm the self-regulatory reserve that is indexed by higher baseline HRV. Perhaps this is akin to being able to lift a 50-pound weight two or three times, but being unable to lift a 100-pound weight even once because it is too heavy. In exercise physiology, strength refers to the maximum force generated by a muscle, while endurance refers to the ability of a muscle to sustain repeated contractions against a resistance for a period of time (Nieman, 2003). Self-regulatory capacity as a muscle is a commonly used metaphor for the “strength model” of self-regulation, though given the findings that self-regulatory training tends to improve stamina or endurance rather than maximum force (Muraven, Baumeister, & Tice, 1999), a more accurate label may be the “endurance model”

of self-regulation. Consistent with this conception, our results suggest that baseline HRV represents a measure of the capacity for self-regulatory endurance rather than the capacity for self-regulatory strength. Two simultaneous self-regulatory tasks, such as pain tolerance and practicing unfamiliar mindfulness skills, may require self-regulatory strength as well as endurance, which may explain why baseline HRV did not predict CPT tolerance in the mindfulness groups.

In a previous study (Solberg Nes et al., 2010), higher levels of baseline HRV predicted higher self-regulatory capacity in pain-free controls but not in chronic pain patients. In addition, although chronic pain is associated with a host of other psychological factors such as depression, anxiety, and fatigue, only individual differences in pain were associated with self-regulatory deficits. Therefore, the combination of self-regulatory demand and pain – acute in the present case and chronic in the previous case – appears to be particularly demanding and potentially detrimental to self-regulation. There may be something specific about the experience or underlying neurobiology of pain that interacts with self-regulatory capacity, and this is an important direction for future research.

The sample consisted of asymptomatic undergraduate students coping with experimentally induced acute pain, so it is important to explore the replicability and implications of the findings from the current study in clinical samples. Mindfulness-based treatments for patients with pain complaints typically begin with less demanding exercises practiced in relaxed and comfortable positions and work gradually toward mindfulness of painful experiences. The present findings support the utility of this approach by showing that brief training in unfamiliar mindfulness skills can sap self-regulatory resources in the short term. Clinicians who employ mindfulness-based approaches should be open to the possibility that initial efforts to learn mindfulness could lead to temporary increases in symptoms, failures in other areas of self-regulation, or both. Graded training may mitigate against these adverse effects.

We acknowledge several limitations of the current study. First, because there was no measure of participants' previous experience with mindfulness, it is possible that this approach was not novel for some of those in the mindfulness strategy groups. However, it is unlikely that a significant number of these participants had prior experience with mindfulness as previous studies suggest that well over 90% of college undergraduates have no experience with mindfulness (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). Second, combining the two mindfulness groups together is potentially problematic because the strategy used by the observe-only group was arguably not a "true mindful" approach without the addition of the description and acceptance components. However, observing by itself is not a commonly used approach for coping with pain (Cioffi, 1991), and may therefore be similar to a more comprehensive mindful approach in its demands on self-regulatory resources. Indeed, the lack of differences between these two groups on their reported strategies during the CPT and the relevant outcome variables provides further justification for this view and the decision to merge the two groups. Third, we did not test pain tolerance prior to the experimental instructions, and so the effect of mindfulness on *change* in pain tolerance could not be tested. However, a baseline pain tolerance test would have provided a self-regulatory challenge in and of itself, complicating the design and

interpretation of the study. Therefore, we relied on random assignment to ensure that groups were roughly equal in their baseline pain tolerance. The very small correlation between group and HRV ($r = .04$) suggests that they were at least roughly equal in this index of self-regulatory capacity.

Taken together with other recent findings regarding pain and self-regulation, it appears that tasks requiring self-regulatory energy undertaken by someone in pain, either chronic or acute, may overwhelm or rapidly deplete whatever self-regulatory resources were initially present due to the taxing nature of simultaneous self-regulatory demands. Although there is evidence that mindfulness training is effective for improving the quality of life for those in chronic pain, it is likely to be an initially depleting practice. With training over time, however, it may be possible to build up one's self-regulatory resources, decrease the self-regulatory demand of mindfulness, or both (Bargh & Chartrand, 1999; Muraven et al., 1999). Perhaps use of frequent, repeated assessments, especially early in mindfulness training, could help identify when and for whom these processes occur.

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Figure 1.
Interaction between baseline HRV and Group Assignment predicting CPT Tolerance.

Table 1

Descriptive Statistics for Primary Study Variables by Group (N = 63)

	Mindfulness Group	Control Group
1. Gender	49% female	50% female
2. Age	18.79 (.88)	19.38 (1.66)
3. Baseline HRV (log HF power)	5.98 (.85)	5.91 (1.01)
4. CPT Tolerance (log10 secs)	1.88* (.32)	2.09 (.41)
5. Use of Observing (0–100)	69.26* (18.63)	42.13 (15.81)
6. Use of Describing (0–100)	56.14* (24.17)	37.97 (26.92)
7. Use of Accepting (0–100)	61.94 (13.84)	55.20 (11.78)
8. Use of Distraction (0–100)	35.92* (26.03)	61.05 (21.72)
9. Use of Ignoring (0–100)	39.47* (28.15)	72.91 (22.58)
10. Use of Suppression (0–100)	50.48* (21.10)	68.81 (13.33)

Note. Standard deviations are in parentheses. HRV = heart rate variability; HF = high frequency; CPT = cold pressor test.

*
 $p < .05$.

Table 2

Correlations Among Primary Study Variables

	1	2	3
1. Baseline HRV	—	.04	.30*
2. Group assignment (1 = mindful)		—	-.27*
3. CPT tolerance			—

Note.

* $p < .05$.

Table 3
Hierarchical Regression of Cold Pressor Task Persistence on Baseline HRV, Group Assignment, and their Interaction

Variable	β	p	Total R^2	R^2	p
Cold Pressor Task Persistence (log10 secs)					
Step 1			.09*	.09	.02
Baseline HRV	.30	.02			
Step 2			.17*	.08	.02
Baseline HRV	.31	.01			
Group Assignments	-.28	.02			
Step 3			.22*	.05	.05
Baseline HRV	.64	.003			
Group Assignment	-.28	.02			
Baseline HRV x Group Assignment	-.41	.05			

Note.

* Indicates that ANOVA for full model was significant at $p < .05$.