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ORIGINAL PAPER

Examining Practice Effects in a Randomized Controlled Trial: Daily Life Mindfulness Practice Predicts Stress Buffering Effects of Mindfulness Meditation Training

Andrew W. Manigault[1] · Jeremiah Slutsky[2] · Julianna Raye[3] · John David Creswell[4]

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Abstract

Objectives Mindfulness practice is thought to underlie the therapeutic effects of mindfulness interventions. Yet, more research is needed to evaluate mindfulness practice effects and identify effective practice types. The present study examined the effects of two types of mindfulness practice (audio-guided and daily life mindfulness practice) on measures of stress and coping in a workplace sample.

Methods Employees from a digital marketing firm undergoing stressful organizational restructuring ($n_{final} = 60$; aged 21–57; 95.0% white; 66.7% women) were randomly assigned to a high- (1-day seminar plus 6-week practice) or low-dose (1-day seminar) mindfulness training program. Participants completed 3 days of ecological momentary assessments of stress/coping pre- and post-interventions. Audio-guided mindfulness practice was assessed by the number of audio-guided practice sessions completed during the intervention period; daily life mindfulness practice was indexed by how often participants reported applying mindfulness to daily activities during the intervention period.

Results Across the full sample, more frequent daily life mindfulness practice buffered against pre- to post-intervention increases in stress ratings ($\beta = -.18$, $p = .002$), stressor frequency ($\beta = -.32$, $p < .001$), and stressor intensity ($\beta = -.27$, $p = .003$), and decreases in successful coping ($\beta = .25$, $p = .005$). Comparable (but weaker) results were observed for audio-guided mindfulness practice (stress ratings: $\beta = -.15$, $p = .013$; stressor frequency: $\beta = -.27$, $p < .001$; stressor intensity: $\beta = -.22$, $p = .015$; successful coping: $\beta = .17$, $p = .066$).

Conclusions Much of the mindfulness meditation RCT literature to date has not measured or reported guided or daily life practices, and this work suggests that measuring both may be important for understanding the stress buffering effects of mindfulness meditation training.

Keywords Mindfulness · Practice · Stress · Buffering

Mindfulness-based interventions exhibit reliable and robust stress reduction effects (Chiesa & Serretti, 2009; Khoury et al., 2015). For example, a review of 29 studies (Khoury et al., 2015) found that mindfulness-based stress reduction, or MBSR (Kabat-Zinn & Santorelli, 1999) interventions, showed strong effects on stress in the context of both pre- to post-intervention differences (Hedge's $g = 0.83$) and differences relative to control groups (Hedge's $g = 0.74$). Yet, relatively little is known about the critical factors driving stress reduction effects of mindfulness training. One leading idea is that mindfulness meditation *practice* is key to the benefits of these programs (Kabat-Zinn, 1990; Vettese et al., 2009). Consistent with this view, contemporary mindfulness training protocols reliably direct trainees to spend most of their time practicing mindfulness. For example, MBSR interventions may assign 15–45 min of formal meditation and yoga daily (6 days per week), and 15–45 min of informal practice daily to be completed outside of weekly 2-h group

✉ Andrew W. Manigault
andrewmanigaultw@gmail.com

1 Department of Psychology, Ohio University, 200 Porter Hall, Athens, OH 45701, USA

2 Department of Psychology, University of South Florida, Tampa, FL, USA

3 Unified Mindfulness, Los Angeles, CA, USA

4 Department of Psychology, Carnegie Mellon University, 354L Baker Hall, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA

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sessions (Lengacher et al., 2009). Similarly, some mindfulness retreats involve 2 h of guided meditation/discussion and 6 h of solitary practice daily (Jacobs et al., 2013).

Yet, mindfulness practice is seldom a focal point in experimental studies evaluating mindfulness intervention effects. The association between mindfulness practice and trial outcomes is typically reported in a minority of studies evaluating the effects of mindfulness-based interventions (Parsons et al., 2017; Strohmaier, 2020; Vettese et al., 2009). Moreover, more commonly reported measures of practice like intervention adherence are often only assessed by the number of intervention sessions attended (e.g., the number of 2-h weekly sessions attended in the case of MBSR). This approach is problematic because it ignores informal forms of mindfulness practice. This is surprising given that the mindfulness meditation literature has long documented that daily life mindfulness practices are one of the most valued and commonly used elements of mindfulness meditation training programs, according to participant self-reports (Kabat-Zinn et al., 1992).

Moreover, the extant literature reports mixed evidence for an association between mindfulness practice and trial outcomes. According to one review, mindfulness practice was linked with improved trial outcomes in approximately half (13/24) of studies reviewed (Vettese et al., 2009), but it should be noted that trial outcomes were highly varied. Similarly, a recent meta-analysis found only a small relationship ($r = 0.26$) between mindfulness practice and varied trial outcomes (Parsons et al., 2017). Finally, a recent meta-regression found no significant association between frequency/duration of recommended mindfulness practice and trial outcomes (Strohmaier, 2020). Yet, these weak/mixed meta-analytic results could be attributed in part to issues of measurement, outcome heterogeneity, and aforementioned research practices. More specifically, prior reviews (Parsons et al., 2017; Vettese et al., 2009) examined studies that measured mindfulness practice with varying degrees of granularity (e.g., daily logs, weekly logs, assessments separated by months) and focused on diverse outcomes (e.g., attention, stress, depression, cortisol, BMI, well-being). Yet, practice effects may be best compared among a more homogeneous set of outcomes. Notably, emerging theories (Creswell & Lindsay, 2014; Lindsay & Creswell, 2017) imply that mindfulness operates by buffering against the effects of stressors on health and thus could suggest that practice effects are more salient in the context of stress-related outcomes. Moreover, the association between mindfulness practice and trial outcomes may be best captured using detailed measures of practice (Re et al., 2013).

Finally, some forms of mindfulness practice may be more effective than others (e.g., formal v. informal practice; Birtwell et al., 2019; Crane et al., 2014; Hawley et al., 2014). Few studies compare mindfulness practice types, and none examines stress buffering effects to the authors' knowledge. Two prior studies reported that formal (e.g., scheduled audio-guided practice, and sitting meditation) but not informal (e.g., mindfulness during routine activities, breathing spaces, and noticing) practice predicted lower depressive relapse risk (Crane et al., 2014), as well as lower rumination and depressive symptoms (Hawley et al., 2014). By contrast, a recent study linked both informal and formal mindfulness practice with increased well-being, but only informal practice with increased psychological flexibility (Birtwell et al., 2019). Accordingly, some preliminary evidence suggests that differentiating between practice types is warranted.

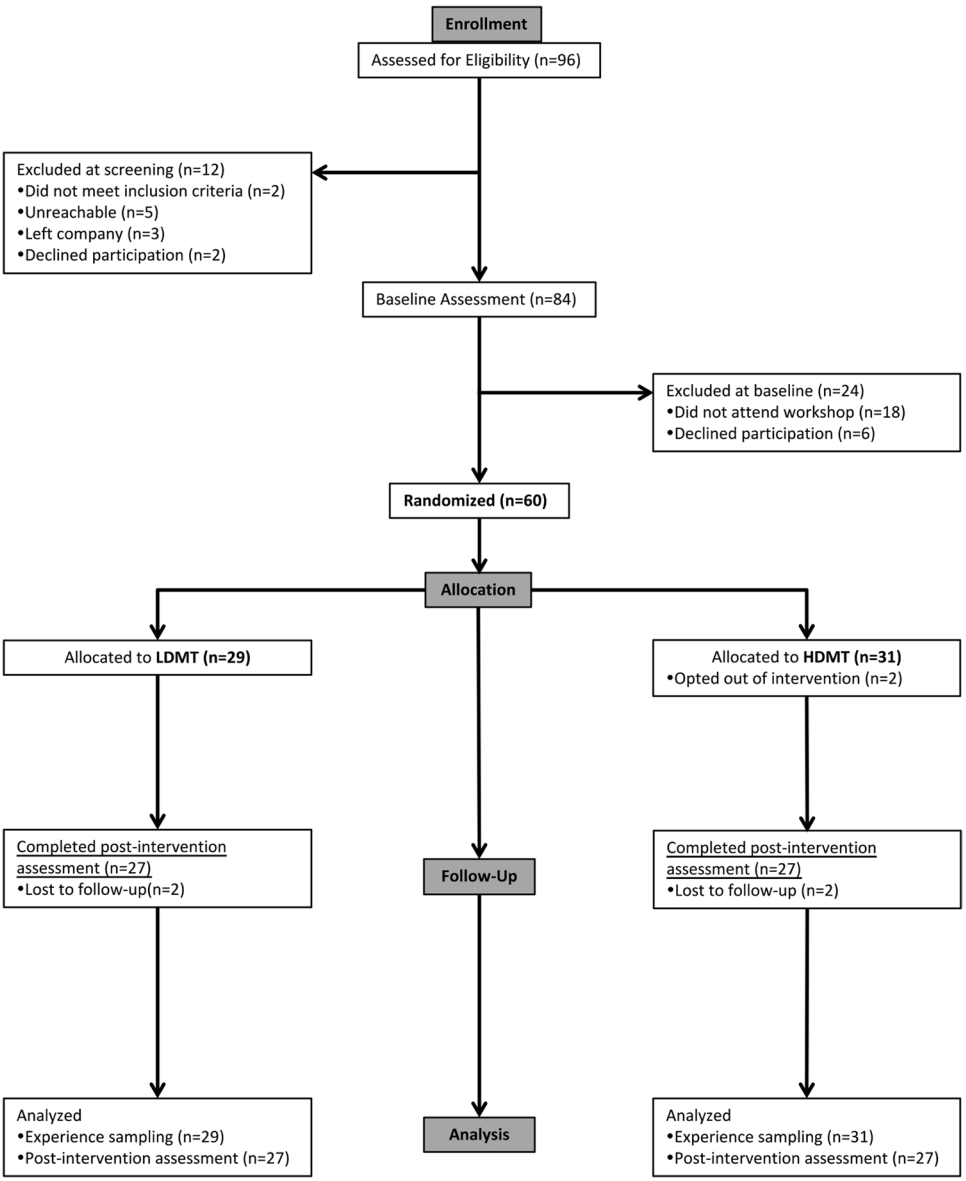
The present study used existing data from a published randomized controlled trial (Chin et al., 2019; Slutsky et al., 2019), to examine the effects of two types of mindfulness practice (audio-guided and daily life mindfulness practice) on pre- and post-intervention ecological momentary assessments of stress and coping. In this trial, employees completed either a high- (1-day seminar plus 6-week practice) or a low- (1-day seminar) dose mindfulness training during a period of time when they faced the stress of organizational restructuring—an ideal scenario for testing stress buffering effects. The Unified Mindfulness System was used to obtain detailed practice measures (described in Methods), including (1) the number of audio-guided training sessions completed, and (2) the frequency at which participants reported applying mindfulness to daily life activities. We hypothesized that more frequent mindfulness practice during the intervention period would be associated with stress buffering effects (i.e., reduced stress and increased coping). We also aimed to descriptively compare effect sizes associated with each practice type.

Methods

Participants

Participants were 60 adults randomized to a high- or a low-dose mindfulness training as part of a randomized controlled trial (see Fig. 1 for CONSORT flowchart). Participants were recruited from a digital marketing firm undergoing significant organizational restructuring during the study intervention period. This allowed for the interventions to be tested in a context where stress levels were expected to rise. Most participants were young (aged 21–57; $M = 30.52$, $SD = 7.80$), white (95.0%), and women (66.7%). Eligibility criteria included being at least 18 years of age, a smartphone user (android/iOS), a fluent English speaker, and reporting no significant experience with mindfulness (i.e., no daily practice for at least one of the previous 6 months). The study protocol was IRB approved and all participants provided informed consent. Participants received no compensation

Fig. 1 CONSORT flowchart



beyond the free mindfulness training provided as part of the interventions. Limiting compensation was expected to improve generalizability (because a typical company is likely to offer free mindfulness lessons without additional compensation).

Procedures

Interested individuals completed an online screener survey containing eligibility criteria and assessing availability during the study period. Eligible participants ($N = 96$) were invited to be consented into the study and complete a baseline assessment (84 individuals consented and completed the baseline assessment). During the following week, participants completed 3 days of pre-intervention ecological momentary assessment (EMA) during workdays. EMAs were delivered via participant's smartphone using MetricWire (Kitchener, Ontario). Experience sampling surveys were sent to participants during each of four 2-h blocks distributed between 9:00 AM and 5:00 PM (for a total of 12 surveys assessing stress and coping). During the following week, all participants were asked to attend one of three identical 4-h in-person mindfulness workshops directed by an experienced mindfulness instructor. Immediately after the workshop, participants were randomly assigned to one of two conditions—high- v. low-dose mindfulness training (i.e., 1-day seminar + 6-week training v. 1-day seminar only). A total of 60 participants underwent randomization. Immediately following the 6-week intervention period, participants completed post-intervention EMAs during three workdays. Post-intervention EMAs were identical to pre-intervention EMAs.

Data collection took place between September 2016 and November 2016.

Mindfulness Workshop

As part of the workshop, participants were provided with didactic information about mindfulness. Instructions included (1) the mechanisms by which mindful awareness can improve dimensions of well-being, (2) a conceptual framework for classifying sensory experience and developing mindful attention, (3) a conceptual model for applying mindfulness in life, and (4) a range of situations where practice can be carried out. Next, participants were introduced to 3 techniques and guided through exercises aimed at fostering mindful awareness and acceptance of present moment visual, auditory, and somatic experience as well as the creation of positive emotional states. This included the application of mindfulness during activities such as eating, music listening, and conversation.

High-Dose Mindfulness Training

As part of the 6-week high-dose mindfulness training (HDMT), participants were presented with didactic audio recordings describing the principles of the Unified Mindfulness System (called the Core training). Participants were prompted to complete 5 guided audio practice sessions each week (except for the first week where only 2 sessions could be completed). The content of audio-guided practice included a range of technique options that organized sensory experience into 3 categories—See, Hear, and Feel. The audio-guided sessions also emphasized reward states, such as restfulness, and a range of pleasant experience to foster engagement. The techniques learned were easily applicable to practice in daily life. HDMT participants were also sent a link to complete post-practice surveys along with each audio training. Participants assigned to HDMT also participated in weekly group conference calls where they discuss training efforts and received additional instructions. The focus of these calls was primarily on practice in life, and included a range of specific strategies and techniques for bringing the skills of mindful attention into various daily activities. Finally, participants assigned to HDMT were offered an optional 15-min phone meeting with the mindfulness instructor to discuss their experiences with the training. These conversations centered on clarifying how to practice mindfulness and discussing specific ways to bring mindfulness into daily life activities.

Low-Dose Mindfulness Training

As part of the 6-week low-dose mindfulness training (LDMT), participants received no additional training following the workshop and were explicitly asked to refrain from completing any additional mindfulness practice until the conclusion of the study.

Measures

Stress and Coping Outcomes

Stress and successful coping were measured using four items collected as part of EMAs. These items assessed momentary stress ratings ("How much stress are you experiencing or feeling right now?" [1 = mild; 7 = severe]), stressor intensity ("How severe was your experience of stress since the last survey?" [1 = mild; 7 = severe]), stressor frequency ("Since the last survey, how much of the time were you feeling stressed?" [1 = very little, 0–10%; 7 = almost the entire time, 90–100%]), and successful coping ("How successful were you in coping with stress since the last survey?" [1 = not at all; 7 = extremely]). Each item was examined separately. Greater scores on these items indicate higher stress ratings, higher stressor intensity, higher stressor frequency, and more successful coping, respectively.

Audio-Guided Mindfulness Practice

Participants assigned to the HDMT listened to a series of guided audio recordings instructing them in how to develop mindful attention, based on the principles of the Unified Mindfulness System. During the 6-week intervention period, HDMT participants were prompted to listen to 2 audio recordings during the first week and 5 audio recordings per week thereafter (for a maximum of 27 sessions of audio-guided mindfulness practice). Participants were considered to have completed an audio-guided practice session if they listened to 90% of the audio recording (297 out of 427 sessions started). Adherence was tracked through Wistia, a video hosting platform. A total audio-guided practice score was computed for each participant by counting how many audio-guided practice sessions were completed over the 6-week intervention period (see Table 1 for descriptive statistics). In final analyses, total audio-guided practice was natural log transformed (after adding 1 to each score) to address skewness.

Daily Life Mindfulness Practice

Daily life mindfulness practice was assessed as part of post-practice surveys. In these surveys, participants were asked "In the past 24 h, I practiced during these times (pick as many as apply):" and could select multiple answers from 6 lists: golden, down, connection, stress, physical, and mind times. These names reflected a salient feature of the grouping. For instance, "Golden" refers

Table 1 Descriptive statistics for practice frequency over the full intervention period

Practice type	*M*	SD
Audio-guided total	13.23	9.35
Daily life total	54.42	55.40
Daily life golden	14.28	14.22
Daily life down	9.40	10.96
Daily life connection	14.12	17.21
Daily life stress	5.66	5.75
Daily life physical	6.88	9.27
Daily life mind	7.40	7.81

to opportunities to dedicate a higher degree of attention toward practicing a technique, and for a longer period of time, such as while exercising or eating. "Mind" refers to times when the participant is actively engaged in thinking about something. Those situations would require a different strategy for implementing a mindfulness technique than during golden times. A sum was computed for each list to derive golden, down, connection, stress, physical, and mind practice subtype scores (see Table 2). Total practice score was computed by summing all items endorsed across all lists (see Table 1 for descriptive statistics and Table 2 for a full list of daily life mindfulness practice items). In final analyses, all daily life practice variables were natural log transformed (after adding 1 to each score) to address skewness.

Data Analyses

Treatment of Missing and Outlying Data

Two participants dropped out of HDMT (96.7% retention). These participants were included in final analyses, consistent with an intent to treat approach. A total of 830 ecological momentary assessments were completed, and produced 830 stress ratings, as well as 403 successful coping, stressor frequency, and stressor intensity ratings. No outliers (±3 SDs from the mean) were identified among stress and coping outcome variables.

Among the 31 individuals allocated to HDMT, 30 (96.7%) completed at least one guided audio practice session and at least one post-practice survey, and thus had valid practice data. No outliers were identified among natural log-transformed practice variables. When included in analyses, participants assigned to the low-dose mindfulness training were coded as 0 on all audio-guided and daily life practice variables since they were not assigned audio-guided or daily life practices (nor did they have access to materials) after the initial workshop.

Modeling Approach

Restricted maximum likelihood mixed linear models were used to examine the effect of time (0 = pre-intervention; 1 = post-intervention), and practice variables on primary outcomes (i.e., stress ratings, stressor frequency, stressor intensity, and successful coping). Mixed linear models were run using the lmerTest R package on R 3.6.0, and thus used the Satterthwaite's degrees of freedom method. Three-level models were fitted such that sampling occasions (level 1) were nested within days (level 2), and days were nested within individuals (level 3). As shown in the following equations, day-level and individual-level intercepts were modeled as random effects, whereas time and practice were modeled as fixed effects:

$$\text{Level 1 (sampling occasion)}: \text{Outcome}_{ijk} = \pi_{0jk} + e_{ijk} \tag{1a}$$

$$\text{Level 2 (day)}: \pi_{0jk} = \beta_{00k} + \beta_{01k} * (\text{time}_{jk}) + u_{0jk} \tag{1b}$$

$$\text{Level 3 (individual)}: \beta_{00k} = \gamma_{000} + \gamma_{001} * (\text{practice}_{k}) + u_{00k} \tag{1c}$$

$$\beta_{01k} = \gamma_{010} + \gamma_{011} * (\text{practice}_{k}) \tag{1d}$$

These models characterize the dose–response relationship between a given mindfulness practice variable and a given outcome variable using the slope assigned to the interaction of practice by time (γ_{011}), where slopes that deviate more strongly from 0 imply a stronger dose–response relationship. Next, significant interactions were probed using tests of simple slopes, to examine how time slopes (i.e., pre- to post-intervention change in outcomes) differed depending on how much practice was reported. Practice variables were re-centered on 0 (corresponding to individuals who reported no practice), mean centered (corresponding to individuals who reported average levels of practice), and centered on + 1SD above the mean (corresponding to individuals who reported high levels of practice). We present both unstandardized (reported as *b*) and standardized (reported as β) slopes, using standardization methods proposed by prior work (Lorah, 2018). The Holm's adjustment was used to limit family-wise type I error rates to 0.05 (Holm, 1979).

Results

As shown in Table 1, on average, participants assigned to HDMT completed a total of 13.23 (out of 27) audio-guided practice sessions over the full intervention period. Similarly, the average participant assigned to HDMT reported

Table 2 Itemized daily life practice type during the full intervention period

	N-total	%-total	N	%
Golden times (total)	400	26.23%		
Exercising			84	5.50%
Eating			66	4.33%
Driving			162	10.62%
Music listening			70	4.59%
Live event/show			3	0.20%
Other			15	0.98%
Down times (total)	254	16.66%		
Waiting in line			23	1.51%
Waiting for my computer to boot			42	2.75%
Waiting for a meeting to start			37	2.43%
Waiting at the gas pump			10	0.66%
Passively listening to someone speak			73	4.79%
Walking down the hall or from place to place			48	3.15%
Other			21	1.38%
Connection times (total)	354	23.21%		
Friends			78	5.11%
Family			68	4.46%
Romantic partner			61	4.00%
Co-workers			90	5.90%
Clients			5	0.33%
Familiar faces			3	0.20%
Strangers			6	0.39%
Pets			42	2.75%
Community events			1	0.07%
Stress times (total)	153	10.03%		
Prepping for an important meeting or call			26	1.70%
Prior to or during a difficult conversation			9	0.59%
While meeting a deadline			32	2.10%
Facing or thinking about a challenging situation			55	3.61%
In an argument			4	0.26%
In a moment of distress			19	1.25%
Other			8	0.52%
Physical times (total)	179	11.74%		
Brushing teeth			30	1.97%
Showering			94	6.16%
Washing dishes			13	0.85%
Cleaning			19	1.25%
Envelope stuffing[a]			8	0.52%
Setting up a meeting room			3	0.20%
Other			12	0.79%
Mind times (total)	185	12.13%		
Typing at my computer			49	3.21%
Checking Facebook			14	0.92%
Writing up a report or creative copy			11	0.72%
Making sales calls			0	0.00%
Problem solving a client issue			16	1.05%
Analyzing yourself or your life			59	3.87%
Watching TV/movie/media			30	1.97%
Other			6	0.39%
Total daily life practice	1,525	100.00%		

Table notes. [a]Scale item was shortened in the table; the full item states: "Envelope stuffing, using the scanner or other work tasks that don't require much thought."

practicing mindfulness in daily life on 54.42 occasions over the full intervention period. Daily life practice in the context of golden and connection times was most frequently reported.

Time Effects Across the Full Sample

Across the full sample, successful coping decreased pre- to post-intervention ($b = -0.29$, $\beta = -0.21$, $t(365.40) = 2.18$, $p = 0.029$), and stress ratings ($b = 0.04$, $\beta = 0.02$, $t(744.77) = 0.46$, $p = 0.64$), stressor frequency ($b = 0.21$, $\beta = 0.14$, $t(367.12) = 1.57$, $p = 0.11$), and stressor intensity did not change pre- to post-intervention ($b = 0.19$, $\beta = 0.13$, $t(373.12) = 1.38$, $p = 0.16$).

Intervention Effects

As described in a previous publication of this data (Chin et al., 2019), assignment to study condition moderated the pre- to post-intervention change in momentary stress ratings, stressor frequency, stressor intensity, and successful coping such that participants assigned to the HDMT exhibited no significant pre- to post-intervention change in stress ratings, stressor frequency, stressor intensity, and successful coping, whereas individuals assigned to LDMT exhibited significantly increased stress ratings, stressor frequency, stressor intensity, and decreased reports of successful coping.

Practice Effects Across the Full Sample

Tests of Interactions and Dose–Response Comparison

Across the full sample, audio-guided practice interacted with pre- to post-intervention slopes to predict stress ratings ($b = -0.18$, $\beta = -0.15$, $t(704.31) = 2.47$, $p = 0.013$), stressor frequency ($b = -0.32$, $\beta = -0.27$, $t(342.72) = 3.21$, $p < 0.001$), stressor intensity ($b = -0.26$, $\beta = -0.22$, $t(350.81) = 2.43$, $p = 0.015$), and successful coping ($b = 0.19$, $\beta = 0.17$, $t(344.58) = 1.84$, $p = 0.066$), such that more frequent audio-guided practice predicted diminished pre- to post-intervention increases in stress ratings, stressor frequency, and stressor intensity, and diminished pre- to post-intervention decreases in successful coping. Similarly, total daily life practice interacted with pre- to post-intervention slopes to predict stress ratings ($b = -0.14$, $\beta = -0.18$, $t(711.13) = 3.05$, $p = 0.002$), stressor frequency ($b = -0.25$, $\beta = -0.32$, $t(344.88) = 3.84$, $p < 0.001$), stressor intensity ($b = -0.20$, $\beta = -0.27$, $t(348.80) = 2.97$, $p = 0.003$), and successful coping ($b = 0.18$, $\beta = 0.25$, $t(342.44) = 2.79$, $p = 0.005$), such that more frequent daily life practice predicted diminished pre- to post-intervention increases in stress ratings, stressor frequency, and stressor intensity, and diminished pre- to post-intervention decreases in successful coping.

Tests of Simple Slopes

Stress buffering effects were expected, such that significant pre- to post-intervention increases in stress ratings, stressor frequency, and stressor intensity, and significant pre- to post-intervention decreases in successful coping would be observed for individuals who reported low practice frequency. In contrast, stress ratings, stressor frequency, stressor intensity, and successful coping were expected to remain constant among individuals who reported frequent practice.

Consistent with Fig. 2a, tests of simple slopes revealed that individuals who reported no audio-guided practice (none) exhibited a marginally significant increase in stress ratings pre- to post-intervention ($b = 0.25$, $\beta = 0.16$, $t(722.84) = 1.89$, $p = 0.058$). In contrast, individuals who reported moderate (mean) and frequent (+ 1SD) audio-guided practice exhibited no significant change in stress ratings pre- to post-intervention ($b = 0.06$, $\beta = 0.04$, $t(714.72) = 0.59$, $p = 0.55$, and $b = -0.16$, $\beta = -0.11$, $t(693.04) = 1.32$, $p = 0.18$, respectively). Tests of simple slopes revealed a distinct pattern for total daily life practice (see Fig. 3a), where individuals who reported no daily life practice (none) exhibited a significant increase in stress ratings pre- to post-intervention ($b = 0.31$, $\beta = 0.20$, $t(730.05) = 2.33$, $p = 0.019$). Other tests of simple slopes were comparable.

Consistent with Fig. 2b, tests of simple slopes revealed that individuals who reported no audio-guided practice (none) exhibited a significant increase in stressor frequency pre- to post-intervention ($b = 0.56$, $\beta = 0.39$, $t(354.49) = 3.11$, $p = 0.002$), whereas individuals who reported moderate audio-guided practice (mean) exhibited a marginally significant increase in stressor frequency pre- to post-intervention ($b = 0.22$, $\beta = 0.15$, $t(351.34) = 1.66$, $p = 0.096$), and individuals who reported frequent audio-guided practice (+ 1SD) exhibited no change in stressor frequency pre- to post-intervention ($b = -0.17$, $\beta = -0.12$, $t(335.27) = 1.02$, $p = 0.31$). Tests of simple slopes revealed the same pattern for total daily life practice (see Fig. 3b).

Consistent with Fig. 2c, tests of simple slopes revealed that individuals who reported no audio-guided practice (none) exhibited a significant increase in stressor intensity pre- to post-intervention ($b = 0.49$, $\beta = 0.34$, $t(360.55) = 2.59$, $p = 0.009$). In contrast, individuals who reported moderate (mean) and frequent (+ 1SD) audio-guided practice showed no change in stressor intensity pre- to post-intervention ($b = 0.22$, $\beta = 0.15$, $t(358.45) = 1.57$, $p = 0.12$, and $b = -0.10$, $\beta = -0.07$, $t(342.97) = 0.53$, $p = 0.59$, respectively). Tests of

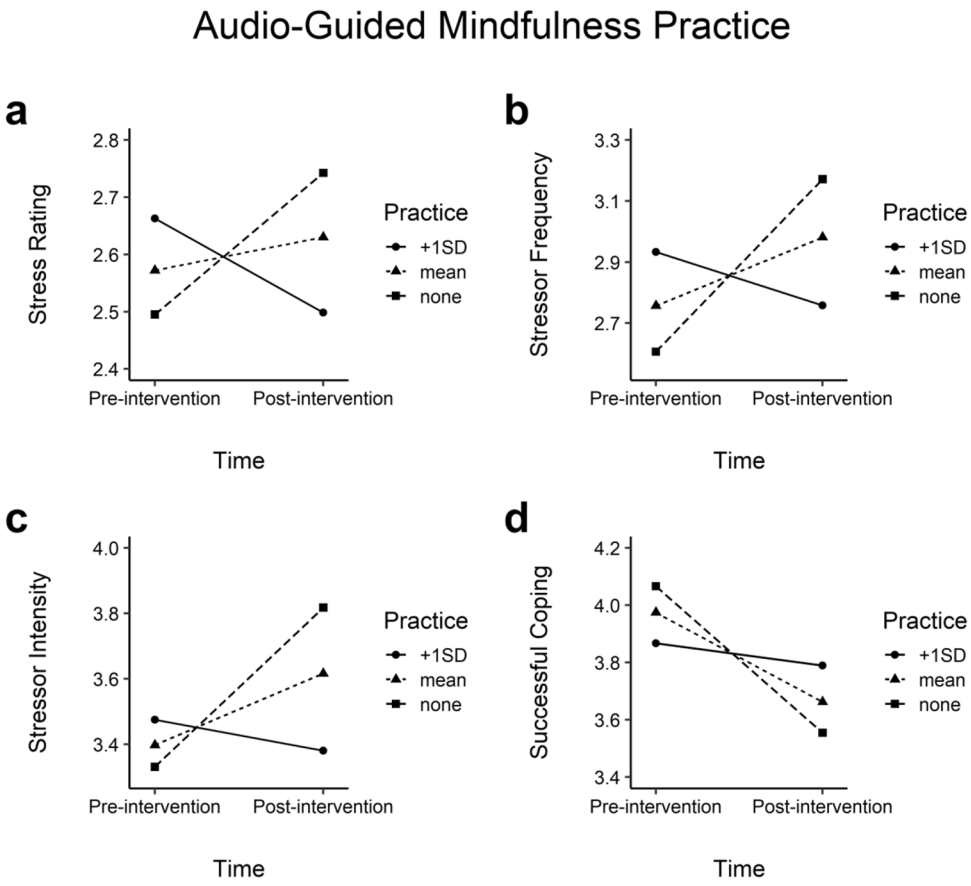


Fig. 2 Predicted levels of self-reported levels of stress ratings (panel a), stressor frequency (panel b), stressor intensity (panel c), and successful coping (panel d) as a function of time (pre-intervention v. post-intervention) and total audio-guided mindfulness practice (none v. mean v. + 1SD). Simple slopes presented in each plot were generated by re-centering the audio-guided mindfulness practice variable on 0 (corresponding to individuals who reported no practice), the mean value (corresponding to individuals who reported average levels of practice), and + 1SD above the mean (corresponding to individuals who reported high levels of practice)

simple slopes revealed the same pattern for total daily life practice (see Fig. 3c).

Consistent with Fig. 2d, tests of simple slopes revealed that individuals who reported no audio-guided practice (none) and moderate audio-guided practice (mean) exhibited a significant decrease in successful coping pre- to post-intervention ($b = -0.51$, $\beta = -0.37$, $t(356.89) = 2.75$, $p = 0.006$, and $b = -0.31$, $\beta = -0.22$, $t(353.75) = 2.26$, $p = 0.024$), whereas individuals who reported frequent audio-guided practice (+ 1SD) exhibited no change in successful coping pre- to post-intervention ($b = -0.08$, $\beta = 0.06$, $t(336.21) = 0.44$, $p = 0.66$). Tests of simple slopes revealed the same pattern for total daily life practice (see Fig. 3d).

Practice Effects Among Participants Assigned to HDMT

When participants assigned to LDMT were excluded from analyses, the interaction of time by daily life practice remained significant (or marginally significant) when predicting stress ratings ($b = -0.26$, $\beta = -0.15$, $t(352.99) = 1.81$, $p = 0.071$), stressor frequency ($b = -0.65$, $\beta = -0.42$, $t(172.38) = 3.37$, $p < 0.001$), stressor intensity ($b = -0.66$, $\beta = -0.39$, $t(169.87) = 2.89$, $p = 0.004$), and successful coping ($b = -0.42$, $\beta = -0.27$, $t(165.33) = 1.98$, $p = 0.048$; non-significant under Holm's adjustment). In contrast, the interactions of time by audio-guided practice no longer significantly predicted stress ratings ($b = -0.06$, $\beta = -0.04$, $t(352.12) = 0.39$, $p = 0.69$), stressor frequency ($b = -0.19$, $\beta = -0.12$, $t(179.04) = 0.91$, $p = 0.36$), stressor intensity ($b = -0.30$, $\beta = -0.17$, $t(185.11) = 0.1.25$, $p = 0.21$), or successful coping ($b = -0.07$, $\beta = -0.04$, $t(177.88) = 0.31$, $p = 0.75$).

Discussion

The primary aim of the present study was to test the association between mindfulness practice and ecological momentary assessments of stress and coping. Studying mindfulness practice effects is important because mindfulness practice is thought to underlie the therapeutic effects of mindfulness interventions (Kabat-Zinn, 1990; Vettese et al., 2009), and this view is reflected in the structure of contemporary mindfulness interventions where practice takes up most of trainees' time. As expected, we found a dose–response relationship for both audio-guided mindfulness practice and daily life mindfulness practice, such that more frequent practice was associated with diminished pre- to post-intervention increases in self-reported stress ratings, stressor frequency, and stressor intensity, as well as diminished

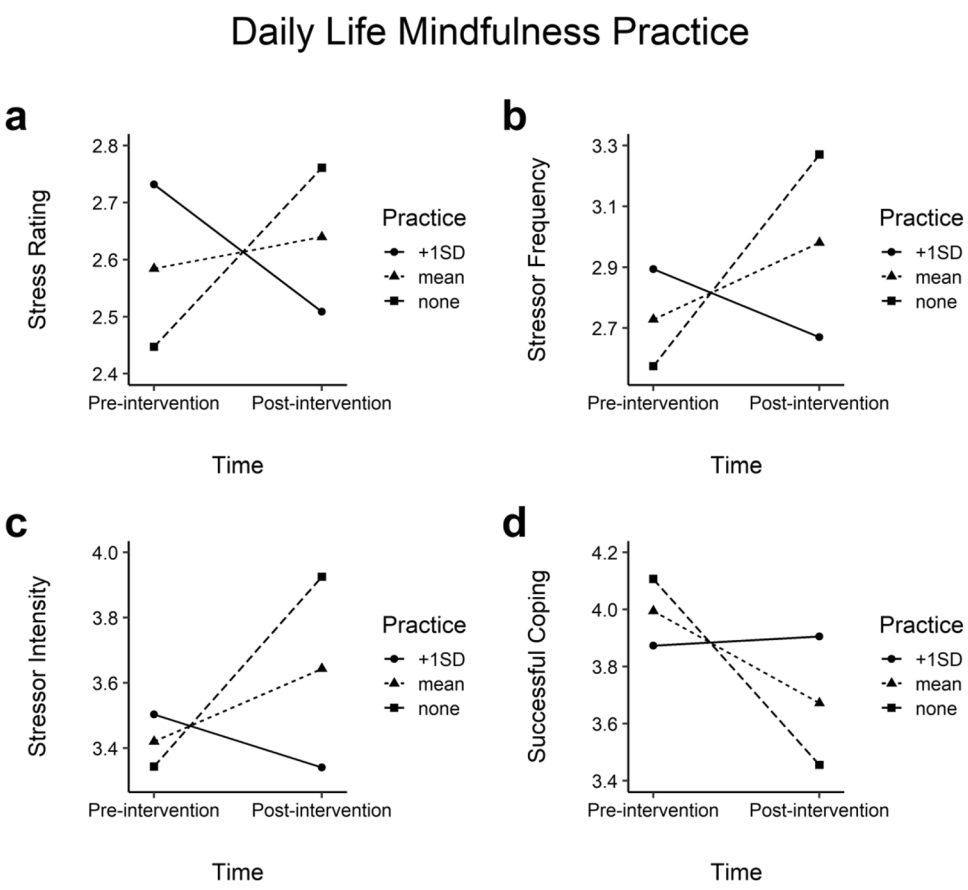


Fig. 3 Predicted levels of stress ratings (panel a), stressor frequency (panel b), stressor intensity (panel c), and successful coping (panel d) as a function of time (pre-intervention v. post-intervention) and total daily life mindfulness practice (none v. mean v. + 1SD). Simple slopes presented in each plot were generated by re-centering the daily life mindfulness practice variable on 0 (corresponding to individuals who reported no practice), the mean value (corresponding to individuals who reported average levels of practice), and + 1SD above the mean (corresponding to individuals who reported high levels of practice)

pre- to post-intervention decreases in successful coping. Accordingly, more frequent mindfulness practice was associated with larger stress buffering effects. We also aimed to descriptively compare the effectiveness of practice types, and observed a stronger dose–response relationship for daily life mindfulness practice relative to audio-guided mindfulness practice.

The present study contributes to the literature by empirically linking mindfulness practice to stress buffering effects. All participants faced the stress of their firm undergoing significant organizational restructuring during the intervention period, and more frequent mindfulness practice may minimize the effects of this ongoing stressor. Consistent with this view, we found that self-reported stress ratings, stressor frequency, and stressor intensity all increased pre- to post-intervention among individuals who did not practice mindfulness. In contrast, frequent practice was associated with non-significant pre- to post-intervention change in self-reported stress ratings, stressor frequency, and stressor intensity. A comparable (but inversed) pattern was observed for successful coping. Altogether, these results imply that the magnitude of stress buffering effects exhibited by mindfulness practitioners is a function of practice frequency, where more frequent practice yields larger stress buffering effects. This is important because mindfulness practice is hypothesized to underlie therapeutic effects of mindfulness training (Kabat-Zinn, 1990; Vettese et al., 2009), and mindfulness interventions are thought to improve a broad range of outcomes via stress-buffering effects (Creswell & Lindsay, 2014). Accordingly, the present results provide empirical evidence that mindfulness practice could yield salutary effects at least in part by buffering against increased stress, consistent with extant theories. Nevertheless, the present study was limited to self-reported stress measures and the inclusion of additional outcomes (e.g., physiological stress markers, physical health indices) will be necessary to fully test a mechanistic model where mindfulness practice leads to stress buffering effect that in turn protect mental and physical health.

The present study also contributes to the literature by comparing types of mindfulness practice. Results implied a reliably stronger dose–response relationship for mindfulness practice applied to daily life relative to audio-guided mindfulness practice. Moreover, daily life practice effects remained (at least marginally) significant when restricting analyses to participants assigned to HDMT, whereas audio-guided practice effects were non-significant. This result was unexpected and contrasts prior work (Crane et al., 2014; Hawley et al., 2014) which examined the effect of formal (including audio-guided practice) and informal practice

(including mindfulness practice in daily life) on depression outcomes. We considered multiple explanations for these results. First, the present study used a detailed measure of daily life practice where mindfulness practice was assessed in relation to over 40 daily activities (on up to 27 separate occasions). In contrast, prior work used relatively narrower measures and grouped daily life mindfulness practice with other practice types to derive a measure of informal practice. Accordingly, the present results could imply that examining daily life practice separately from other informal mindfulness practices and assessing practice in relation to numerous daily activities best capture effects of mindfulness practice in daily life. Related, participants could complete a finite number of guided practices but were not limited in how often (or briefly) they practiced in daily life. This may be important as recent research suggests that novice practitioners may especially benefit from brief practice (Strohmaier et al., 2021). Second, while most mindfulness-based interventions focus on the importance of carrying mindfulness practice into daily life (Kabat-Zinn & Santorelli, 1999), the Unified Mindfulness System we used offers significant reminders and concrete guidance on when and how to practice in daily life. Accordingly, it is possible the present results are specific to interventions derived from the mindfulness meditation system we used here (Lindsay et al., , 2018, 2019). Finally, it may be that applying mindfulness practice to daily life is a more important and pervasive aspect of mindfulness training than completing scheduled audio-guided mindfulness practice. One common observation is that participants drop off on the frequency of their formal mindfulness home practice after completing mindfulness interventions (Canby et al., 2021), but that they keep up regular informal mindfulness practices in daily life (Kabat-Zinn et al., 1992). Accordingly, the frequency at which trainees apply mindfulness skills to daily life during the intervention may be an important marker of long-term intervention success.

Limitations and Future Research

Limitations of the present study warrant discussion. We controlled for recent mindfulness practice (within the last 6 months) but lifetime mindfulness practice was not controlled. Daily life practice frequency measures relied on self-reports whereas audio-guided practice measures did not. Related, daily life practice produced a larger range of practice frequency and this difference could explain why only daily life practice continued to predict stress buffering effect when analyses were restricted to participants assigned to HDMT. In addition, it remains unclear how well audio-guided and daily life practice frequency measures translate into objective measures of time, or whether participants who progressed through a full audio lesson actually listened to the full recording. For example, it may be that a given individual needed to commit 10 h of audio-guided practice to score 1 standard deviation above the mean of audio-guided practice frequency scores, whereas 20 h of daily life practice was needed to score 1 standard deviation above the mean of daily life practice frequency scores. In sum, given that audio-guided practice and daily life practice were not measured on the same scale (e.g., time), the present study cannot compare the effectiveness of these types of mindfulness practices on a "per hour" basis. A fruitful venue for future research lies in replicating the present study using measures of mindfulness practice based on time. Future work may also benefit from examining perceived interruptions; daily life practice does not require trainees to interrupt their routine and thus could be perceived as less time-consuming than other types of mindfulness practices (e.g., sitting meditation). Finally, examining the dose–response relationship between mindfulness training adherence and trial outcomes in more varied populations is warranted to evaluate generalizability.

Author Contribution AWM: performed the data analysis, wrote the paper. JS: executed the study, assisted with the data analysis, assisted with designing the study, collaborated in writing and editing of the manuscript. JR: delivered the mindfulness intervention, wrote part of the methods, collaborated in writing and editing of the manuscript. JDC: designed the study, supervised execution of the study, supervised data analysis, supervised manuscript preparation.

Declarations

Ethics Approval and Consent to Participate Informed consent was obtained from all individual participants in this study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Carnegie Mellon University Institutional Review Board and the American Psychological Association.

Conflict of Interest JR is an owner and lead trainer of Unified Mindfulness/UM-HUB LLC; JDC received research funds from Headspace, Inc; AWM and JS report no conflicts of interest.

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