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Recovery from stress: an experimental examination of focused attention meditation in novices

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Abstract Identifying strategies that aid in recovery from stress may benefit cardiovascular health. Ninety-nine undergraduate meditation novices were randomly assigned to meditate, listen to an audio book, or sit quietly after a standardized stressor. During recovery, meditators' heart rate variability and skin conductance levels returned to baseline, whereas only heart rate variability returned to baseline for the audio book and control groups. Positive and negative affect were no different than baseline following meditation, whereas, both audio book and control groups had lower positive affect and higher negative affect following the intervention. Findings suggest that the sympathetic nervous system is uniquely affected by meditation, and novices may benefit emotionally from meditating after a stressor. Further research is needed to determine meditation's utility in recovering from stress.

Keywords Cardiovascular recovery · Coping · Meditation · Stress

Introduction

Research shows that people who have greater cardiovascular reactivity during stress are more likely to have poorer cardiovascular health in the future (Carroll et al., 2001; Light et al., 1992; Murphy et al., 1992; Markovitz et al., 1998; Newman et al., 1999). More recent cardiovascular research shows that people who take longer to recover from a stressful event also are more likely to have poorer future cardiovascular health (Chida & Steptoe, 2011; Stewart et al., 2006; Brosschot et al., 2005; Treiber et al., 2001; Borghi et al., 1986). Given the recovery period—the time immediately following a stressful event—is linked to health outcomes and it is a better time to focus on stress-reduction than during a stressor, it seems prudent to find techniques that help people's cardiovascular system recover from stress.

A handful of studies have shown that simply filling out questionnaires (Glynn et al., 2002), walking in place (Chafin et al., 2008), and listening to music (Chafin et al., 2004) can lead to better cardiovascular recovery times compared to doing nothing. The underlying mechanism for these quicker recovery times, one could argue, is distraction of participants from negative thoughts (i.e., rumination) about the stressor.

Meditation, specifically the act of focusing the mind on something (e.g., an object, the breath, a mantra, or the moment) and gently steering the mind back to the task when it wanders, may likewise distract a person from a stressor and lead to quicker recovery. However, its effects on the cardiovascular system should extend beyond that of simple distractions because meditation also involves the slowing of one's breath. Slower breathing is linked to increases in parasympathetic nervous system activity (Braboszcz et al., 2010; Van Diest et al., 2014). Meditation is also linked to decreases in sympathetic nervous system activity (SNS; Cuthbert et al., 1981; Holmes et al., 1983). These changes in the autonomic nervous system may lead to decreases in blood pressure (BP) and heart rate (HR; Benson et al., 1974a). Therefore, meditation may lead to

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quicker BP and HR recovery from stress compared to simple distractions.

Indeed, meditation studies examining physiological activity during meditation, at rest or across the day (while not meditating) show that meditation leads to immediate and long-term decreases in BP and HR (Barnes et al., 1999; Benson et al., 1974b, 1974c; Cauthen & Prymak, 1977; Cuthbert et al., 1981; Ditto et al., 2006; English & Baker, 1983; Holmes et al., 1983; Manikonda et al., 2008; Peters et al., 1977; Solberg et al., 2004; Rainforth et al., 2007). However, currently there is only one dissertation study (Key, 2010) regarding the cardiovascular effects of meditating during recovery from stress; Key (2010) found no differences in BP and HR when comparing a mindfulness meditation group to a distraction group during recovery from stress.

The lack of published studies with people meditating during recovery from stress may be a null-findings file-drawer problem; researchers have noted the difficulty of capturing the effects of meditation in the lab, particularly when working with novices (Cuthbert et al., 1981; Ditto et al., 2006; English & Baker, 1983). Given the need for high-quality study designs that include random assignment to groups while also managing time-constraints, several researchers have trained novices to meditate in their studies. Because meditation is a skill that takes time to hone and is typically practiced in a calming environment, examining novice meditators in the sterile laboratory may underestimate its effects. Therefore, in addition to examining BP and HR when using novice meditators, it would be valuable to also look at underlying autonomic variables; Key (2010) measured only BP and HR in novices meditating during recovery from stress. Ditto et al. (2006) examined respiratory sinus arrhythmia (i.e., index of PNS) and pre-ejection period (i.e., index of SNS), in addition to measuring HR and BP in novices who meditated without a stressor present. Results of this study indicated that meditation seemed to increase arousal, which is contrary to commonplace understandings that meditation leads to relaxation. Interestingly, Ditto et al. (2006) found that both PNS and SNS activity increased when novices meditated, but not when they listened to an audio book; however, there were no differences between groups in HR decreases over time. This study highlights the value of collecting indices of PNS and SNS activity because they can lead to a fuller understanding of meditation's physiological effects, especially when there appears to be no effects of meditation on HR.

In the current study, we replicate existing studies that compare the effects of guided meditation to distraction and sitting quietly (Ditto et al., 2006; Key, 2010) and extends research by using a different form of meditation and distraction in the context of post-stress recovery. BP, HR, heart rate variability (HRV; i.e., index of PNS), skin conductance (i.e., index of SNS), and mood were measured. In order to determine whether focused-attention meditation has any unique effect on the cardiovascular system, it was compared to simple distraction (i.e., listening to an audio book) and to resting quietly (i.e., control group) during recovery from stress. Consistent with past work (Ditto et al., 2006), an audio book was used to control for the fact that the meditation group was following along with a voice recording, and the simple act of listening to a voice could potentially be distracting enough to influence recovery from stress. We hypothesized that, following a stressor, BP and HR would be lower earlier in the recovery period for the meditation group than for audio book and control groups. We also hypothesized that mood would be more positive and less negative in the meditation group compared to the other two groups. Finally, we explored the extent to which meditation would lead to differential recovery in markers of parasympathetic activity (HRV) and sympathetic activity (skin conductance). Previous findings are mixed in terms of meditation's effects on the SNS, with some studies showing decreases in SNS activity (Cuthbert et al., 1981; Holmes et al., 1983) and others showing an increase in SNS activity (Ditto et al., 2006). Nonetheless, if meditation brings about a relaxation response during recovery, PNS activity should increase and SNS activity should decrease.

Method

Study design

This study was a randomized design that included three groups (meditation, audio book, and control). At the testing session, participants sat quietly for a baseline, were exposed to a stressor, and then engaged in their respective intervention. Baseline responses were compared to recovery period responses, making this a 3 Group (meditation, audio book, and control) × 19 time (1 baseline average and 18 1-min epochs of recovery) mixed model design.

Participants

Participants were recruited over a 6-month period via an online recruitment system of psychology undergraduates in a Midwestern university. Participants were randomly assigned to either the meditation, audio book, or control group (ratio 1:1:1). Block-randomization by gender (via randomizer.org) ensured that there were equal numbers of men in each group given a higher number of women in the research pool. Ninety-nine participants (60 women, 39 men, M_{age} = 18.94 years, age range 18–22 years) attended

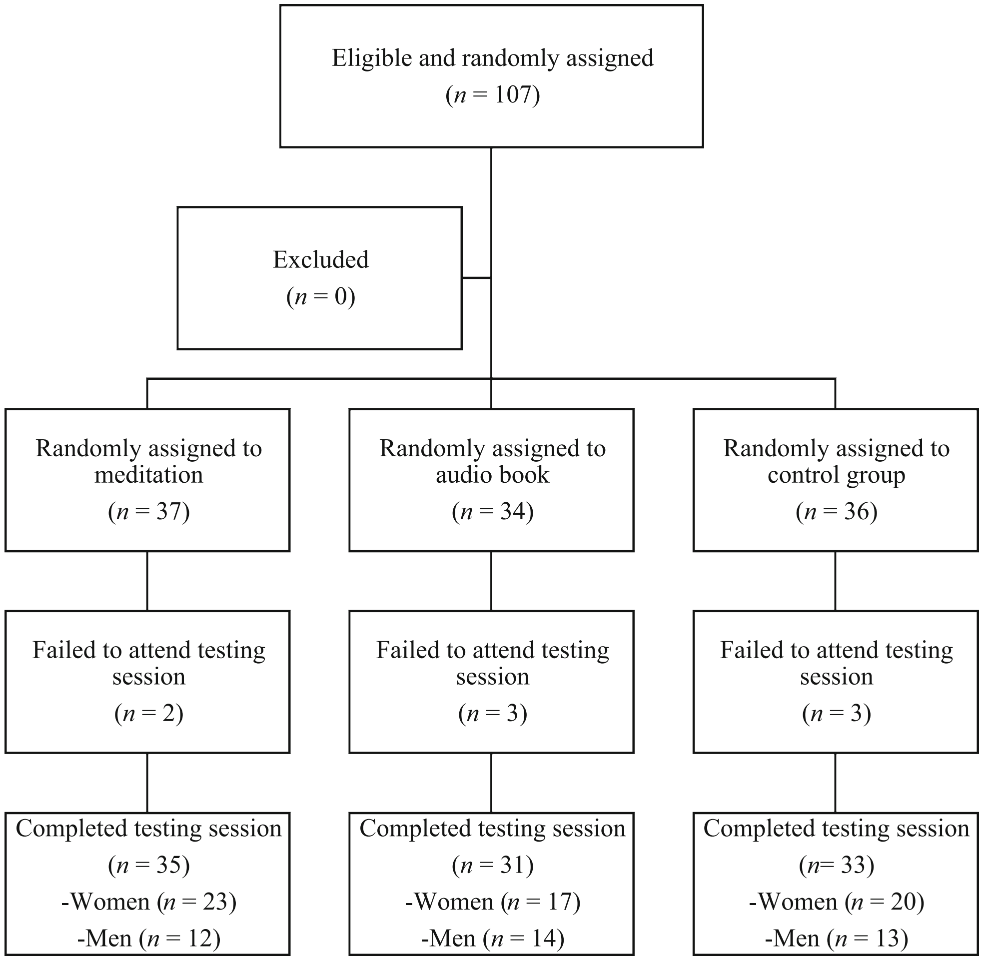

Fig. 1 Participant flow diagram

both adaptation and testing sessions (see Fig. 1). Due to physiological equipment failure or failure to answer questions, sample size varied for the analyses. In order to avoid expectancy effects, participants were asked after the study how often they meditated; three people in the meditation group, two in the audio book group, and three in the control group reported meditating several times and all other participants reported meditating either never, once, or a few times. All of the participants were included in the reported analyses because experience with meditation was equally distributed across groups and results remained the same when they were excluded from analyses. Participants attended two 1-h sessions and received two research credits (1 credit/1 h session) and $10 for the completion of the second session. Participants were restricted to men and women who: (a) had no major medical problems (i.e., hypertension, heart or blood vessel diseases, seizures, or other chronic conditions), (b) did not routinely take medications other than birth control, (c) were non-smokers, (d) were not pregnant or nursing, (e) had not exercised for 2 h prior to the session, and (f) had not consumed alcohol for 12 h or caffeine for 2 h prior to the session.

Procedure overview

Session 1 and 2 were spaced approximately one week apart at the same time of day. During both sessions participants filled out questionnaires and participated in one of three activities (listening to a meditation CD, listening to an audio book CD, or sitting quietly). At the second session, participants additionally engaged in a standardized stressor prior to their assigned intervention. Physiological measures were collected throughout each session.

Interventions

Meditation

Participants in the meditation group were trained using an audio CD (Hoblitzelle, 2014, track 1). The opener to the track invites participants to relax, focus their attention, and engage in the meditation practice. The script contains several focused attention meditation techniques (e.g., focusing on the breath, the body, or a mantra). The 20-min CD was played at both sessions with the following prompt: "Please sit quietly for the next 20 min and follow along with the instructions you will hear shortly."

Audio book

In an attempt to control for potential distraction effects of listening to the voice on the meditation CD, an audio book with seemingly neutral material was included as a comparison group. A Study in Scarlet, (Doyle, 1894/2010), was recorded, using the same woman's voice, tone, and speech pattern as the meditation CD. Participants in the meditation and audio book groups, therefore, spent the same amount of time sitting quietly while listening to the same woman's voice. The first 20 min of the book were played at the adaptation session, the next 20 min of the book were played at the testing session. The following prompt started the intervention: "Please sit quietly for the next 20 min and listen to the audio book that you will hear shortly."

Control group

Participants in this group sat quietly and did not listen to a CD. They were given the following prompt: "Please sit quietly for the next 20 min and try not to fall asleep."

Measures

Demographics and health questions included: age, gender, race, class standing, health history, and medication use.

Expectancy questionnaire

During the adaptation session, participants were asked the extent to which they thought 11 activities would help them cope with a stressful experience; meditation and listening to an audio book were embedded among the nine distractor items (e.g., listening to music, talking to friends, exercising, drinking, watching a movie). Visual analog scales were used with endpoints "not at all" and "very much so".

Positive and negative affect schedule

The Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) is a 20-item questionnaire that assesses affect. Participants rate 10 positive affect adjectives and 10 negative affect adjectives on a 5-point scale ranging from "very slightly/not at all" to "extremely" in terms of how they feel right now. The positive and negative scales are largely independent of one another. Scores are summed separately for the two scales. Both the positive and negative affect scales are highly correlated with other measures of positive and negative affect (Watson et al., 1988). Items for each scale were summed (and reverse scored when necessary).

Blood pressure and heart rate

An Ohmeda Finapres 2300 BP monitor assessed systolic blood pressure (SBP), diastolic blood pressure (DBP), and HR continuously. The finger cuff was placed on the participant's third finger of his or her non-dominant hand immediately before baseline, and his or her hand rested at heart level on a small adjustable table at the participant's side. The Finapres reliably measures changes in BP (Nelesen & Dimsdale, 2002). Prior to baseline, one or more intermittent brachial BP measurements were taken using a Colin Press Mate BP monitor (Colin Medical Instruments, Inc), and the arm was repositioned if necessary so that readings were no more than 10 mmHg different between the two machines.

Skin conductance

Skin conductance level was measured to index SNS activity. A Biopac MP100 system, Biopac UM100A coupler and standard 4 mm well-type electrodermal transducers (Biopac TSD103A Ag/AgCl) with electrode electrolyte gel continuously measured skin conductance levels and responses. The MP100 was interfaced with a Dell computer running AcqKnowledge 3.2.6 software. Two electrodes were placed on the participant's non-dominant hand, one on the volar surface of the distal phalange of the 4th finger and the other on the 5th finger. AcqKnowledge was calibrated for lower frequency response at DC conductance ranges. Gain settings on the coupler were set to 5 µmho/V, and the selection switch for lower frequency response was set at DC. The sampling rate was 200 samples per second.

Heart rate variability

HRV was measured to index PNS activity's influence on the heart. A Polar RS800cx WearLink® W.I.N.D. sensor and transmitter belt collected R–R interval data continuously and noninvasively and sent this data wirelessly to a computer. Data were recorded on the computer with Polar Pro-Trainer 5 software (Polar Electro, Kempele, Finland). Kubios HRV Analysis Software 2.0 was then used to correct for artifacts and extract HRV data (Tarvainen et al., 2008). One-minute segments of data were analyzed following recommendations that epochs should be the same size when making comparisons (Task Force, 1996). Data segments were visually examined for artifacts, and when RR intervals were outside the plausible range of values (i.e., 300–2000 ms; Timonen et al., 2006), corrections were applied with the Kubios automated artifact correction option (i.e., artifact beats are replaced using cubic spline interpolation (Tarvainen et al., 2008).

For both the baseline and stressor the middle minute of data was used in analyses as well as each minute of the recovery period. A time-domain parameter, the root mean square of successive differences between inter-beat-intervals (RMSSD), expressed in ms, was calculated by the Kubios 2.0 software. We chose RMSSD as our primary HRV variable of interest because it reflects vagal tone, or the PNS's effect on cardiac regulation. RMSDD is highly correlated with high frequency HRV, and it is less influenced by breathing than other HRV parameters (Hill & Siebenbrock, 2009; Penttilä et al., 2001). RMSSD values were transformed using the natural log (ln) in order to fit the assumptions of linear analyses. Therefore, lnRMSSD was used for statistical analyses.

Manipulation check questionnaire

A visual analog scale with endpoints of "not at all" and "very much so" was used to ask questions gauging the perceived stressfulness of the stressor, ability to cope with the stressor, rumination, relaxation, and how distracted participants were during the recovery period. To answer questions, participants placed a slider bar along the scale. Unbeknownst to the participant, Qualtrics then provided a corresponding numeric value ranging from 0 to 100. Items were modified from Bradley and McCanne (1981) and Chafin et al.'s (2004) studies and were also guided by Benson et al. (1974a) recommendations regarding the necessary components needed to meditate.

In addition, participants in the meditation and audio book groups were asked four specific attention-check questions regarding their respective CDs; they were not told in advance that they would be asked these questions. Each question was geared toward one 5-min period of the CD to determine if participants attended to the CDs throughout the duration.

Mental arithmetic task

The original Paced Auditory Serial Addition Test (PASAT; Gronwall, 1977) was designed to measure cognitive functioning but has also been adapted for use as a psychological stressor because it produces physiological reactions (Willemson et al., 1998). For 6 min, participants are presented with single digits ranging from 1 to 9 at set intervals and are asked to add each new digit to the digit presented immediately before it, saying the answer out loud. An unpaced practice trial of 10 digits is given to participants prior to the actual task in order to ensure participants' understanding of the task instructions; participants are given up to three practice trials if needed. The task is presented via audiotape in 2-min presentations of increasing difficulty: 1 digit per 2.4 s, 1 digit per 2.0 s, and 1 digit per 1.6 s.

Procedure

Sign ups for the study were via an online recruitment system for psychology undergraduates. Participants came to the laboratory for two individual sessions, an adaptation session and testing session, scheduled at the same time of the day within seven days of one another. Because cardiovascular variables were measured, participants were instructed to refrain from the following prior to the laboratory sessions: alcohol for 12 h, caffeine, nicotine, and exercise for 2 h.

Adaptation session

English and Baker (1983) suggest including an adaptation session to reduce reactivity. The adaptation session in this study served two functions: (1) to help acclimate all participants to wearing the physiological equipment and using the survey website, and (2) to give the meditation group practice meditating. The physiological data and most self-report data collected at the adaptation session were not used for the purposes of this study.

Once participants reviewed, asked questions, and signed the consent form, and it was determined that they met all eligibility criteria of the study, physiological recording apparatuses were attached to the participant in the testing room of a laboratory. The room was small, dimly lit, and included a comfortable chair. Physiological variables were measured continuously throughout the session. During the 5-min adaptation and 10-min baseline periods, participants filled out the health and demographics questionnaire and the expectancy questionnaire; all self-report measures were administered through Qualtrics web-based software (www.Qualtrics.com). Participants were given a notification if they missed a question, and they had the option to skip questions they did not want to answer. Participants were then randomly assigned to a group and the experimenter entered the room and provided corresponding instructions. Each participant engaged in their assigned intervention for the next 20 min. At the end of the 20-min, participants scheduled their second session and had their height and weight measured.

Testing session

At the beginning of the session, informed consent was reviewed, physiological apparatuses were attached, and participants sat quietly for roughly 15 min. Then, the participant filled out the PANAS. Next, an experimenter that the participant had not met before entered the room and administered the PASAT math stressor. In order to engage participants in the task, they were told that they should be able to respond correctly to 80% of the summations given their age cohort; in reality, the task is very challenging and reaching 80% is not probable. The experimenter administered the stressor while wearing a white lab coat and standing about two feet in front of the participant during the task recording all errors on a clipboard and prompting the participants to continue when necessary. This experimenter's demeanor was meant to convey a sense of neutrality (the primary experimenter that interacted with the participant at all other times was more cordial in nature). The stressor experimenter did not greet the participant, but merely entered, turned up the lights, explained the task, answered questions, administered the task, turned down the lights, and left after the task ended. Immediately after the experimenter left the room, audio-recorded instructions specific to participant's assigned group played through speakers. Once the 20-min recovery period was over, participants filled out the PANAS and manipulation check questionnaires. When participants were done, the physiological apparatuses were removed, and participants were debriefed, thanked, and given their compensation.

Data reduction and data analysis

All data analyses were performed using SPSS for Windows version 19.0 (SPSS Inc., Chicago, IL, USA; Norusis, 2008), alpha was set at .05, and all analyses were two-tailed. Data that were more than 3 standard deviations from the mean for the baseline or stressor were considered outliers and were excluded from that particular dependent variable analysis (skin conductance, $n = 1$). For RMSSD, prior to transforming the data, outliers in the recovery data were imputed by replacing the value with the average of the other recovery epochs if the value differed from adjacent points by 30 or more; less than two percent of the entire dataset was imputed, with no more than 15% of the data for any one participant. Some data were lost primarily at the start of data collection due to equipment issues (BP & HR, $n = 10$; Skin conductance, $n = 14$; HRV, $n = 27$), and as such, sample sizes varied from analysis to analysis. Sample sizes also vary for self-reported data because participants were allowed not to answer questions.

Mauchly's test of sphericity (Mauchly, 1940) was used and the Greenhouse–Geisser procedure (Greenhouse & Geisser, 1959) was applied when necessary. When appropriate, follow-up pairwise comparisons were performed for each group (with baseline as the reference value) to compare baseline to each of the time points of the recovery period using the Bonferroni correction for multiple comparisons ($p = .05/18$).

Baseline differences

To ensure that there were no baseline differences between groups, separate one-way ANOVAs were performed for SBP, DBP, HR and skin conductance on the mean of min 2–9 of baseline and the middle 1 min of baseline for HRV.

Stress reactivity

To check that all groups showed significant reactivity from baseline to the math stressor, repeated measures ANOVAs were performed for each physiological dependent variable, with group (meditation, audio book, and control) as the between-subjects factor and time as the within factor; time included the average for baseline and the 6-min average of the stressor for SBP, DBP, HR and skin conductance (or the middle 1-min average of the stressor for HRV).

Recovery from stress

In order to test whether those who meditate have lower BP and HR earlier in the recovery period compared to the audio book and control groups, and to explore HRV and skin conductance responses, repeated-measures ANOVAs were performed for each dependent variable. The recovery period lasted 20 min; only the first 18 min were included in analyses because participants displayed increased arousal in anticipation of the end of the laboratory visit. An average for each physiological measure was calculated for each 1-min epoch of the recovery period. The middle 1 min of baseline was used for HRV and an 8-min average of baseline was used for BP, HR, and skin conductance. For all dependent variables, each of the 18 1-min epochs were compared to the baseline epoch in a 3 Group (meditation, audio book, and control) x 19 Time (1 baseline epoch and 18 1-min epochs of recovery) repeated-measure ANOVA, with group as the between-subjects factor and time as the within-subjects factor.

Mood and other questionnaires

To assess for differences between the three groups (Meditation, Audio book, Resting Control) in mood (i.e., PANAS), separate repeated measures ANOVAs were performed for positive affect and negative affect, with group

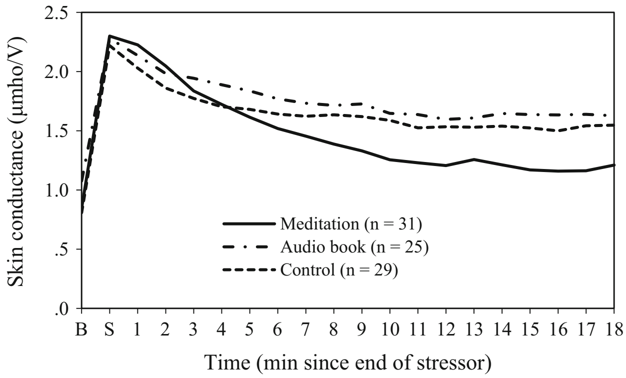

Fig. 2 Skin conductance levels at baseline, stressor, and each 1-min average during the first 18 min of recovery. B, baseline; S, stressor

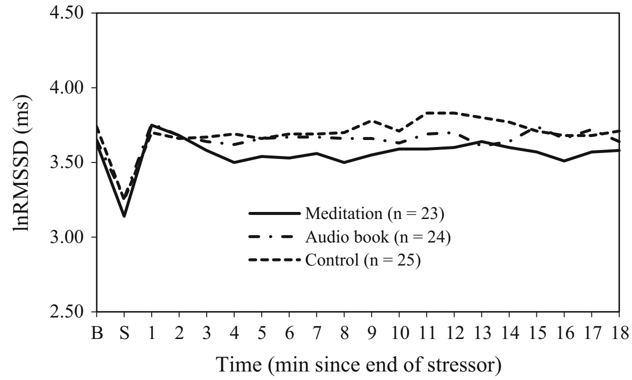

Fig. 3 lnRMSSD at baseline, stressor, and each 1-min average during the first 18 min of recovery. B, baseline; S, stressor

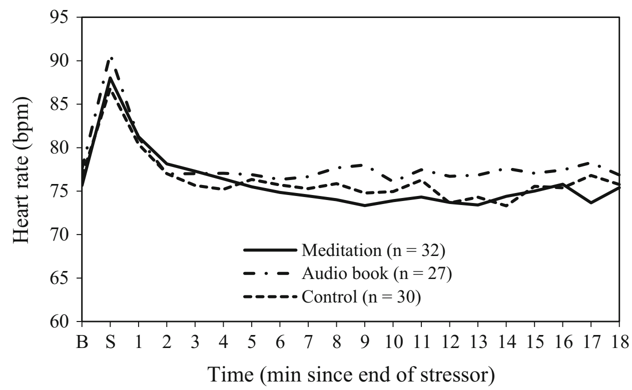

Fig. 4 Heart rate at baseline, stressor, and each 1-min average during the first 18 min of recovery. B, baseline; S, stressor

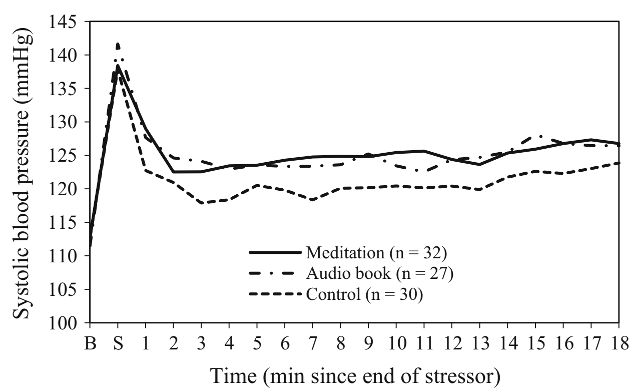

Fig. 5 Systolic blood pressure at baseline, stressor, and each 1-min average during the first 18 min of recovery. B, baseline; S, stressor

as the between-subjects factor and time (after Baseline and after Recovery) as the within-subjects factor. All other self-report questions were analyzed separately using one-way ANOVAs with the Bonferroni adjustment or Chi square test of independence to test for differences among groups.

Results

Physiological results

Baseline comparison

There were no significant differences among groups for any of the dependent variables when comparing baseline physiological values ($ps > .05$). Therefore, none of the subsequent analyses used baseline as a covariate.

Stressor reactivity

Repeated measures ANOVAs confirmed that the math task produced a stress response for all groups; from baseline to stressor, SBP, DBP, HR, and skin conductance significantly increased and HRV significantly decreased ($ps <$ .01). As expected, there were no significant differences across groups in reactivity for any of the dependent variables. See Figs. 2, 3, 4, 5 and 6 for physiological response trajectories by experimental group.

Stress recovery

The meditation group was expected to recover sooner than the other two groups for all dependent variables; however, this was only true for skin conductance (see Table 1 and Fig. 2). Specifically, repeated measures ANOVAs showed there was a significant Time x Group interaction for skin conductance, adjusting for sphericity, $F(5.70, 233.73) = 3.04$, $p = .008$, $\eta_p^2 = .07$, observed power = .90. Pairwise comparisons, using the Bonferroni adjustments, showed that beginning at min 10–12 of recovery, and continuing with min 14–17, the meditation group's skin conductance levels were not significantly different from

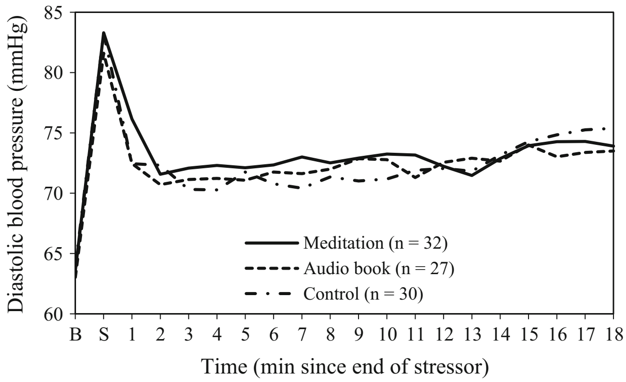

Fig. 6 Diastolic blood pressure at baseline, stressor, and each 1-min average during the first 18 min of recovery. B, baseline; S, stressor

baseline levels. Thus, meditation led to decreases in SNS activity.

For HRV, there was a significant time main effect, adjusting for sphericity, $F(11.17, 770.81) = 1.82$, $p = .05$, $\eta_p^2 = .03$, observed power = .86 (see Table 1). However, within-subjects contrasts showed no significant differences between baseline and recovery periods. As illustrated in Fig. 3, PNS activity returned to baseline levels immediately after the stressor and remained there throughout the recovery period for all groups. Therefore, meditation did not differentially influence HRV recovery.

Table 1 Examination of time × group repeated-measures analysis of variance for each dependent variable

Variable	Group	*n*	*df*	*F*	Observed Power	η_p^2
SC	Meditation	31	5.70, 233.73	3.04*	.90	.07
	Audiobook	25				
	Control	29				
lnRMSSD	Meditation	23	22.34, 770.81	1.11	.85	.03
	Audiobook	24				
	Control	25				
HR	Meditation	32	22.73, 977.37	1.36	.93	.03
	Audiobook	27				
	Control	30				
SBP	Meditation	32	10.68, 459.05	.44	.24	.01
	Audiobook	27				
	Control	30				
DBP	Meditation	32	9.59, 412.18	.53	.27	.01
	Audiobook	27				
	Control	30				

Greenhouse–Geisser correction was used for each dependent variable. lnRMSSD = log-transformed root mean square of successive differences (i.e., an indicator of heart rate variability)

SC skin conductance, *HR* heart rate, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

$^*p < .05$

There were no significant time × group interactions or Group main effects for SBP, DBP, or HR (see Table 1). As shown in Figs. 4, 5 and 6, meditation, compared to the other two conditions, did not influence HR, SBP, or DBP recovery from stress. There were significant time main effects for HR, SBP, and DBP. Unexpectedly, within-subjects contrasts revealed that HR returned to baseline levels 1 min after the stressor ended and remained at baseline levels throughout the recovery period, Fs = .02–3.54, ps > .05, except for a few increases in the middle of the recovery period (during min 10, 12, and 13). Within-subjects contrasts also revealed that SBP and DBP levels remained significantly higher than baseline throughout the recovery period for all groups, SBP, Fs = 37.58–59.96; DBP, Fs = 43.01–85.14, ps < .003.

Self-report results

Panas

The PANAS was given immediately before the stressor and immediately after the recovery period to assess mood. Cronbach's α for the positive affect scale was .89 prior to the stressor and .78 after the recovery period. For negative affect, Cronbach's α was .91 prior to the stressor and .84 after the recovery period. There were no differences among groups at baseline for positive affect, $F(2, 91) = .189$, $p = .83$, or negative affect, $F(2,90) = .67$, $p = .51$. Unexpectedly, there was also no significant group × time interaction for positive affect, $F(2, 84) = .78$, $p = .46$, $\eta_p^2 = .02$, observed power = .18, or negative affect, $F(2, 81) = .89$, $p = .42$, $\eta_p^2 = .02$, observed power = .20. However, across time there was an overall decrease in positive affect, $F(1, 84) = 16.93$, $p < .001$, $\eta_p^2 = .17$, observed power = .98, and an overall increase in negative affect, $F(1,81) = 18.82$, $p < .001$, $\eta_p^2 = .19$, observed power = .99, presumably as a result of the math stressor.

Consistent with hypotheses, positive affect appeared to improve for only the meditation group. Specifically, there was no difference in positive affect from pre-stressor to post-recovery for the meditation group and a significant decrease in positive affect from pre-stressor to post-recovery for both the audio book and control groups (ps < .01; see Table 2). Likewise, negative affect was not different from pre-stressor to post-recovery for the meditation group and was higher after the recovery period for the audio book and control groups (ps < .01).

Prior expectations

Before participants were assigned to groups at the first session, they were asked to what extent they thought a

Table 2 Positive and negative affect results

	Meditation		p	Audio book		p	Control		p
	Pre	Post		Pre	Post		Pre	Post	
Positive affect									
n	27	27	.19	30	30	.01*	30	30	.002*
M	22.74	21.37		22.47	19.87		23.20	20.10	
SD	8.39	7.72		7.36	7.47		7.37	6.53	
Negative affect									
n	30	30	.12	29	29	.01*	25	25	.002*
M	12.93	13.97		12.10	13.90		12.96	15.28	
SD	3.26	5.08		2.64	4.33		4.37	4.61	

Pre pre-stressor, *Post* post-recovery

P-values reported are for pre-stressor, post-recovery post hoc contrasts for each group adjusted using the Bonferroni correction

variety of activities (meditation and audio books included) would help them cope with a stressful experience. A repeated measures ANOVA with group as the between-subject variable and responses to the meditation and audio book questions as the within-subjects variable revealed that there were no significant differences among groups in their expectations about how helpful meditation would be in aiding coping with stress, nor were there differences in how helpful they thought audio books would be in aiding coping (see Table 3). However, participants thought meditation would be significantly more helpful than audio books, $F(1,83) = 33.08$, $p < .001$, $\eta_p^2 = .285$, observed power = 1.00.

Manipulation check questionnaires

The stressor led to similar reports of stress among the three groups, with all groups indicating high levels of perceived stress (see Table 3). As expected, the control group thought significantly more about non-study related topics during the recovery period than the meditation group ($p = .01$; see Table 3). However, the three groups reported spending the same amount of time thinking about the math task ($p = .43$; see Table 3). The meditation group found their CD to be more relaxing ($p = .009$) and easier to focus on ($p < .001$) than the audio book group found their CD (see Table 3). Despite participants' prior expectations, there were no differences between the meditation and audio book groups in how effective they thought the CDs were in helping them cope with the stress associated with the math task (see Table 3).

Audio book and meditation attention-checks

In order to see if participants were paying attention to the meditation and audio book CDs, four questions were asked pertaining to the CD. A Chi square test of independence was conducted to compare the meditation and audio book groups on the number of correct answers they produced. The test revealed a significant difference in the pattern of correct answers, $\chi^2(3) = 9.06$, $p = .029$. Overall, 97% of those in the meditation group and 74% of those in the audio book group answered at least 3 out of 4 questions correctly. Therefore, most participants attended to the meditation or audio book CDs well enough to answer the majority of questions correctly, though the audio book group had more difficulty paying attention to their CD.

Discussion

The goal of this study was to replicate and extend previous research with meditation novices by (1) determining if meditation has beneficial effects on mood and the cardiovascular system and (2) comparing meditation to simple distraction during recovery from stress.

We found that meditation did have beneficial effects on mood that appeared to buffer the effects of the stressor. While the PANAS was not administered immediately after the stressor because recovery data was being recorded, we can deduce that the stressor negatively affected mood. Both the physiological results during the stressor and self-reports collected after the recovery period indicate that all groups found the math task to be stressful. According to PANAS data, the meditation group's mood levels were at baseline levels following the recovery period, whereas both the audio book and control groups had worsened moods compared to baseline. In other words, positive affect did not decline as much in the meditation group as it did in the other two conditions and negative affect did not increase as much. The meditation group also reported feeling significantly more relaxed than the audio book group while lis-

Table 3 Self-reports

	Meditation group	Audio book group	Control group	*F*
Perceived effectiveness of meditation in aiding coping				.96[a]
n	36	33	32	
M	51.19	41.52	47.25	
SD	22.73	33.08	29.14	
Perceived effectiveness of audio books in aiding coping				1.01[a]
n	29	32	28	
M	23.10	19.53	28.93	
SD	26.12	23.98	27.12	
Perception of stressfulness of math task				1.07
n	30	30	31	
M	76.17	66.70	73.58	
SD	25.27	30.23	21.66	
Math-task related thoughts during recovery				.43
n	31	29	31	
M	34.23	40.24	39.10	
SD	28.05	26.42	26.08	
Amount of non-study related thoughts during recovery				4.86**[b]
n	31	29	31	
M	43.06	56.24	66.35	
SD	28.63	31.42	28.45	
CD effectiveness in aiding coping with stress from the math task				2.81
n	31	29		
M	62.10	50.00		
SD	24.33	30.56		
Extent that listening to CD led to relaxation				7.27**
n	31	29		
M	69.03	51.83		
SD	22.50	26.87		
Extent that distractions disrupted attention to CD				4.77*
n	31	29		
M	47.73	62.83		
SD	26.96	26.61		
Ability to focus attention on CD				9.90**
n	31	29		
M	57.52	37.59		
SD	23.89	25.18		

All questions were administered using a visual analog scale, ranging from 0 to 100, with 0 indicating "not at all" and 100 indicating "very much so"

[a]This question was asked at the first session, prior to the intervention, along with several distractor questions

[b]Meditation and control groups were significantly different from each other when using the Bonferroni correction

$^{*}p < .05$; $^{**}p < .01$

tening to the CDs. Taken together, these findings suggest that meditation was effective in helping mood recover from the stressor.

Although emotional response varied between the experimental conditions, we did not observe group differences in stressor-related thoughts, or rumination. Prior work has shown that compared to relaxation training, mindfulness meditation training reduces ruminative thoughts (Jain et al., 2007). In the current study, self-reports indicate that all groups ruminated about the math stressor to the same extent. One possible explanation for the discrepancy between our results and past work is that the meditation intervention in the current study was brief, whereas Jain et al. (2007) trained participants for one month. Freeing the mind from stress-related ruminative thoughts (or thoughts more generally) can be challenging. Thus, more practice (especially for novices) is likely necessary to master this skill.

The effects of meditation on physiological recovery from stress were mixed. Meditation led to decreases in skin conductance but had no unique effect on other physiological variables. The skin conductance findings lend some support to the relaxation response theory (Benson et al., 1974a) and to other studies that show decreased SNS activity when meditating (Cuthbert et al., 1981; Holmes et al., 1983), but conflict with Ditto et al. (2006) who found *increased* SNS activity in novice meditators.

Unexpectedly, HRV and HR returned to baseline levels for all groups immediately after the stressor, therefore the manipulation had no effect on these variables. Interestingly, the meditation group displayed both decreases in SNS activity and increases in PNS following the stressor which did not subsequently have effects on BP. SBP and DBP remained significantly higher than baseline levels for all three groups during the recovery period.

The BP findings are counter to some previous research showing that distractions lead to better BP recovery compared to control groups (Glynn et al., 2002; Chafin et al., 2004, 2008). However, it is consistent with a study in which novices were trained to meditate in the laboratory during recovery from stress (Key, 2010). There are several possible reasons why BP did not return to baseline. Because meditation is a skill that improves with practice, one explanation may be that these novices did not have enough practice to be able to meditate adequately in the face of a strong stressor. In the current study, the focused-attention meditation techniques (e.g., observing the breath, using a mantra) were chosen because they are considered relatively easier to achieve for novices than open-monitoring techniques (e.g., mindfulness meditation; Lutz et al., 2008). It is possible that one practice session was inadequate to see effects on cardiovascular outcomes, especially when the second exposure, one week later, was during recovery from stress. However, Key (2010) examined recovery from stress both on the first day of practice and after four weeks of mindfulness meditation practice and still found no differences between groups in BP recovery. Thus, lack of practice may not fully explain why there were no BP differences in the current study.

Alternatively, the laboratory situation may diminish the cardiovascular effects of meditation. The contrived situation of telling people to follow a meditation CD may be less effective compared to a person choosing to use meditation as a coping strategy. Furthermore, it may be difficult to fully immerse oneself in one's meditation practice in the laboratory when people typically practice meditation in a comfortable place in their home. Indeed, research shows that when expert meditators practice meditation in the laboratory (Holmes et al., 1983; Solberg et al., 2004) or novices are used in within-subjects designs (Ditto et al., 2006) it does not always lead to greater decreases in BP compared to control groups. However, studies that have used naturalistic settings or multiple collection days have been more likely to show that meditation produces decreased BP (Benson et al., 1974b, 1974c; Peters et al., 1977; Manikonda et al., 2008; Stuart et al., 1987; Wenneberg et al., 1997).

Steps were taken in the current study to make the laboratory more conducive to meditation. Specifically, in order to reduce reactivity, participants came to the lab twice, and continuous BP measurements were used to reduce interruptions during meditation and increase reliability of the measurements. The laboratory included a comfortable chair and was dimly lit. In spite of these attempts, we were not able to replicate previous BP findings. However, it is possible that the addition of the stressor made it even more challenging to capture BP effects of meditation on novices.

The fact that meditation led to decreases in skin conductance but had no unique effect on the physiological variables during recovery period was unexpected, and warrants some consideration. To help shed light on these findings, we focus our discussion on the underlying physiological mechanisms that determine skin conductance as well as those that influence HR, BP, and HRV. As described by Saul (1990), both SNS and PNS inputs control the rate and variability of HR. Systolic and diastolic blood pressure are multiply determined by complex autonomic, cardiac, and vascular processes, including heart rate, cardiac output, and peripheral resistance (Andreassi, 2007). In contrast, skin conductance can be considered a "pure" measure of SNS activity as eccrine sweat glands are innervated by cholinergic fibers of the SNS, but not PNS fibers. Thus, it is possible that there were greater decreases in SNS activity in the meditation group (as indexed by skin conductance), but we did not observe meditation effects on the HRV or cardiovascular measures (HR, SBP, DBP) because there was some combination of complex SNS and PNS effects during the recovery. To further explore, this possibility it may be useful to assess cardiac output and total peripheral resistance in future studies to provide more information on PNS and SNS activation, especially in terms of their relationship to meditation and cardiovascular recovery.

Limitations

There are a few limitations in the current study. Self-report measures were not taken immediately after the stressor or during the recovery period because previous research found that filling out questionnaires can help people recover from stress (Glynn et al., 2002). Therefore, all questions pertaining to the stressor and the recovery period were collected after the recovery period and are reliant on the memory of the participant.

Meditation can alter breathing, and breathing can in turn influence HRV. Therefore, breathing should be considered when examining HRV in meditation studies. However, breathing rate was not collected in the current study. Because other researchers have shown that RMSSD is less influenced by breathing (Hill & Siebenbrock, 2009; Penttilä et al., 2001) than other HRV parameters, it was chosen for the current study. In the current study, we observed no differences between groups for HRV. However, it will be important to directly measure respiration in future studies of meditation and HRV recovery from stress.

It is possible that the audio book could have led to boredom and influenced self-reports of mood, particularly because the content primarily described characteristics of Sherlock Holmes and the intonation of the narrator was matched to the relaxing tone of the meditation CD. Although we did not assess boredom specifically, the related term "interested" is included in the positive affect subscale of the PANAS. Examination of this variable revealed that there were no differences between groups in how interested they were following the recovery period. The differences between the meditation and audio book groups in mood do not, therefore, appear to be a result of differences in boredom. Nonetheless, researchers should consider alternative active control conditions that are more engaging or pleasant in future investigations.

In order to avoid expectancy effects, there was no mention of meditation in the recruitment materials and no explanation was given to participants for why they were being asked to listen to meditation or audio book CDs. However, in future studies, providing participants with more information about upcoming procedures, as Chafin et al. (2004) did, may reduce unintentional reactivity. Other researchers have also provided cover stories about manipulations that occurred during the recovery period, which may have helped participants fashion a rationale for the purpose of the intervention. For example, Glynn et al. (2002) were interested in the effect of distraction on recovery. Their distraction intervention was filling out questionnaires, and they made a point to tell participants that there were no right or wrong answers on a questionnaire, which may have eased anxiety for the participants. Likewise, Chafin et al. (2004), in a study that examined the effects of music on recovery from stress, used deception to avoid suspicion about why music was played after a math task by casually apologizing to participants for forgetting to play music during the baseline and promising to play it after the math task to help pass the time. Providing a cover story when examining meditation may lead to participants being less suspicious or confused about the situation while also minimizing demand characteristics and anxiety and allow them to better focus on the activity at hand.

Future directions

This is the first study to examine meditation and indexes of SNS and PNS in the context of recovery from stress and only the second study to also examine BP and HR during recovery from stress. Key (2010) used an open-monitoring form of meditation (i.e., mindfulness meditation), whereas focused-attention meditation techniques were used in the current study. More research is needed to understand the physiological effects of meditation during recovery from stress.

The underlying mechanism examined in both the current study and in Key's study (2010) was distraction. However, there may be other mechanisms that lead to meditation's effects that have yet to be examined. For example, expectations may play a role in meditation's relaxation effects. The current study attempted to control for expectations by not using the term "meditation" in the sign-up materials, and only mentioning it during the meditation CD, but an examination of expectancy effects would help our understanding of meditation's effects.

Conclusion

Because one's ability to recover from stress is associated with future health outcomes (Borghi et al., 1986; Brosschot et al., 2005; Chida & Steptoe, 2011; Stewart et al., 2006; Treiber et al., 2001), it is important to determine ways to improve recovery from stress. The results of the current study suggest that meditation has some unique effects during recovery from stress, but findings were not consistent across all physiological measures. The findings of the current study expand our understanding of the effects of meditation and suggest that, even for inexperienced meditators, meditation can aid in mood regulation and decreases in SNS activity following a stressor.

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Compliance with ethical standards

Conflict of interest Amy R. Borchardt and Peggy M. Zoccola declare that they have no conflict of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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