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A single session of meditation reduces of physiological indices of anger in both experienced and novice meditators

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ABSTRACT

The goal of the present study was to explore how anger reduction via a single session of meditation might be measured using psychophysiological methodologies. To achieve this, 15 novice meditators (Experiment 1) and 12 practiced meditators (Experiment 2) completed autobiographical anger inductions prior to, and following, meditation training while respiration rate, heart rate, and blood pressure were measured. Participants also reported subjective anger via a visual analog scale. At both stages, the experienced meditators' physiological reaction to the anger induction reflected that of relaxation: slowed breathing and heart rate and decreased blood pressure. Naïve meditators exhibited physiological reactions that were consistent with anger during the pre-meditation stage, while after meditation training and a second anger induction they elicited physiological evidence of relaxation. The current results examining meditation training show that the naïve group's physiological measures mimicked those of the experienced group following a single session of meditation training.

1. A single session of meditation reduces of physiological indices of anger in both experienced and novice meditators

Anger can be defined as a state that is elicited through frustration, threats to one's authority or reputation, disrespect, and/or a sense of injustice or violation of norms or rules (Spielberger & Reheiser, 2010). It is normal and healthy to experience occasional anger (Tyson, 1998), but excessively frequent and/or intense angry periods can be harmful (Bushman, 2002; Bushman, Bonacci, Pedersen, Vasquez, & Miller, 2005). There are numerous interventions shown to reduce harmful levels of anger (Beck & Fernandez, 1998; Hofmann, Grossman, & Hinton, 2011). One such intervention is meditation (Hofmann et al., 2011), or "the intentional self regulation of attention from moment to moment" (Kabat-Zinn, 1982, p. 82). Explorations using psychophysiological and/or neuroimaging techniques have begun to elucidate the mechanisms underlying the benefits of meditation and its link to anger reduction.

One possible explanation for the role of meditation in reducing anger proneness is that it improves general cognitive functioning (Lutz, Jha, Dunne, & Saron, 2015; Lutz, Slagter, Dunne, & Davidson, 2008; Tang & Posner, 2013; Tang et al., 2007). More specifically, routine meditation is associated with reduced neural activity during resting brain states (e.g., within the default mode network) and enhancement in the neurocognitive mechanisms involved in emotion regulation (e.g., cognitive flexibility, cognitive control) (Ainsworth, Eddershaw, Meron, Baldwin, & Garner, 2013; Chiesa, Calati, & Serretti, 2011; Denson, 2013; Desbordes et al., 2012; Ivanovski & Malhi, 2007; Kang, Gruber, & Gray, 2012; Luders, Toga,

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Lepore, & Gaser, 2009; Lutz et al., 2008, 2015; Taylor et al., 2011). Compared to non-meditators, habitual practitioners of meditation elicit reduced activity in areas of the default mode network associated with self-reported *mind-wandering*, or the tendency to think about events of the future and past (Berkovich-Ohana, Glicksohn, & Goldstein, 2012; Brewer et al., 2011; Pagnoni, 2012). Mind-wandering is positively associated with self-reported unhappiness and the use of meditation reduces this tendency (Brewer et al., 2011; Killingsworth & Gilbert, 2010). The introduction of meditative practice to inexperienced meditators reduced mind-wandering frequency (Chambers, Lo, & Allen, 2008; Keng, Smoski, & Robins, 2011; Robins, Keng, Ekblad, & Brantley, 2012).

There is evidence that meditation can show immediate improvements in functioning for individuals who are naïve to meditation. New practitioners of mindfulness meditation report reduced rumination, reduced negative emotional reactivity, and reduced depressive symptoms (Borders, Earleywine, & Jajodia, 2010; Chambers et al., 2008; Paul, Stanton, Greeson, Smoski, & Wang, 2013; Shapiro, Oman, Thoresen, Plante, & Flinders, 2008). In naïve meditators, four meditation training sessions were associated with a broad range of cognitive and affective improvements (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). There is also evidence that a single session of meditation in naïve individuals can have analogous effects to habitual meditation practice (Carlson, Bacaseta, & Simanton, 1988; Fabes & Eisenberg, 1997; Rausch, Gramling, & Auerbach, 2006), though most studies of novel meditation practice explore training protocols that typically last ten days or more (Shapiro et al., 2008). The psychophysiological mechanisms of these improvements are not yet fully known.

The autonomic nervous system (specifically, respiration, blood pressure, and heart rate) can be used as an index for different emotional states. Within the autonomic nervous system, anger has been found to be highly related to increased sympathetic nervous system activity (Critchley et al., 2005). Respiration rate (RR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) increase when anger is induced (Ax, 1953; Rainville, Bechara, Naqvi, & Damasio, 2006; Sinha, Lovallo, & Parsons, 1992). These same measures decrease during meditation (Ditto, Eclache, & Goldman, 2006; Hussain & Bhushan, 2010; Nyklíček, Mommersteeg, Van Beugen, Ramakers, & Van Boxtel, 2013; Rubia, 2009; Travis, 2001), perhaps because the parasympathetic nervous system (PNS) becomes more engaged during a meditative state (Craig, 2010; Tang & Posner, 2013).

Heart rate variability (HRV), the variance of inter-beat intervals during cardiac activity, has been receiving attention for its potential in exploring emotional states and ability to discriminate sympathetic from parasympathetic influence in the central nervous system (Appelhans & Luecken, 2006). According to Polyvagal Theory, emotional experience is a result of multiple physiological states (Porges, 1995, 2001, 2007). There is also evidence that physiological reactivity can be modified in a top-down manner, such as through meditation or other effortful methods to regulate emotion (Craig, 2010; Taylor, Goehler, Galper, Innes, & Bourguignon, 2010). Greater PNS input results in more pronounced acceleration and deceleration of respiration and more variable intervals between heartbeats due to the rapid activity of the vagus nerve's metabolic control; these changes are measured as higher HRV (Berntson, 1997; Berntson, Cacioppo, & Quigley, 1993; Brindle, Ginty, Phillips, & Carroll, 2014; Somsen, Jennings, & van der Molen, 2004). HRV may be expressed as a function of frequency: high frequency bands (.15–.40 Hz) are indicative of parasympathetic influence corresponding to vagal influence on the sino-atrial node; low frequency bands (.05–.15 Hz) are affected by both sympathetic and parasympathetic domains of the baroreceptor influence on heart rate (Berntson, 1997).

High frequency heart rate variability (HF-HRV) is negatively correlated with self-reported anger (Appelhans & Luecken, 2006; Marci, Glick, Loh, & Dougherty, 2007); thus decreased parasympathetic influence is associated with increased anger. There is emerging evidence that HF-HRV increases as a result of the meditative state, which is suggestive of increased PNS activity (Burg, Wolf, & Michalak, 2012; Takahashi et al., 2005). Whereas it is generally believed that HF-HRV is influenced by the PNS, it is debated whether the sympathetic system influences this measure. One proposed solution has been to calculate a ratio of both high frequency and low-frequency heart rate variability, referred to as the Sympathovagal Balance ratio (Berntson, 1997; Pagani et al., 1986; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996), though the validity, utility, and effectiveness of this solution has long been controversial (Billman, 2013; Eckberg, 1997). Previous research has shown that the Sympathovagal Balance improved with meditation interventions (Kharya et al., 2014; Pal, 2015; Pal, Agarwal, Karthik, Pal, & Nanda, 2014; Sarang & Telles, 2006), so we included it as a variable in the present study.

The present pair of experiments had three primary aims regarding meditation and anger: (a) to determine if an acute meditative state will decrease an anger response both subjectively and physiologically; (b) to examine emotional reactivity in individuals naïve to meditation to determine if a relatively short exposure to meditation training can lead to significant changes both in perceived anger and in the physiological markers of anger; (c) to compare the reactivity of naïve meditators to that of practiced meditators, both as a point of comparison for the naïve group and extend current psychophysiological research examining the benefits provided by meditation during anger regulation. For both experiments, we utilized a modified A–B–C–A–B experimental design. We induced anger in two sessions: a baseline-anger condition and one following meditative training while physiological measures (HRV, RR, SBP, DBP) were recorded throughout. Following the initial anger reduction, we expected similar patterns of physiological reactivity (i.e. increased RR, SBP, & DBP; and decreased HF-HRV) and subjective report of anger (i.e., VAS) in both Experiment 1 and Experiment 2, though the effect sizes for the experienced meditators would be smaller than for the naïve group. We also hypothesized that both groups would show improvement in these same measures following meditation training, though the effect sizes for the naïve group would be greater than for experienced meditators.

2. Experiment 1: Naïve meditators

2.1. Methods

2.1.1. Participants

Fifteen healthy undergraduates (8 women) were recruited from introductory psychology courses at the University of Kansas. Participants were compensated with course credit. Participants were excluded if they reported any history of meditative practice; thus, the naïve group reported zero hours of meditation. By self-report, participants had no history of head trauma, psychological, or neurological disorders. Participants were excluded if they had any cardiac problems or were prescribed psychotropic medications. Each participant completed informed consent procedures before beginning the experiment. Consistent with being an undergraduate sample, the participants had an average age of 18.7 years (SD = .72, Mdn = 19.0, Range: 18–20 years). The University of Kansas Institutional Review Board approved all aspects of the current research.

2.1.2. State-level anger

A paper-and-pencil visual analog scale (VAS) was used as a subjective report of anger. The low end of the scale (to the left) was labeled as "not angry at all" and the high end (to the right) was "absolute rage" connected by an unmarked, 7.5 cm long horizontal line. There were no anchors in the middle of the scale. Participants were instructed to mark the line where they felt their current levels of anger were. The VAS was collected at four time points: before and after the first anger induction, before the meditation and after the second anger induction (described further below). The dependent variable in this instrument was the distance from the leftmost part of the line measured in centimeters. Use of similar VASs have been found to be a valid and reliable marker of state- and trait-affect (e.g., Abend, Dan, Maoz, Raz, & Bar-Haim, 2014; Nyenhuis, Stern, Yamamoto, Luchetta, & Arruda, 1997)

2.1.3. Trait-level anger

The Novaco inventory of anger-proneness was used to assess trait-level anger (Novaco, 1975). The instrument has been found to be a valid and reliable instrument in clinical and non-clinical populations (e.g., Culhane & Morera, 2010; Jones, Thomas-Peter, & Trout, 1999).

2.1.4. Physiological measures

All physiological assessments were gathered using a BIOPAC acquisition system (Biopac Systems, Inc., Goleta, CA) for the duration of the session. The equipment included an MP 35 acquisition unit. An electrocardiogram recorded using SS2L leads attached to Ag–AgCl electrodes applied on opposite sides of the chest (Ditto et al., 2006), and was sampled at 1 kHz. Respiration rate was measured continuously using a respiration belt around the participants' chest. Blood pressure was taken using the auscultatory method with a SS19L sphygmomanometer and a SS30L stethoscope on the non-dominant arm at various time intervals. One experimenter took all blood pressure measurements, and the same unit (millimeters of mercury; mmHg) was utilized to keep any variability associated with measurement constant across participants.

2.1.5. Procedure

Fig. 1 presents a graphical depiction of the procedure for the study. Upon entering the lab, participants completed informed consent and questionnaires that confirmed demographics and history of meditation practices. The experimenter then applied all physiological recording apparatuses. After the participant was comfortably seated, 5-min baseline physiological measurements were recorded, after which the participant filled out the first VAS. Participants then completed the anger induction (described below), followed immediately by blood pressure measurement. Participants then filled out a series of questionnaires, including the Novaco measure (Novaco, 1975) and VAS as well as others that were unrelated to the present analysis. The questionnaires took approximately 20 minutes to complete, allowing a return to baseline between TP1 and TP2. After questionnaires were completed, participants began the meditation intervention (also described below). After meditation, blood pressure was measured and the participants completed a VAS. Participants were then given the same instructions for the anger induction, and were asked to recollect a different memory or further elaborate on the previous one. They were then asked to, again, type a narrative description of the anger inducing experience. Blood pressure and subjective report of anger were measured at the conclusion of this step. The entire experiment took about 1.5 h to complete.

2.1.6. Anger induction

Participants were instructed to recall a time within the past six months when they were angry. Participants were informed that the memories should have a theme where there was a threat to their authority or reputation, they were disrespected, they felt a sense of injustice, or they witnessed a violation of norms or rules. The participants were given two minutes to think about a situation and were asked to "really relive it." They were then given three minutes to type a narrative about the experience on a personal computer. This method was chosen because recent research suggests that autobiographical recall inductions are ecologically valid and show equal or greater effectiveness in inducing angry mood states as other methodologies (Jallais & Gilet, 2010; Salas, Radovic, & Turnbull, 2012).

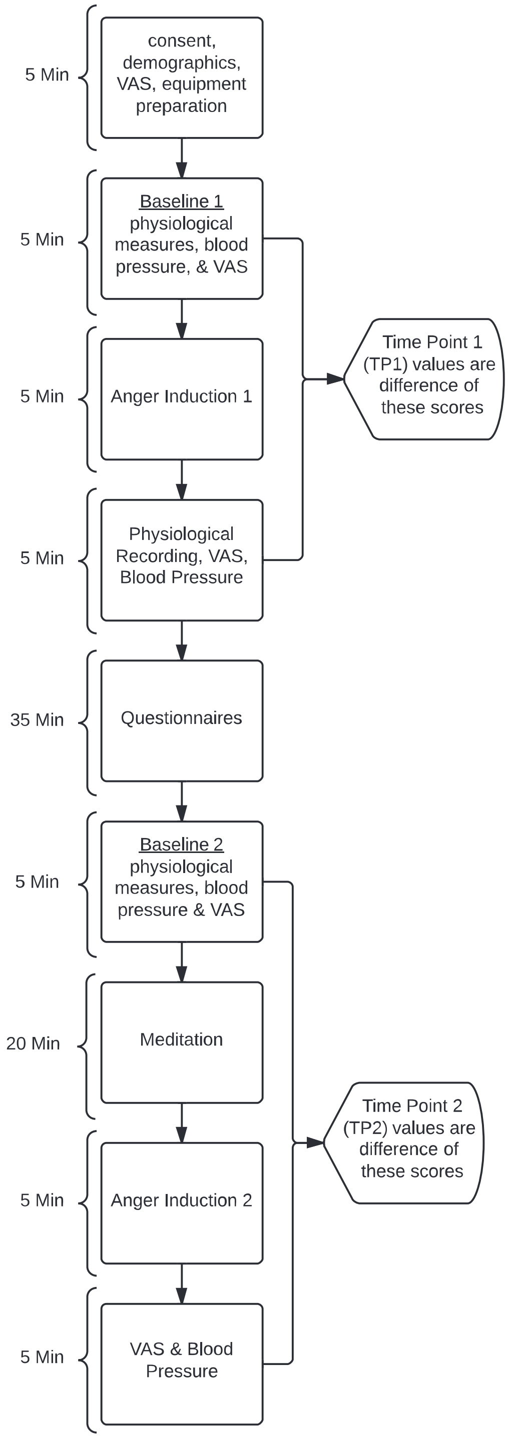

Fig. 1. Timeline of procedure with approximate duration of each step in minutes (left) and what was measured at each step (center). Note that TP1 and TP2 are difference scores of the anger induction measures from the baseline for the control and meditation conditions, respectively.

2.1.7. Meditation intervention

Participants were provided instruction on how to meditate for 20 min using methods derived from a Zen Buddhist meditation, an open monitoring (OM) style (Lutz et al., 2008). Participants sat comfortably on a meditation cushion in a dimly lit room. Participants were told to focus on the area a couple of fingers below their navel and to slightly open their eyes while staring at the ground in front of them. They were instructed to count each inhale and exhale up to ten and then back down to one. They were told to let thoughts come and go and not hold on to any. If they found themselves getting caught up in a thought they were instructed to restart the counting of their breath. A researcher (AF) sat behind the participant to deliver instructions for the duration of the procedures. Any questions were answered before beginning the meditation training.

2.1.8. Physiological data preparation

ECG data were band pass filtered offline between 0.5 and 35 Hz using 8000 coefficients to remove baseline drift and high frequency noise. R–R intervals in the segments of interest were manually examined to verify the accuracy of the data and to correct missed and ectopic beats (Berntson, Lozano, & Chen, 2005). Artifacts were corrected and removed in accordance with guidelines from the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). Acqknowledge 4.4 (Biopac Systems, Inc., Goleta, CA) was used to determine inter-beat intervals from the corrected ECG data, and then HRV was analyzed using the power spectrum density analysis for five different 5-min segments. Fast Fourier transform using a Hamming window was used (Takahashi et al., 2005). The various spectral components were broken down according to their frequencies to very low frequencies VLF (0–.04 Hz), LF (.05–.15 Hz), or HF (.15–.40 Hz) bands (Takahashi et al., 2005). The frequencies were reported in values of absolute power (ms^2). The values were then transformed to normalized low and high frequencies to show the relative power of each component in relation to the total power minus the VLF power. All values for HF-HRV are reported in normalized units, which represent the proportion of HRV occurring in the high frequency band. In addition, sympathovagal balance was calculated as a concomitant measure of HF-HRV influence. HF-HRV is a reflection of the parasympathetic fluctuations resulting from changes in respiration (Task Force, 1996); we controlled for these putative fluctuations by calculating a Sympathovagal Balance of LF/HF HRV to capture both sympathetic and parasympathetic activity (Eckberg, 1997; Pagani et al., 1986). Both SBP and DBP were obtained by averaging three different measures taken in the different condition (baseline, non-meditative anger induction, anger baseline, post-meditation, and meditative anger induction). Respiration was obtained in a similar manner by taking the average breaths per minute (BPM) over three different breathing cycles in the different conditions. All present analyses were compared to analyses by a research assistant blind to the experimental hypothesis, and there was no deviation detected between data sets.

2.1.9. Data analysis

We calculated difference scores at each time point by subtracting the post-anger induction data from pre-induction data, at both time points, for all measures (see Fig. 1); positive values indicate a measurement decreased post-induction, and negative values indicate the measurement increased. Thus, the dependent variables in the study were the difference scores of each measurement at time-point 1 (TP1; the baseline anger condition) and time-point 2 (TP2; anger induction following meditation training). We completed a series of within-subjects or paired-sample t-tests to ensure the anger manipulation worked at TP1, and to assess change in reactivity at TP2. We also conducted paired-sample t-tests to compare the difference scores at TP1 and TP2 to determine if the magnitude of change (i.e., difference scores) were reduced at TP2. We calculated and present Cohen's d as the effect size for these measures (for one-sample t-tests, d_z was calculated; it is assessed comparably to d).

2.2. Results

Descriptive statistics for all time points and for all measures, is presented in Table 1.

2.2.1. Pre-mediation anger (TP1)

Table 2 presents the outcome from the one-sample t-tests utilized for the present analyses delineated by measure and time point. Following the preliminary anger induction, the VAS indicated significantly increased self-reported anger at TP1 ($p < .001$). The t-tests comparing the difference scores to theoretical zero indicated that the anger induction also caused a reliable change in most of the physiological measures utilized in the current research. More specifically, SBP and DBP both increased ($ps < .01$), respiration rate indicated more breaths per minute ($p < .001$), HF-HRV indicated greater time between heartbeats per minute. The Sympatho Vagal balance shifted in the expected direction, however this change trended toward statistical significance ($p < .10$).

2.2.2. Post-mediation anger (TP2)

Following meditation training, at TP2, the direction of Respiration and HF-HRV reversed following the anger induction, such that the number of breaths and beats per minute, respectively, significantly decreased after the anger induction ($ps < .01$). The sympatho vagal balance difference remained unchanged in direction, but was greater after anger induction at trend-level significance. Subjective anger, SBP, and DBP did not approach a significant difference from zero during the anger induction that took place after meditation.

2.2.3. Comparison of TP1 and TP2

Table 3 presents the results of paired-samples t-tests comparing the difference scores of each measure at TP1 and TP2. As can be seen, the difference scores were significantly smaller at TP2 than at TP1 for the VAS and SBP ($ps < .05$). Although the differences did not rise to a level of significance in these analyses, the data were in the expected direction for DBP: TP2 also had a smaller difference score that trended toward significance compared to TP1 ($p = .078$). The scores for HF-HRV was qualitatively different at time points 1 and 2, indicating that the novice meditators had shorter interbeat intervals after the anger induction than before, following meditation training. The difference scores for sympatho vagal ratio did not significantly change at TP2. In sum, subjective measures (VAS) and physiological reactivity (SBP, RESP, DBP, and HF-HRV) indicated attenuated reactivity to an anger induction after meditation training. Each of these differences had a medium to very large effect size.

Table 1
Descriptive statistics of dependent variables across conditions for Experiment 1 (novice meditators).

	B1	A1	TP1 (A1–B1)	B2	A2	TP2 (A2–B2)
RR	17.14 (2.8)	21.65 (2.69)	4.51 (1.49)	16.31 (3.01)	13.24 (3.33)	−3.07 (2.89)
HF-HRV	43.97 (15.36)	36.74 (11.23)	−7.23 (9.48)	34.31 (14.39)	48.02 (21.23)	13.71 (17.07)
Sympatho Vagal	4.06 (0.50)	3.76 (0.43)	0.089 (0.71)	4.046 (0.53)	3.76 (0.64)	−0.29 (0.54)
SBP	125.33 (17.02)	130.55 (19.25)	5.22 (5.87)	120.11 (18.89)	120.56 (17.99)	0.45(5.29)
DBP	80.67 (15.08)	86.44 (16.25)	5.77 (5.56)	79.56 (14.9)	81.11 (14.24)	1.55 (7.11)
VAS	.32 (.62)	2.8 (1.57)	2.48 (1.43)	1.05 (1.03)	1.67 (1.68)	0.62 (1.51)

Notes: Mean (SD); Units for VAS are centimeters, RR are breaths per minute, HF-HRV are normalized units, and SBP/DBP are mmHg; B1 and B2 = Baseline 1 and Baseline 2, A1 and A2 = Post Anger 1 and Post-Anger 2; TP1 and TP2 = Time Point 1 and Time Point 2 (the difference between B1 and A1, and B2 and A2, respectively).

Table 2
One-sample *t*-tests to ensure the anger manipulation worked at TP1, and to assess change in reactivity at TP2 for Experiment 1 (novice meditators).

Measure and time point	*t*	*p*	d_z
VAS TP1	**−6.70***	**<.001**	**−1.73**
VAS TP2	−1.57	.138	−0.41
SBP TP1	**−3.45***	**.004**	**−0.89**
SBP TP2	−0.33	.75	−0.08
Resp TP1	**−11.73***	**<.001**	**−3.03**
RespTP2	**4.11***	**.001**	**1.06**
HF-HRV TP1	**2.95***	**.011**	**0.76**
HF-HRV TP2	**−3.11***	**.008**	**−0.80**
DBP TP1	**−4.03***	**.001**	**−1.04**
DBP TP2	−0.85	.411	−0.22
Sympatho Vagal TP1	−2.13	.052	−0.55
Sympatho Vagal TP2	−2.05	.059	−0.53

Notes: DF 14; **bold** typeface $p < .05$.
* $p < .01$.

Table 3
Results of paired-sample *t*-tests comparing the change scores at TP1 and TP2 for novice meditators.

Measure	TP1	TP2	*t*	*P*	*d*
VAS	**−2.48 (0.37)**	**−0.61 (0.39)**	**−4.97***	**<.001**	**−1.28**
SBP	**−5.22 (1.52)**	**−0.44 (1.37)**	**−2.64**	**.019**	**−0.68**
RESP	**−4.51 (0.38)**	**3.07 (0.75)**	**−8.90***	**<.001**	**−2.30**
HF-HRV	**7.22 (2.45)**	**−13.70 (4.41)**	**4.48***	**.001**	**1.16**
DBP	−5.78 (1.44)	−1.56 (1.84)	−1.90	.078	−0.49
Sympatho Vagal	−0.30 (0.14)	−0.29 (0.14)	−0.06	.950	−0.02

Notes: Descriptive statistics for TP1 (difference scores at Time Point 1) and TP2 (difference scores at Time Point 2) are displayed as M (SEM); values are rounded; **bold** typeface = $p < .05$.
* $p < .01$.

2.3. Discussion

It is apparent that there are broad effects of meditation after a single session of training in the current sample of naïve meditators. Prior to meditation training (TP1) and after an anger induction, the novice meditators reported significantly increased anger via the VAS, and robust physiological markers consistent with anger-related arousal. Following meditation training, the participants showed a robust change such that the anger induction was no longer substantially impactful. In fact, in light of a single meditation training session, following the anger induction, the participants' physiological markers showed *improvement* compared to baseline (i.e., fewer breaths and heartbeats per minute), similar to relaxation. Therefore, this study indicates that engaging in a single session of meditation may be effective for meditation-naïve individuals.

3. Experiment 2: Experienced meditators

3.1. Methods

3.1.1. Participants

Twelve meditators (6 women) responded to flyers posted at meditation centers in the Lawrence, KS area. They provided the number of times per week they meditated, and the length of those sessions. Participants were only included if they reported 30 h of practice within the past six months or 1000 h over their lifetime. Two meditators did not meet the six-month minimum having attained 17.33 and 26.00 h of practice in that time, respectively; however, they were retained in the final analysis as they had completed 1020 and 3000 lifetime hours of practice. The remaining meditators exceeded the minimum for six months of practice (Mean = 75.13, SD = 36.60, Median = 60.67, Range: 34.66–136.50). Seven of the twelve meditators reported that they practiced seven days per week while one each reported practicing 2, 3, 4, 5, or 6 days per week. One meditator primarily practiced Vipassana meditation and the remainder practiced Zen meditation. As with participants in Experiment 1, Experiment 2 participants had no history of head trauma, psychological, or neurological disorders. Participants were excluded if they had any cardiac problems or were prescribed psychotropic medications. Each participant completed informed consent procedures before beginning the experiment. Meditators had an average of age of 52 years (SD = 13.27, Mdn = 51.5, Range: 32–70 years) In comparison to the participants who contributed to Experiment 1, this group was significantly older ($t_{(25)} = -8.69$, $p < .001$, $d = 4.76$).

3.1.2. Procedures

All methodological characteristics of Experiment 2 (with the exception of the research participants utilized) were identical to those described for Experiment 1 (see Fig. 1).

3.2. Results

Descriptive statistics for all time points and for all measures utilized in Experiment 2 are presented in Table 4.

3.2.1. Pre-mediation anger induction (TP1)

As seen in Table 5, at TP1, the subjective measure of anger (VAS) significantly increased following an anger induction in the experienced meditator group ($p = .001$). Also at TP1, this group elicited decreased respiration rate (breaths per minute) following an anger induction ($p < .05$). Though difference scores did not reach significance, this group also elicited a numeric decrease in HF-HRV (time between beats per minute) at TP1 following the anger induction. These observed physiological changes reflect an increase in relaxation rather than an increase in angry arousal.

3.2.2. Post-mediation anger (TP2)

At TP2, change in subjective anger from prior- to post-anger induction was no longer statistically reliable, though the group did report a mean increase in subjective anger following the mood induction. The experienced meditators also elicited reduced breaths per minute ($p = .001$) and increased HF-HRV ($p < .05$) following the anger induction (indicative of relaxation, as in TP1). No other measures at any time point were significantly differing from zero.

3.2.3. Comparison of TP1 and TP2

As seen in Table 6, the VAS was in the expected direction, though not statistically reliable, with a numerically smaller difference in anger at TP2 ($p = .095$). However, no other measure approached significant change as a function of the a single session of meditation. In sum, meditators did not robustly differ in their physiological reactivity and anger levels as a result of having engaged in meditation in the present experimental paradigm.

3.3. Discussion

Although experienced meditators reported increased anger during at least their first session of anger induction, their physiological data contradicted this perceived increase. Their physiological data actually indicated that they were showing trivial change in arousal or even some increase in relaxation following the anger induction. More specifically, at TP1, they elicited more breaths per minute prior to anger induction than after it, indicative of increased relaxation. No other measure approached significance, nor did they reach significance when change scores from both time points were compared directly. Taken together, these data indicate that the meditators were not robustly impacted by the anger induction in terms of physiological arousal.

4. Comparison of participants from Experiments 1 and 2 (exploratory analyses)

As an exploratory exercise, we conducted a series of between-subject *t*-tests comparing the novice and experienced meditators' physiological change scores both at TP1 and at TP2. Table 7 shows the results of independent-samples *t*-tests that compared naive (Experiment 1) and experienced meditators (Experiment 2) separated by time point. Interestingly, the two participant groups did not differ in their self-reported levels of anger either at TP1 or TP2 (see Table 7). As can be seen, experienced meditators significantly differed from the naïve meditators in many important ways when they are both experiencing the first anger induction. The experienced meditators had fewer breaths, greater time between heartbeats, and lower DBP and SBP than novice meditators following the anger induction at TP1. However, at TP2, the groups did not significantly differ on any measure and all effect sizes were substantially smaller (see Table 7).

These analyses were conducted to elucidate whether, and how, a single session of meditation may impact otherwise novice meditators *compared to* experienced meditators. We characterize this cross-group analysis as exploratory given that

Table 4
Descriptive statistics of dependent variables across conditions for Experiment 2 (experienced meditators).

	B1	A1	TP1 (A1–B1)	B2	A2	TP2 (A2–B2)
RR	16.28 (5.55)	13.82 (5.14)	−2.46 (3.74)	15.39 (5.14)	10.5 (3.69)	−4.89 (3.71)
HF-HRV	34.26 (18.76)	42.96 (22.87)	8.7 (15.3)	22.29 (19.17)	34.49 (21.79)	12.2 (16.79)
Sympathovagal	3.96 (0.40)	4.04 (0.40)	−0.30 (0.54)	4.04 (0.36)	3.96 (0.48)	−0.08 (0.64)
SBP	124.17 (14.56)	123.47 (16.46)	−0.7 (7.73)	125 (18.83)	121.81 (16.41)	−3.19 (7.33)
DBP	85.28 (11.59)	85.56 (14.1)	0.28 (5.22)	85.56 (13.73)	85.83 (11.99)	0.27 (4.81)
VAS	.51 (1.05)	2.5 (1.53)	1.99 (1.43)	.82 (1.54)	1.83 (2.06)	1.01(1.78)

Notes: Mean (SD); Units for VAS are centimeters, RR are breaths per minute, HF-HRV are normalized units, and SBP/DBP are mmHg; B1 and B2 = Baseline 1 and Baseline 2, A1 and A2 = Post Anger 1 and Post-Anger 2; TP1 and TP2 = Time Point 1 and Time Point 2 (the difference between B1 and A1, and B2 and A2, respectively).

Table 5
One-sample *t*-tests to ensure the anger manipulation worked at TP1, and to assess change in reactivity at TP2 for Experiment 2 (experienced meditators).

Measure and time point	t	p	d_z
VAS TP 1	**−4.83***	**.001**	**−1.39**
VAS TP2	−1.98	.073	−0.57
SBP TP1	0.31	.762	0.09
SBP TP2	1.51	.159	0.44
Resp TP1	**2.28**	**.044**	**0.66**
RespTP2	**4.57***	**.001**	**1.32**
HF-HRV TP1	−1.97	.074	−0.57
HF-HRV TP2	**−2.52**	**.029**	**−0.73**
DBP TP1	−0.19	.857	−0.05
DBPT TP2	−0.20	.845	−0.06
Sympatho Vagal TP1	0.44	.672	0.13
Sympatho Vagal TP2	−0.41	.692	−0.12

Notes: DF for experienced meditators were all 11; **bold** typeface $p < .05$.
* $p < .01$.

Table 6
Results of paired-sample *t*-tests comparing change scores at TP1 and TP2 of experienced mediators.

Measure	TP1	TP2	t	P	d
VAS	−1.99 (0.41)	−1.02 (0.51)	−1.83	.095	−0.47
SBP	0.69 (2.23)	3.20 (2.12)	−0.85	.415	−0.22
RESP	−2.45 (1.08)	4.89 (1.07)	−1.77	.104	−0.46
HF-HRV	−8.70 (4.42)	−12.20 (4.85)	0.55	.596	0.14
DBP	−0.28 (1.51)	−0.28 (1.39)	0.00	1.0	0.00
Sympatho Vagal	0.09 (0.20)	−0.08 (0.19)	0.94	.367	0.24

Notes: Descriptive statistics for TP1 (difference scores at Time Point 1) and TP2 (difference scores at Time Point 2) are displayed as M (SEM); values are rounded.

the novice group of meditators was substantially younger than the experienced meditators, and, because of age-related changes in baseline physiology, direct comparisons are not advisable due to this difference (Brindle et al., 2014; Labouvie-Vief, Lumley, Jain, & Heinze, 2003). However, since we were analyzing change scores rather than raw data at each step of the experiment, we argue that it makes sense to cautiously examine the relative magnitude of change exhibited by both groups in order to better explicate the benefits of a single session of meditation. The current results provide early evidence that the two groups did not differ in the subjective experience of anger following the anger induction. Both groups reported comparable changes in mood following the anger induction; however the two groups showed marked differences in their physiological response to the first round of anger induction. In other words, the present data indicate that the anger induction was significantly more impactful on the novice meditators than on the experienced group prior to meditation. Importantly, the novice group's difference scores mimicked those of the experienced group after one session of meditation training. Taken together, these results suggest that the physiological benefit of meditation were seen immediately in naïve participants.

5. General discussion

The present study had three aims: to determine if a single meditation session reduces responsiveness to anger subjectively and physiologically, to determine if routine meditation practice can further influence physiological reactivity in naïve

Table 7
Results of exploratory data analyses comparing the difference scores on each measure between novice and experienced meditators at TP1 and TP2.

Measure and time point	Novice [M (SD)]	Experienced [M (SD)]	*t*	*p*	*d*
VAS TP1	−2.48 (1.43)	−1.99 (1.43)	−0.88	.387	0.35
VAS TP2	−0.61 (1.51)	−1.02 (1.78)	0.64	.530	0.25
SBP TP1	**−5.22 (5.87)**	**0.69 (7.73)**	**−2.26**	**.033**	**0.90**
SBP TP2	−0.44 (5.29)	3.20 (7.33)	−1.50	.147	0.60
Respiration TP1	**4.51 (1.49)**	**2.45 (3.74)**	**−6.62***	**<.001**	**2.65**
Respiration TP2	3.07 (2.89)	4.89 (3.71)	−1.44	.163	0.58
HF-HRV TP1	**7.22 (9.48)**	**−8.70 (15.30)**	**3.32***	**.003**	**1.33**
HF-HRV TP2	−13.70 (17.07)	−12.20 (16.79)	−0.23	.821	0.09
DBP TP1	**−5.78 (5.56)**	**−0.28 (5.22)**	**−2.62**	**.015**	**1.05**
DBP TP2	−1.55 (7.11)	−0.28 (4.81)	−0.53	.600	0.21
Sympatho Vagal TP1	−0.30 (0.54)	0.09 (0.71)	−1.61	.120	0.64
Sympatho Vagal TP2	−0.29 (0.54)	−0.08 (0.64)	−0.93	.362	0.37

Notes: All DF = 25; Means, standard deviations, and *d*-values are rounded; **bold** typeface indicates $p < .05$.
* $p < .01$.

meditators, and to compare naïve and experienced meditators reactivity after the introduction of meditation. We hypothesized that a meditative state would lessen self-reported and physiological markers of anger in novice meditators, and would have a greater beneficial effect on experienced meditators; these hypotheses were largely supported. To explore these hypotheses, we asked novice and experienced meditators to engage in anger induction procedures prior to, and then following, meditation training. We expected physiological and self-reported anger to significantly reduce for both groups following meditation training, and that the reactivity would show greater reductions in the novice group than in the experienced group. These hypotheses were supported for the novice group. The experienced meditators did not show any initial indication of anger arousal beyond subjective report, and they showed limited change following the meditation.

Both novice and experienced meditators reported similar levels of trait anger and subjective state anger following an autobiographical induction procedure. As seen in Experiment 1, prior to meditation training, the novice meditators had substantially increased physiological reactivity to the anger induction, while in Experiment 2, experienced meditators exhibited physiological reactivity with either no change in arousal or even in increased relaxation. Further, after a single training session in meditation, both groups exhibited comparable physiological reactivity to anger. Previous studies that demonstrated the benefits of meditation focused on interventions that lasted several days (Shapiro et al., 2008; Tang et al., 2007; Zeidan et al., 2010), and/or compared well-experienced meditators to naïve meditators (Desbordes et al., 2012; Luders et al., 2009; Lutz et al., 2008; Taylor et al., 2011). Therefore, the current study supports and extends previous findings that showed meditation to be an effective approach for reducing state anger (Borders et al., 2010; Robins et al., 2012). To our knowledge, this is the first study to measure the effectiveness of meditation using psychophysiological methodologies following one session.

Autonomic nervous system activity can be used as an index of the type and intensity of emotional states that a person is experiencing. Measures of sympathetic arousal, including RR, SBP and DBP, increase when anger is induced (Ax, 1953; Rainville et al., 2006; Sinha et al., 1992). When asked to "really relive" a past experience that made them angry, all participants in the present study reported increased subjective anger, though only non-meditators exhibited sympathetic arousal consistent with anger response (Ax, 1953; Rainville et al., 2006; Sinha et al., 1992). When the anger induction was completed following a single session of OM meditation at TP2, both groups' subjective anger reduced, and most of the physiological measures of the novice meditators decreased in a pattern similar to routine practitioners. Therefore, the subjective and physiological experience of anger reduced in both groups of participants.

Heart rate variability, which indexes the influence of the PNS influence in the central nervous system (Appelhans & Luecken, 2006), was also significantly increased by a single mediation session for those who were meditating for the first time. Past research results suggest that higher HRV reflects a greater capacity for emotional regulation and the use of constructive coping strategies (Appelhans & Luecken, 2006; Fabes & Eisenberg, 1997; Geisler & Kubiak, 2009; Porges, 2007; Thayer & Lane, 2000). According to Polyvagal Theory, PNS activation is thought to allow for an increase in mental effort for the purposes of inhibition and planning—a *vagal brake*—that occurs during periods of high HRV (Porges, 2007; Segerstrom & Nes, 2007). The use of the vagal brake then reduces energy demands in the periphery, makes glucose available for the metabolic costs of mental effort, and promotes composed reflection (Fairclough & Houston, 2004; Porges, 2001, 2007; Thayer & Lane, 2000). Consistent with this theory, our findings that HF-HRV increased as a result of the meditative state suggests increased PNS activity (Burg et al., 2012; Takahashi et al., 2005).

Also consistent with previous research, the present sample of novice participants showed reduced RR and increased HF-HRV following meditation training (Burg et al., 2012; Rainville et al., 2006), though previous literature has not used anger induction in their investigations. The present findings provide further support that sympathetic influence dominates the autonomic nervous system during an angry experience (Marci et al., 2007; Rainville et al., 2006; Tyson, 1998), and that the sympathetic nervous system's activation can be reduced by PNS activation via meditation (Burg et al., 2012). Despite their reported experience of subjective anger, experienced meditators showed no marked changes in physiological reactivity following an anger induction, suggesting their PNS dominance may have become automatic over time (Tang & Posner, 2013).

The sympathovagal balance was not significantly impacted by the anger induction or the meditation intervention for experienced meditators. For novice meditators, the balance approached significance following both anger inductions; however, the difference scores did not significantly differ between groups, nor did they significantly change between time points. As discussed above, HF-HRV has been proposed as an index of parasympathetic fluctuations resulting from changes in respiration, though this hypothesis has long been controversial (Billman, 2013; Eckberg, 1997). The Sympathovagal Balance is a ratio of LF/HF HRV and, therefore, putatively captures fluctuations related to both sympathetic and parasympathetic systems. There are a number of limitations of this method that prevent its ability to adequately control for both frequencies (Billman, 2013). One explanation for the present findings is that alterations in the LF component negated the effect of the Sympathovagal Balance (Billman, 2013). In previous studies that have demonstrated change in the ratio of LF/HF using meditation and/or yoga, the interventions had been longer, had higher intensity, and/or focused almost exclusively on altering respiration than the present intervention (Kharya et al., 2014; Pal, 2015; Pal et al., 2014). Additionally, there is evidence that the LF/HF ratio is sensitive to the type of meditation used (Pal, 2015; Sarang & Telles, 2006). It may be that the short duration of the intervention and/or the use of an OM style of meditation is not sufficient to elicit changes in the LF/HF ratio using the present methods. Additional time, participants, and/or more intensive interventions may elicit more notable effects than observed in the present study.

Prior findings suggest short-term meditation interventions are successful for novice meditators at increasing positive affect and reducing distress (Borders et al., 2010; Chambers et al., 2008; Prasad, Wahner-Roedler, Cha, & Sood, 2010; Rausch et al., 2006; Shapiro et al., 2008). While there have been several investigations of a single session of meditation on naïve participants (Carlson et al., 1988; Fabes & Eisenberg, 1997; Rausch et al., 2006), to our knowledge, no previous study has utilized psychophysiological measures to elucidate the immediate effects of meditation. Both of our participant groups exhibited a reduction in physiological activity after meditation, but the change was more striking for the naïve group. The present results support the use of meditation as an effective adjunct in the treatment of anxiety, stress, and emotion dysregulation both subjectively and with potentially immediate benefit to physiology (Carlson et al., 1988; Hofmann et al., 2011; Jain et al., 2007; Lutz et al., 2015; Pawlow & Jones, 2002; Saini, 2009).

The exploratory examination of between–groups differences in physiological reactivity at TP1 suggests that there are sustained benefits of regularly meditating, consistent with previous literature (Desbordes et al., 2012; Luders et al., 2009; Lutz et al., 2008; Taylor et al., 2011). Our results suggest that regular meditation may alter the way in which angry situations are internally experienced, leading to reduced physiological reactivity compared to when an individual has never meditated. There is evidence that altered (typically improved) cognitive processing of negative and/or emotionally arousing situations may also reduce physiological reactivity, and this might be one mechanism by which OM meditation leads to a change in perspective allowing a flexible reaction to angry situations (Chiesa et al., 2011; Denson, 2013; Kang et al., 2012), perhaps through improvement in cognitive functioning (Ainsworth et al., 2013; Lippelt, Hommel, & Colzato, 2014; Zeidan et al., 2010). Future studies could investigate the role of meditation both with physiological measures and using cognitive assessments.

We characterize the between-groups analyses as exploratory because there was a large age difference between the two participant samples utilized in the experiments. We recognize that age may have impacted the physiological reactivity that may have contributed to differences between the two groups at TP1. Previous research has shown that older adults are less physiologically reactive to anger than younger adults (Brindle et al., 2014; Labouvie-Vief et al., 2003). Despite these age-related differences, it is striking that, following meditation training, novice meditators exhibited a complete reversal of their physiological measures while subjective measures did not significantly differ between groups. These findings highlight the impact of meditations after just one session of meditation training: the anger-related reactivity of the naïve group not only mimicked habitual meditators, but that of older adults. Future studies should investigate age-related impacts of meditation training.

5.1. Limitations and future directions

Although this study makes important contributions to our understanding of the mechanisms of change that meditation may produce, the findings should be interpreted in light of some limitations. We used a single-subject design that can begin to address the causality of the meditation intervention; however, the present study cannot address whether meditation reduced the anger proneness of practitioners, or if they were naturally less anger-prone prior to meditative practice. There is some evidence that individuals with lower emotional reactivity begin and sustain meditative practice (Geisler & Kubiak, 2009), while others show that anger-prone individuals are more likely to sustain meditative practice (Segerstrom & Nes, 2007). The two groups in this study did not reliably differ on a measure of trait anger-proneness, though it was beyond the scope of the present study to examine this potential confound further. The autobiographical method of anger induction has shown validity in previous research (Salas et al., 2012), though other methodologies and/or means of inducing and validating anger could be used. It is possible that individuals can fake their physiological reactions as a result of unknown demand characteristics (Burg et al., 2012; Porges, 2001); however, the concordance of subjective and physiological reports makes this unlikely in the present study. We utilized an open-monitoring style of meditation, but there are other styles that can be included for comparison in future studies (e.g., focused-attention) as they have been found to impact cognition in different patterns (Lutz et al., 2015). Future investigations may consider using different study designs (e.g. crossover or multiple baseline), meditation styles, integrating a placebo condition, or controlling for social desirability to replicate and extend the current findings.

Despite these limitations, the present study shows clear evidence that a single session of meditation can have strong impact on the experience of anger. It remains unclear to what degree the physiological (i.e., patterned breathing) and cognitive (i.e., refocused attention) components of OM are necessary in combination, or can be implemented separately, in order to be an effective intervention for state and trait anger. Doing so can also elucidate the role of top-down or bottom-up processing in emotional experience. It is an important avenue for future research to understand the mechanisms of change due to meditation in order to emphasize these aspects in treatment or other interventions. An additional avenue for future research could include neuroimaging methods to better clarify how these psychophysiological changes may be represented in the brain and mind. Extant research suggests that habitual meditators, as compared to novice controls, show reduced amygdala and medial prefrontal cortex activation while in a non-meditative state (Desbordes et al., 2012; Taylor et al., 2011), and have larger gray matter volume in the right orbitofrontal cortex, all of which are associated with emotion regulation (Luders et al., 2009). Future research should investigate how a single session of meditation may impact these and other brain regions.

Conflict of Interest

The authors declare no conflicts of interest.

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