Mindfulness meditation as attention control training: A dual-blind investigation

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Abstract

Mindfulness meditation is a form of secular meditation that emphasizes non-judgmental awareness of the present moment. Research into mindfulness has greatly expanded in recent years (Davidson & Kasniak, 2015) and a growing literature has documented effects of mindfulness training on cognition. However, the specific aspects of mindfulness meditation training for novice practitioners that might influence cognition remain unexplored. The present study used a rigorous, dual-blind design to investigate whether the attention-monitoring component of mindfulness meditation reduces mind-wandering and improves performance during reading comprehension and sustained attention tasks. When compared with relaxation meditation, mindfulness training improved recall of specific details from a text but did not reduce mind-wandering or affect sustained attention. The results are discussed with respect to design considerations when studying a meditation intervention.

Keywords: mindfulness; meditation; mind-wandering; text comprehension; sustained attention

Introduction

In recent years, there has been a dramatic increase in the application of mindfulness meditation training (MMT) across many sectors of our society. MMT is a form of secular meditation emphasizing non-judgmental awareness of thoughts, feelings, and sensations in the present moment (e.g., Kabat-Zinn, 1994). In some sense, mindfulness can be thought of as the inverse of mind-wandering (MW; Mrazek, Smallwood, & Schooler, 2012), with mindfulness arising from full engagement with the present moment and MW arising from attention moving away from the present moment.

Several studies have found positive effects of MMT on cognition, including fundamental functions such as attention control and working memory (e.g., Jha, Morrison, Dainer-Best, Parker, Rostrup, & Stanley, 2015; MacLean, Ferrer, Aichele, Bridwell, et al., 2010; Mrazek, Franklin, Phillips, Baird & Schooler, 2013; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010; but see Banks, Welhaf, & Srour, 2015) and higher-order abilities, such as reading comprehension (e.g., Mrazek et al., 2013). Indeed, positive benefits of MMT on cognition have been found after brief inductions lasting 6-8 minutes (e.g., Mrazek et al., 2012) as well as training programs of between 4 and 8 hours of practice (e.g., Mrazek et al., 2013; Zeidan et al., 2010) and highly intensive interventions (e.g., MacLean et al., 2010). A challenge to interpreting the findings from these studies is that they employed comparison groups that were engaged in very different kinds of activities than MMT, such as wait-list controls (e.g., Jha et al., 2015; MacLean et al., 2010), attending a nutrition class (Mrazek et al., 2013) or listening to an audiobook (Zeidan et al., 2010). The many differences between treatment and control groups leaves open the possibility that differences between groups were due to nonspecific factors, such as differing expectancy effects across groups. Just as importantly, the studies leave unexplored *what components* of MMT contribute to cognitive effects.

MMT has many components, some of which may be more strongly related to specific aspects of cognition than others. The present study sought to closely examine one of those components, attention monitoring, while controlling for a second, relaxation. Specifically, we tested the hypothesis that the *attention-monitoring component* of MMT provides a form of attention training for the novice practitioner that reduces MW in non-meditation contexts. In testing our hypothesis we adhered to many recommendations suggested by Davidson & Kazniak (2015) in their recent critical review of research on mindfulness and meditation.

First, in designing our comparison group, we used the "dismantling strategy" advocated by Davidson & Kazniak (2015) in which the control intervention contains all of the elements of the treatment intervention except for the component under investigation. In order to isolate potential effects of the attention-monitoring component of MMT above and beyond the general benefits that one might expect from beginning a meditation practice, we trained two groups of participants in meditations inspired by MMT. Both forms involved directing attention inward and focusing on the breath but the two groups differed in the explicit goal that was set for them in the meditation and the specific guidance given during meditation. The Relaxation Meditation Training group (RMT) were told that the meditation training they were doing was a form of "relaxation training" and that their goal was to relax as much as possible. They were guided to relax by observing their breath. The Mindfulness Meditation Training group (MMT) were told that the meditation training they were doing was a form of "attention training" and that their goal was to improve their mental focus. They were guided to engage in a relaxation task of counting their breaths and were given additional instructions specifically related to MW.

Second, our study procedure followed a "dual-blind" model and included the 4 desiderata outlined by Davidson

& Kazniak (2015): Comparison groups were matched for 1) structural dosage, 2) daily practice and 3) instructor characteristics, and 4) participants were blind as to which was the "experimental" intervention. In addition, experimenters were blind to the group assignment of participants during data collection.

In order to test for effects of the attention-monitoring component of MMT on MW and cognitive performance, we used outcome measures that have been shown by previous work to be sensitive to the effects of MW and that are relevant to both basic and applied theories of cognition: text comprehension and sustained attention. Clearly, MW reduces time-on-task, which may in and of itself impair performance. Further, MW may reflect a failure of attention control that could have repercussions across the cognitive system (McVay & Kane, 2009).

In the present study, meditation-naïve participants made 4 visits to the lab over 8 calendar days. On the first visit they completed demographic questionnaires, the pre-test for text comprehension and sustained attention and finally were introduced to the meditation and given 20 minutes to practice. Visits 2 and 3 consisted of 45 minutes of meditation practice. Finally, on visit 4, participants began with 10 minutes of meditation practice, followed by the post-tests in text comprehension and sustained attention. Thus, our study design can be thought of as testing state effects of MMT relative to RMT, augmented by prior practice. Our analyses focus on 1) replicating the expected effects of MW on objective performance markers in text comprehension and sustained attention and 2) testing the Meditation Group X Session interaction for both the measures of MW and objective performance markers in the text comprehension and sustained attention tasks.

Method

Participants

Participants were young adults with no significant prior meditation experience. They were selected on a first-come-first serve basis from respondents to an online pre-screening questionnaire. All reported (1) normal or corrected-to-normal hearing and vision, (2) being a native speaker of English, (3) being between 18 and 40 years of age, (4) no more than minimal prior meditation experience, and no experience with mindfulness meditation, (5) no intensive long-term yoga experience, and (6) no prior diagnosis of a neurological or psychiatric condition. Participants were paid $90 for the approximately 6 hours of total study time.

Data was collected from a total of 86 participants. The sample consisted of university students (62 undergraduate and 20 graduate students, 3 non-students and 1 who declined to report) and was ethnically diverse (34% European American, 33% African American, 18% Asian American, 5% Hispanic, 9% other). Nine participants were excluded from all analyses for indicating in the first session that they failed to meet one or more of the inclusion criteria (6), consistently failing to follow the instructions (2), attrition after the first session (1). Participants in the final sample (N = 77) were randomly assigned to two experimental groups: Mindfulness Meditation Training (MMT; N=37; 27 females; M age=20.4 years, SD=2.0) or Relaxation Meditation Training (RMT; N=40; 28 females; M age=22.4 years, SD=4.3).

Materials

Meditation Training In each meditation training session, participants were seated at a computer, reviewed written instructions and then listened to pre-recorded audio over headphones. Instructions were tailored to the meditation condition and session, emphasizing either relaxation meditation training (RMT) or the attention monitoring meditation training (MMT). Participants were not informed that different participants were doing different types of meditation or the specific hypotheses of the study.

Participants were instructed to sit comfortably, with feet on the floor, hands in their lap and chin up, with their eyes closed or looking ahead with a dull stare. The first session included one 20-minute auditory guided meditation, sessions 2 and 3 consisted of 40 minutes of auditory guided meditation and session 4 included one 10-minute auditory guided meditation and a 5-minute non-auditory meditation reminder. The guided meditations used in training were created by CASL researchers after referencing Jon Kabat-Zinn meditations. They consisted of instructions alternating with silence to allow for the participant to practice on their own. The transcripts were recorded by a male talker with experience with meditation.

The guided meditations for the two conditions contained the same general pattern of instructions and silences but the content of the instructions varied between groups. Instructions for MMT focused on counting breaths. The auditory and written instructions also explicitly asked participants to (a) notice when MW occurred, without judging the content or frequency of the experience, and (b) bring attention back to the breath-counting task when they became aware of their MW. The focus on counting breaths was intended to give participants a concrete marker by which to notice MW when it occurred. In contrast, instructions for RMT were designed to follow the same general pattern of instruction (i.e., they also had a task to do during meditation) but to maximally encourage relaxation. The guided meditation asked participants to relax by focusing on their breath (without counting) and did not explicitly mention MW at all. After completing the Text Comprehension task and before completing the SART, participants engaged in a 5-minute "reminder" meditation. They read instructions on the computer asking them to use the techniques they had been learning during their training. At the end of the 5 minutes a tone sounded to end the meditation.

Self-evaluation of meditation training and relaxation Immediately prior to each auditory meditation, participants indicated their level of relaxation at that moment using a visual analog scale. In Sessions 2 to 4, participants were also asked whether they had used the meditation techniques they were learning on their own since the last session.

After each meditation training session participants again rated their relaxation. They also completed a retrospective attention report, using a slider to indicate the percentage of time they were 1) completely engaged with the task, 2) thinking about the task more generally, and 3) thinking about things unrelated to the task (i.e., task unrelated thoughts or TUTs).

Text Comprehension The text comprehension task was modeled on the self-paced paradigm used by Feng, D'Mello and Graesser (2013). Participants read passages one sentence at a time, pressing the space bar to advance to the next sentence. Each passage was followed by a set of multiple-choice questions with four possible responses. The questions fell into one of two categories: Sentence-Linked or General. Each Sentence-Linked question assessed comprehension of a specific detail from the passage (e.g., What did the poet Homer do in old age?), while General questions assessed comprehension of the passage as a whole (e.g., One can conclude Momaday knows about ……?).

Attention probes were inserted between sentences at several points in each passage, fixed across participants. Each probe asked "Were you mind wandering when you read the previous sentence? Press 1 for Yes and 2 for No." There were two categories of attention-probes: Each *Question-Linked* attention probe (66% of total) immediately followed a sentence whose comprehension would be assessed on a Sentence-Linked question. *Filler* attention probes were placed in pseudorandom positions in the passage and were not linked to specific questions.

The passages used were from the reading comprehension section of Forms G and H of the Nelson-Denny Reading Test™, a standardized assessment of reading ability appropriate for high school and four-year college students (www.riversidepublishing.com). Each Form consisted of 7 passages: one long passage (approximately 600 words) with 6 attention probes (4 Question-Linked and 2 Filler) and 7 associated questions and 6 shorter passages (approximately 225 words each) with 3 total probes (2 Question-Linked and 1 Filler) and 4-5 associated questions. Participants completed one Form (i.e., G or H) at Session 1 and the other Form at Session 4, randomly assigned and counterbalanced across subjects.

The text comprehension task began with detailed instructions presented on the computer. These instructions defined MW as when "attention drifts away from the task" and provided examples of MW. Participants were told to report NO mind-wandering if they were "completely engaged in the task of reading and understanding the passage" and to report YES if they were either a) thinking about what they were reading AND something else or b) thinking only about something else. After the instructions, participants completed a short practice passage with attention probes and then advanced through the 7 passages in a fixed order.

Sustained Attention to Response Task (SART) The SART is "go/no-go" task in which participants make a response to "non-targets" and withhold that response to "targets." Each trial in the SART consisted of a # symbol (42 pt) presented for 1200 ms followed by a single uppercase letter (36 pt) presented for 800 ms. All stimuli were presented in the center of the computer monitor in black Arial Monospaced font on a grey background. Participants were told to make no response to the target (the letter "X") and to respond by pressing the letter "m" with the index finger of their dominant hand for all non-targets (all non-X letters of the alphabet).

Participants completed 4 blocks of 150 trials each. Blocks alternated between Low Frequency Target (12.5% of total trials) and High Frequency Target (50% of total trials) conditions. The exact sequence of trials within each block was randomly determined at the beginning of each block for each participant. Before the 4 blocks of test trials, participants completed a block of 15 practice trials with feedback in order to make sure they understood when to respond. The Low Frequency condition was expected to be significantly more challenging than the High Frequency condition. Block order was counterbalanced across participants and fixed across sessions.

Our dependent measures were target sensitivity (d_L) and response time variability (calculated as RT-CV, or the standard deviation of each participant's response latencies divided by their mean). Target sensitivity provides a measure of target accuracy while controlling for overall response bias (see Equation 1, in which H and FA refer to the proportions of hits and false alarms, respectively). RT-CV is generally thought to capture MW, with participants who are less attentive to the task showing greater variability in response latencies (McVay & Kane, 2009). RT-CV is typically negatively correlated with d_L.

(1) $d_L = \ln \{[H(1 - FA)]/[1 - H)FA]\}$

As a subjective measure of MW, participants were asked to complete the same retrospective attention report after the SART as the post-meditation report described above.

Procedure

While participants worked at individual computers, there were between 1 and 12 participants present in the testing room for each session. Session proctors were blind to the participants' meditation condition, as (i) presentation of written and spoken meditation materials was done automatically through E-Prime computer scripts, (ii) the audio instructions were delivered through closed headphones, and (iii) single sessions typically included participants in both meditation conditions. This ensured that proctors could not influence participants' expectations based on meditation group. Proctors actively monitored participants to ensure they were completing the expected tasks during their session. All participants completed all 4 sessions within a minimum of 7 and a maximum of 9 calendar days (days between Sessions 1 and 4: MMT: M=7.1 , SD=0.5; RMT: M=7.3, SD=0.6).

Results

Meditation Training Manipulation

Participants' self-reports were analyzed to examine whether the general effects of the meditation experience (level of relaxation and overall engagement) varied between groups (see Table 1). Participants in both the MMT and RMT groups reported feeling substantially more relaxed after each meditation session than they did before each session. A linear mixed-effect model was fit to the reported change in relaxation with fixed effects of Session (1 to 4) and Meditation Group (MMT or RMT) and random effects of Subject. The model revealed a significant Session X Meditation Group interaction (b=3.06, SE=1.47, t= 2.08). The RMT group, but not the MMT group, reported increasing changes in relaxation across the 4 sessions. This difference was largely driven by the fact that the RMT group reported a smaller change in relaxation after the first meditation session than the MMT group. After Session 1, the meditation was equally relaxing for both groups.

The same linear mixed-effect model as described was fit to percentage of On-Task time. The model revealed a significant effect of Session (b=4.20, SE=0.77, t=5.49) but no effect of Group or interaction. The effect of Session is likely due to the increase in On-Task reported for Session 4 (which was only 10 minutes in duration). Participants in both groups were equally likely to report having used the meditation techniques at home since the last session (59% of the MMT group and 65% of the RMT group, $\chi^2(1)<1.0$)) Thus, participants in both groups were equally engaged in the meditations.

Table 1. Mean (SD) self-reported changes in relaxation (scale 0-100) and percent of time on task for each meditation session. Note that sessions varied in duration.

	Session	1	2	3	4
Relax Change	MMT	23.0 (18.6)	20.2 (14.6)	20.3 (14.7)	20.9 (17.0)
	RMT	14.8 (18.7)	23.6 (17.3)	24.8 (19.0)	22.6 (20.6)
% OnTask	MMT	49.3 (21.8)	44.7 (22.1)	47.6 (23.9)	61.1 (21.6)
	RMT	45.2 (22.6)	45.8 (20.8)	48.4 (21.5)	59.5 (24.6)

Text Comprehension

Descriptive statistics for accuracy on Sentence-Linked and General questions and amount of MW are provided for both groups in Table 2.

MMT facilitates retention of details A multi-level logistic model was fit to Sentence-Linked question accuracy with fixed effects of Group (MMT or RMT) and Session (1 or 4) and random effects of Subject, Item and Subject X Session interaction. Group and Session were dummy coded with MMT and Session 1 as the reference groups. There was a main effect of Session (b=0.38, SE=0.16, z= 2.34, p=0.02) and a significant Group X Session interaction (b=-0.47, SE=0.22, z= -2.12 , p=0.03) and no main effect of Group (p=0.87). Thus, Sentence-Linked accuracy increased significantly from Session 1 to 4 for participants in the MMT group but not participants in the RMT group. When the same model was fit to the General question accuracy and to the amount of reported MW, no main effects or interactions were significant for either measure.

Table 2. Means (SD) for test accuracy and reported MW (percentage of "yes" responses) for text comprehension.

	MMT		RMT	
Session	1	4	1	4
Sentence-Linked	0.75 (0.1)	0.80 (0.1)	0.75 (0.2)	0.73 (0.2)
General	0.73 (0.1)	0.73 (0.1)	0.73 (0.1)	0.75 (0.1)
MW	0.28 (0.16)	0.28 (0.23)	0.34 (0.20)	0.30 (0.21)

Effects of MW equivalent across groups and sessions Participants' mean accuracy for Sentence-Linked questions are illustrated in Figure 1, split by whether participants reported mind-wandering during the corresponding sentence. As is clear from the figure, participants had significantly better comprehension of sentences read with their full attention than sentences on which they reported MW. A multi-level logistic model was fit to the raw Sentence-Linked question accuracy with fixed effects of Meditation Group, Session, reported MW (Yes or No) and their interactions and random effects of Subject, Item and Subject X Session interaction. The model revealed a significant main effect of MW (b= -0.69, SE=0.12, z= -5.9, p<0.001) and no other significant effects (all p>0.3).

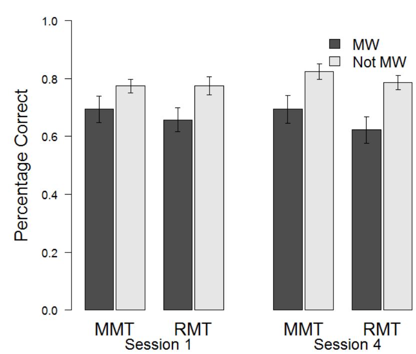

Figure 1. Accuracy on Sentence-Linked questions split by participants' responses to subsequent MW probes.

In addition to MW affecting comprehension of what is read *during* a MW episode, MW may also negatively influence the reader's ability to integrate information about the passage as a whole. We tested the relationship between total amount of MW reported during a passage and participants' accuracy on the General questions for that passage. Participants' mean accuracy for General questions for each passage were fit with a linear mixed-effects model with fixed effects of Meditation Group (MMT or RMT), Session (1 or 4) and reported MW (Yes or No), and random factors of Subject and Passage. Interactions were tested, but in no case were interactions between the fixed effects significant. Participants who reported more MW during a passage were significantly less accurate on the General questions for that passage (b= -0.11, SE=0.03, t= -4.0) and the MW effect was equivalent across Session and Group.

Sustained Attention

Target detection and MW were equivalent across groups
The data reveal the general pattern of effects expected for the SART frequency manipulation: Participants had higher d_L and lower RT-CV (MW) on high-frequency target than low-frequency target blocks (see Table 3). Greater RT-CV was also associated with lower d_L for both conditions, for both Groups and Sessions ($r(75)$=-0.64 to -0.75, all p<0.001).

Table 3. Means (SD) for SART dependent measures.

	MMT		RMT	
Session	1	4	1	4
d_L Low Freq	5.39 (1.86)	6.04 (1.57)	5.75 (2.08)	5.99 (2.15)
d_L High Freq	7.0 (1.88)	7.37 (1.78)	7.23 (1.72)	7.38 (1.93)
RT-CV Low Freq	0.26 (0.08)	0.23 (0.06)	0.24 (0.08)	0.23 (0.09)
RT-CV High Freq	0.22 (0.06)	0.23 (0.06)	0.21 (0.07)	0.22 (0.07)
%TUT self-report	29.6 (21.0)	21.5 (19.3)	28.3 (22.6)	24.3 (24.0)

There was no evidence for a differential effect of MMT over RMT on target sensitivity, though d_L scores improved overall across sessions: A multi-level linear model was fit to the target sensitivity scores with fixed effects of Meditation Group, Session and Target Frequency (High or Low) and random effects of Subject, Subject X Session and Subject X Target Frequency interactions. The model revealed a very strong and significant main effect of Target Frequency (b=1.44, SE=0.102, t=14.31) and a smaller main effect of Session (b=0.36, SE=0.172, t=2.07), but neither of these factors interacted with Group, nor was there a main effect of Group. The same interaction model as above was fit to RT-CV and revealed only a significant effect of Target Frequency (b=-0.021, SE=0.004, t=-5.42), with no interactions.

While RT-CV did not decrease after training, participants in both groups reported greater task engagement during SART in Session 4 relative to Session 1. A multi-level linear model was fit to reported TUTs with fixed effects of Meditation Group and Session and random effects of Subject. The model revealed a significant effect of Session (b=-5.92, SE=2.53, t=-2.34) but no main effect of or interaction with Meditation Group[1].

Discussion

Our data reveal at most mixed results with respect to the hypothesized effect of MMT influencing cognitive performance through improvements in attention control. We found that novice practitioners who completed MMT improved more at retrieving specific details from a passage than those who completed RMT. However, this change in performance was not found for general comprehension and did not appear to be facilitated by decreased MW, as we hypothesized, as the two groups reported similar amounts of MW during reading at post-test. The sustained attention task revealed no significant group differences across sessions.

A limitation of the current design is the reliance on self-report of MW during text comprehension. It is possible that the attention-monitoring instructions in the MMT made participants more *aware* of their MW without giving participants enough practice to better control it (Davidson & Kazniak, 2015). Such increased awareness might result in participants reporting MW at equal or higher rates even if objectively they were MW less. This is particularly plausible since MW is a graded phenomenon, and participants might initially consider themselves "on-task" if they were even partially engaged in the task but after MMT might consider themselves "off-task" at the same level of engagement.

We did find a consistent detrimental effect of MW on reading comprehension. Both recall of specific details and synthesis of the passage as a whole were negatively affected by MW (see also Feng et al., 2013; Smallwood et al., 2008). We also found that increased MW, as measured by both an objective measure (response time variability) and retrospective self-report, was detrimental to target detection. These results are important for establishing key paradigms that produce reliable effects of MW and can therefore be used to test the effects of attention training.

Given the sensitivity of the outcome measures to MW, the fact that we did not find that MMT was more beneficial than RMT for reducing MW or for improving most objective performance markers is revealing. This pattern stands in contrast to that found by Mrazek and colleagues (2013), who found increases in reading comprehension accuracy were mediated by decreases in MW after MMT. Our study differs from that of Mrazek in several ways that might account for this divergence. First, our training was about a

[1] Individual models fit to the MW measures for the sustained attention task do find significant effects of session for the MMT group for both the objective measure, RT-CV (b=-0.03, SE=0.01, t=-2.47) and the subjective measure, reported TUTs (b=-8.05, SE=3.89, t=-2.07). The RMT group did not have significant effects of session for either RT-CV (b=0, SE=0.01, t<1) or TUTs (b=-3.95, SE=3.29, t=-1.20). This is at most weak evidence of an effect of MMT on MW during the sustained attention task.

quarter of the duration of that employed by Mrazek et al. and therefore may have not been long enough to influence MW (though note that benefits of MMT have been found after interventions as short as 8 minutes (Mrazek et al., 2012)). Second, the structure of our reading task prevented rereading and this may have affected the relationship between MMT and participants' comprehension. One possibility is that MMT facilitated partial engagement during MW and this partial engagement was sufficient to support encoding of some additional details but not to support the abstract schema formation required for synthesis of the passage as a whole. Further study is required to determine how MMT, MW and reading comprehension may be related under different task demands.

In the present study, participants in both groups showed improvements in sustained attention at post-test. Because we did not have a non-meditation control group, we cannot say whether this change in performance is due to non-specific benefits of meditation or are practice effects. One recent study did find group differences in cognition (working memory) when comparing MMT specifically to RMT (Banks et al., 2015). However, the role of MMT appeared to be one of protecting cognition from the effects of stress rather than an overall benefit to cognition and the relationship between meditation, MW and cognition was not tested. One possibility for future research would be to focus more specifically on the effects of stress on performance, rather than on MW in the absence of stress.

Our experimental manipulation, comparing meditation training with and without instructions to monitor attention, was necessarily subtle. Both groups reported similar changes in relaxation and engagement with the meditation. It's further possible that asking about MW during pretest prompted the RMT group to closely monitor their attention even though we didn't instruct them that attention control was the objective of their training. The current study is an initial attempt at the dual-blind design advocated by Davison and Kasniak (2015). However, the present study necessarily samples a very specific set of the many possible parameters for this type of intervention. It is certainly possible that changing the duration of training, its mode of delivery or other factors could result in different patterns between the MMT and RMT groups. However, it is precisely this type of comparison that will allow us to understand how *and why* different meditation practices may influence cognition.

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