Working memory is a core cognitive construct that is thought to support many forms of higher-order cognition. If such a core cognitive construct could be enhanced, this should lead to improvement in higher-order cognition supported by working memory. Mindfulness meditation has been shown to improve functioning of the working memory system, but no study has yet met the necessary criteria (i.e., using multiple, valid outcome measures that are different from the trained tasks; using an active, adaptive control group) for concluding that working memory capacity has been improved. The current study includes the necessary criteria by comparing two weeks of mindfulness meditation training to active, adaptive cognitive (i.e., memory and attention) training regarding improvement on multiple, valid indicators of working memory capacity. The results showed that only the mindfulness meditation group significantly improved working memory capacity following training, yet there were no group differences. In conclusion, mindfulness meditation may enhance working memory capacity; this was demonstrated while meeting almost all necessary criteria for validly concluding that working memory capacity has been improved.
MINDFULNESS MEDITATION MAY ENHANCE WORKING MEMORY CAPACITY

A thesis submitted
To Kent State University in partial
Fulfillment of the requirements for the
Degree of Master of Arts

by

Michael Baranski

December, 2017
© Copyright
All rights reserved
Except for previously published materials
LIST OF FIGURES

Figure 1. WMC Composite Score by Group at Pretest and Posttest………………………… . 24

Figure 2. WMC Composite Score by Group at Pretest and Posttest With Low-Scoring Participant
Data Dropped………………………………………………………………………………….. 27

Figure 3. OSPAN, RSPAN, and SSPAN Proportion Correct by Group at Pretest and Posttest. 29
LIST OF TABLES

Table 1. WMC Individual Task Scores and Proportion Correct, and WMC Composite Score... 22

Table 2. Descriptive Statistics for WMC Composite at Pretest and Posttest....................... 23

Table 3. Paired Samples t-test for WMC Composite at Pretest and Posttest With Low-Scoring Participant Data Dropped................................................................. 26

Table 4. Repeated Measures ANOVA Tests of Individual WMC Tasks.............................. 28

Table 5. Paired Samples t-tests on Individual WMC Tasks by Group at Pretest and Posttest... 29

Table 6. ANOVA. Regression, and Multiple Regression Results for Predicting WMC Composite Score at Posttest From Training Scores......................................................... 31

Table 7. Mindfulness Meditation Group’s Guided Meditation Trainings............................. 48

Table 8. Cognitive Training Group’s Training Tasks............................................................ 49
Acknowledgements

Thank you to Christopher A. Was for his assistance in study design, execution, analysis, and reporting of this work; the Graduate Student Senate (GSS) for the generous GSS Research Award, without which this study would not have been possible; the members of the Was Lab (Erin Graham, Leah Cooney, Jhni Fleming, Jacob Fresty, Jessica Kotik, Michael Lasher, Megan Leamon, Carly Nelson, Sean Sabihi, Leanna Thomas, and Chelsea Wheeler) for their advice and assistance with executing and analyzing the study; Katherine Rawson, for advice and feedback on creating a well-designed study; and all of the participants who were apart of this study.
I. Introduction

Working memory is described as the cognitive system that mentally maintains and processes task-relevant information, and is thought to underlie higher-order cognition. If the information processing capacity of this cognitive system could be enhanced via training, this may lead to improvements in higher-order cognition. Mindfulness meditation has shown promise in enhancing the capacity and efficiency of the working memory system. Many other attempts to improve working memory capacity via computerized training have not yielded conclusive results as to whether this cognitive system can be enhanced. Four specific criteria have been established to convincingly demonstrate that working memory capacity has been improved; the research on mindfulness meditation has met most of these criteria but no study has met all of the criteria. The present study investigates if mindfulness meditation may enhance working memory capacity while meeting all of the appropriate criteria for concluding that working memory capacity has been improved. Demonstrating such an improvement would support the conclusion that a core cognitive system may be improved following brief and inexpensive training, and potentially lead to enhancement of higher-order cognition that is dependent on the working memory system.

Working memory is foundational to complex human information processing and higher-order cognition because it is the cognitive system that mentally maintains and processes task-relevant information (Conway, Jarrold, Kane, Miyake & Towse, 2007). Working memory capacity, one of several indices of the working memory system, has consistently shown high correlations with measures of general intelligence, novel reasoning, problem solving, complex learning, and reading and language comprehension (Conway & Kovacs, 2013; Engle, Tuholski, Laughlin, & Kane, 1999; Unsworth, Redick, Heitz, Broadway, & Engle, 2009). Working
memory is therefore considered a foundational cognitive system that makes possible multiple forms of complex cognition. Despite the demonstrated importance to higher order cognition, prodigious literature, and several attempts to unify extant findings, there is no unified theory or model of working memory (Conway et al., 2007; Cowan, 2016). Cowan identified nine definitions of working memory found in the literature; the working memory definition most aligned with the present work is the attention-control definition put forward by Engle (2002). Here, working memory is defined as “the use of attention to preserve information about goals and sub-goals for ongoing processing and to inhibit distractions from those goals” (pg. 2).

Within the attention-control view of working memory, working memory capacity is thought to correlate with higher-order cognition because of the importance of controlled attention in both contexts (Engle et al., 1999). Both complex span tasks\(^1\) (measuring working memory) and complex cognition tasks require the maintenance of task-relevant representations (goals, information, responses) in the face of interference or distraction (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005; Engle et al., 1999). Therefore, the ability to control attention to maintain task-relevant information in an active, quickly retrievable state is a major determinant of working memory capacity and higher-order cognition (Engle, 2002). This is supported by several influential models of working memory which all include a dynamic attention component: Baddeley’s central executive (Baddeley, 2012), Cowan’s central executive and focus of attention (Cowan, 1999), Kane and Engle’s executive attention (Kane, Conway, Hambrick, & Engle, 2007), and Unsworth and Engle’s primary memory (Unsworth & Engle, 2005).

---

\(^1\) Complex span tasks, described in the Method section of the present paper, are considered valid indicators of working memory capacity in that information must be maintained in memory during ongoing processing. Specifically, these tasks require the maintenance of stimuli (e.g., letters or spatial locations) in memory during interleaved, distracting processing (e.g., verifying equations, sentences, or symmetry). Complex span tasks can be contrasted with simple span tasks (e.g., digit span, word span, letter span), that only require the maintenance of stimuli in memory. Complex span tasks are usually more predictive of higher-order cognition than simple span tasks.
2007). Despite no unified model of working memory (Conway et al., 2007; Cowan, 2016), attention control is not only a consistent feature across diverse working memory models, but considered by each to be a major determinant of working memory capacity and higher-order cognition.

Given its influence on complex cognition, there has been burgeoning research on the malleability of working memory capacity. As people with high working memory capacity tend to perform better on the aforementioned measures of higher-order cognition, increasing one’s working memory capacity may enable improved performance on measures of higher-order cognition. One technique that has been demonstrated to enhance working memory capacity and functioning is mindfulness meditation.

Mindfulness meditation describes a broad variety of attentional practices, processes, and states which can vary along dimensions of object orientation (i.e., focus on a specific aspect of experience), meta-awareness (i.e., capacity to notice background information while focusing on a specific aspect of experience), and dereification (i.e., treating thoughts as mental events rather than as direct representations of reality), as well as secondary qualities of aperture (i.e., the scope of attentional focus), clarity (i.e., vividness of experience), stability (i.e., how an aspect of experience persists over time), and effort (i.e., ease or difficulty in maintaining current mental state) (Lutze, Jha, Dunne, & Saron, 2015). Operationally, mindfulness meditation is defined here as attending to one’s present moment experience in a nonjudgmental and non-elaborative way (Chiesa, Calati, & Serretti, 2011). Evidence of mindfulness meditation’s effects on working memory and working memory capacity are illustrated by the following studies. Jha, Stanley, Kiyonaga, Wong, and Gelfand (2010) observed that a military cohort with high levels of

---

2 Unless noted, all instances of improvement on a working memory capacity measure refer to improvement on the operation span, a complex span task; see Method section for full task description.
mindfulness meditation practice improved their performance on a measure of working memory capacity during an 8-week pre-deployment interval, whereas a low-practicing mindfulness military cohort, a no-mindfulness practice military cohort, and a civilian control group either decreased their working memory capacity performance or remained stagnant. Zeidan, Johnson, Diamond, David, and Goolkasian (2010) demonstrated that four brief mindfulness meditation sessions significantly improved performance on measures of working memory and executive functioning (adaptive n-back and verbal fluency tasks) from pretest to posttest, whereas an active control group did not improve. Mrazek, Franklin, Phillips, Baird, and Schooler (2013) observed that a two-week course in mindfulness meditation significantly improved performance on measures of working memory capacity and reading comprehension (i.e., GRE verbal section reading comprehension) and significantly reduced instances of mind wandering, whereas an active control group did not demonstrate such improvement. Banks, Welhaf, and Srour (2015) showed that two weeks of mindfulness meditation practice moderated the negative effects of a writing stressor on a single working memory capacity measure compared to an active relaxation group. Finally, Quach, Jastrowski Mano, and Alexander (2016) found that four weeks of bi-weekly mindfulness meditation significantly improved performance on a working memory capacity measure in middle-schoolers whereas an active yoga group and waitlist control group did not improve.

The authors of several of these studies purported that mindfulness meditation led to such improvements in performance due to practitioners learning to better control their attention (Jha et al., 2010; Mrazek et al., 2013; Quach et al., 2016; Zeidan et al., 2010). Similarly, following mindfulness meditation training participants have demonstrated improvement on measures of sustained, selective, and executive attention (Jha, Krompinger, & Baime, 2007; Morrison,
Goolsarran, Rogers, & Jha, 2014; Mrazek, Smallwood, & Schooler, 2012; Tang et al., 2007). As stated previously, attention control is considered to be a major determinant of working memory capacity (Baddeley, 2012; Cowan, 1999; Engle, 2002; Engle et al., 1999; Kane et al., 2007; Unsworth & Engle, 2007). If mindfulness meditation is able to improve attention control, then this is a plausible mechanism for how mindfulness meditation may enhance working memory capacity.

Beyond mindfulness meditation, other attempts to enhance working memory capacity and thereby improve complex cognition have used computerized, adaptive training (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Jaušovec & Jaušovec, 2012; Klingberg, 2010; Melby-Lervåg & Hulme, 2013; Simons et al., 2016). Adaptive training typically uses tasks requiring the maintenance of various stimuli (e.g., spatial locations, words, digits, letters) in memory during ongoing information processing (e.g., hearing or seeing new stimuli, verifying if the current stimulus matches a previous stimulus a specified number of positions back, interleaved verification of math equations or sentence coherence, classification of stimuli into a category). Training tasks require participants to work at their current capacity (i.e., a specific amount of stimuli that can be maintained in memory while performing accurately on the memory and processing portions of the task) before increasing the memory maintenance load to adapt and expand participants’ capacity. Training of this kind is presumed to enhance working memory capacity by having participants work at their current capacity limits, until they adapt and are able to maintain more information. Such training is conducted with normal and atypical populations with the intent of enhancing complex cognition via the expansion of working memory capacity (Chooi & Thompson, 2012; Harrison, Shipstead, Hicks, Hambrick, Redick, & Engle, 2013; Jaeggi et al., 2008; Jaušovec & Jaušovec, 2012; Klingberg, 2010; Melby-Lervåg & Hulme, 2013;
Redick et al., 2013; Shipstead, Hicks, & Engle, 2012; Shipstead, Redick, & Engle, 2012; Simons et al., 2016).

Several of these studies and reviews have reported that working memory capacity can be increased and complex cognition can be enhanced (Jaeggi et al., 2008; Jaušovec & Jaušovec, 2012; Klingberg, 2010). Other studies employing more rigorous methods (e.g., control group, multiple outcome measures, outcome measures different from what participants trained on) to control for validity threats have not demonstrated that working memory capacity can be improved (Chooi & Thompson, 2012; Goghari & Linette Lawlor-Savage, 2017; Harrison et al., 2013; Redick et al., 2013; Thompson et al., 2013). Reviews of the working memory training literature have reached conclusions echoing these latter studies: working memory training does not convincingly increase working memory capacity nor transfer to untrained measures of complex cognition (Melby-Lervåg & Hulme, 2013; Shipstead, Hicks, & Engle, 2012; Shipstead, Redick, & Engle, 2012; Simons et al., 2016). To validly conclude that working memory capacity has increased following training, several criteria must be met: (1) multiple objective outcome measures are used, (2) these outcome measures are considered valid indicators of working memory capacity, (3) the outcome measures are different from the tasks participants train on, and (4) working memory capacity improvement is demonstrated relative to an active, adaptive control group (Shipstead, Hicks, & Engle, 2012; Shipstead, Redick, & Engle, 2012). To the present authors’ knowledge, no study has demonstrated that working memory capacity has been increased while meeting all of these criteria.

The previously mentioned studies demonstrating working memory capacity improvement following mindfulness meditation have included some or most of these criteria in their study design. That is, mindfulness meditation is a technique different from tested outcome measures
(criteria 3) that has been shown to improve performance on valid (criteria 2), individual measures of working memory capacity and working memory functioning when compared to an active control group (part of criteria 4) (Banks et al., 2015; Jha et al., 2010; Mrazek et al., 2013; Quach et al., 2016; Zeidan et al., 2010). Therefore, mindfulness meditation may be an intervention that can increase working memory capacity while meeting all of the criteria for concluding that working memory capacity has been improved. The improvement of attention control via mindfulness meditation is also a plausible mechanism for how mindfulness meditation may improve working memory capacity, as attention control is a major determinant of working memory capacity (Engle, 2002; Kane et al., 2007). This is unlike many computerized working memory training studies that lack a detailed task analysis or specific mechanism(s) of why such training should increase working memory capacity (Melby-Lervåg & Hulme, 2013; Simons et al., 2016). Given the demonstrated improvement on individual measures of working memory and various tasks requiring attention control, mindfulness meditation may be able to enhance working memory capacity while meeting the appropriate criteria to conclude that working memory capacity has been improved following training (Shipstead, Hicks, & Engle, 2012; Shipstead, Redick, & Engle, 2012).

The research question for the current experiment is: can mindfulness meditation enhance working memory capacity? The present investigation includes the appropriate criteria for concluding that working memory capacity has been improved following training: (1) using multiple objective outcome measures, (2) using outcome measures that are considered valid indicators of working memory capacity, (3) using outcome measures that are different from the tasks participants train on, and (4) demonstrating improvement relative to an active, adaptive control group. Using these criteria as part of the study design is an improvement over prior
studies demonstrating working memory capacity improvement following mindfulness meditation: prior studies have not demonstrated working memory capacity improvement on multiple working memory capacity outcome measures as compared to an adaptive control group. The current study compares mindfulness meditation to active, adaptive cognitive training regarding the improvement of working memory capacity. It is hypothesized that (H1) the mindfulness meditation group will significantly increase working memory capacity following training, whereas the cognitive training group will not improve. It is further hypothesized that (H2) the mindfulness meditation group will have a significantly higher working memory capacity than the cognitive training group following training.
Method

Participants

76 undergraduates at a large Midwestern university participated for course credit and compensation, with the declared intent of the 2-week, single-blind\(^3\) study to assess the effects of cognitive training on trained and untrained tasks. There were no inclusion or exclusion criteria. Participants were informed they would receive course credit for 9 out of the 10 lab sessions and $20 or $30\(^4\) after completing the 10\(^{th}\) lab session. Participants were provided with informed consent and scheduled their remaining lab sessions during their first lab session. Of the 76 participants who began the study, 65 completed it (86%): mindfulness group: \(n = 34\), mean age = 21 years old, age range = 17 to 32 years old, 25 females (1 participant did not report gender or age); cognitive training group: \(n = 31\), mean age = 19.5 years old, age range = 18 to 24 years old, 27 females (1 participant did not report gender). Five participants from the mindfulness group withdrew prior to study completion (two after the first day, two after the second day, one after the third day); six participants from the cognitive training group withdrew prior to study completion (three after the first day, one after the third day, two after the fifth day, one after the eighth day). There were no apparent systematic differences between groups regarding participant withdrawals, although this was not directly analyzed.

Measures

\(^3\) Participants knew which training group they were in, but did not know what other training group(s) there were or that mindfulness meditation was the independent variable of interest. Research assistants who prepared the computer stations for participant use knew both which groups participants were in and the independent variable of interest, and gave similar and consistent instructions to reduce experimenter-bias.

\(^4\) Initially, $20 was offered for completing the 10\(^{th}\) lab session. To recruit additional participants before the close of the semester, payment for completing the 10\(^{th}\) lab session was increased to $30. 53 participants completed the study when receiving $20, 12 participants completed the study when receiving $30 dollars.
Pretests and posttests consisted of three validated and reliable indices of working memory capacity: the automated operation, reading, and symmetry span tasks (Conway et al., 2005; Redick et al., 2012; Unsworth, Heitz, Schrock, & Engle, 2005; Unsworth et al., 2009). These tasks measure working memory capacity by requiring participants to temporarily maintain information (i.e., letters and spatial locations) in memory despite ongoing processing (i.e., verification of sentences and equations, symmetry judgments). All tasks were programmed in e-Prime software and performed on laboratory computers; tasks are available upon request at http://englelab.gatech.edu/tasks.html. At pretest, these tasks established baseline working memory capacity for each group and task order was randomized for every participant to control for order effects. At posttest, the tasks assessed changes in working memory capacity following training and were randomized for every individual to control for order effects. The three working memory capacity tasks were the only dependent variables measured in this study.

Automated Operation Span (OSPA) (Unsworth et al., 2005; Unsworth et al., 2009): In this task participants were required to recall sequences of letters while verifying math equations. The task began with a sequence of practice trials. Participants first practiced the memory span portion of the task. They were sequentially presented individual letters (any of the following: F, H, J, K, L, N, P, Q, R, S, T, Y) for 1000ms each, with a span size of two (i.e., they were presented with and had to recall two letters). Following letter presentations, a 4 x 3 matrix of the possible letters (F, H, J, K, L, N, P, Q, R, S, T, Y) was presented. Participants had to click on the presented letters in the correct serial order; they had the option of marking BLANK if they could not remember a particular letter in a specific serial order position. The recall portion was untimed. After recall, participants were presented feedback on how many letters were recalled in the correct serial position.
Participants next practiced the processing portion of the task, which consisted of the verification of math equations. Participants were shown a math equation (e.g., $2 \times 4 - 3 = ?$), told to solve as quickly as possible, and then click on the mouse to advance to the next screen. A number was then displayed (e.g., 5) with two options: TRUE and FALSE. Participants verified if this number was the correct answer to the previous equation by selecting the appropriate option. The processing portion was timed and used during the actual task: each participant’s mean equation verification time + 2.5 SD became the allowable time for verifying equations.

Following the processing portion, participants practiced the actual task where the memory span and processing portions were combined. A trial now consisted of the processing portion (i.e., equation verification) being presented first, followed by the memory span portion (i.e., letter presentation). Participants were given 3 practice trials with a span of two (i.e., 2 letters had to be maintained for recall). The equation verification was counted as an error if verification time exceeded the participant’s mean + 2.5 $SD$ established during practice. This was done to ensure participants were not slowing down on the equation verifications to rehearse letters.

Following practice, participants began the scored OSPAN. The task combined the memory and processing portions, with participants first completing an equation verification then being presented with a letter for later recall. Half of the numbers presented to participants to verify as the correct answer for an equation were correct, and half were incorrect. Each equation verification was again timed, with the maximum allowable time determined by the participant’s mean time + 2.5 $SD$ established during practice. Participants were also encouraged to get at least 85% of the equation verifications correct; this ensured that participants were attending to the processing portion of the task rather than focusing solely on the memory portion. Following the recall of presented letters within a trial, participants were informed of how many letters were
recalled in their correct serial position, as well as their cumulative equation verification accuracy. The number of letters to be maintained in memory on a given trial (i.e., span size) ranged from three to seven, span sizes were presented in randomized order, and each span size was presented three times. This resulted in 75 presented letters, and therefore a total possible score of 75 (i.e., 75 letters potentially recalled in the correct serial position). The partial scoring method was used as the dependent variable. Participants were given credit for any letter recalled in its correct serial position, (described in Results) (Conway et al., 2005; Redick et al., 2012).

Automated Reading Span (RSPAN) (Unsworth et al., 2009): In this task participants were required to recall sequences of letters while reading sentences and verifying if the sentences made sense or not. This task was identical to the OSPAN, with the exception of replacing equation verifications with sentence verifications. The sentence verification consisted of participants first being presented with a 10 to 15-word sentence with the instruction to, as quickly as possible, verify that the sentence made sense. After clicking the mouse to change the screen, participants were presented with TRUE or FALSE options, and had to indicate whether the previous sentence made sense or not. Sentences that did not make sense had one word that, if changed, would make the sentence make sense (e.g., “The prosecutor’s dish was lost because it was not based on fact.”). As with the OSPAN, during the initial sentence verifications during practice, participants were timed to determine their mean verification time. During the final portion of practice as well as during the scored RSPAN, participants were given their mean verification time + 2.5 SD to verify whether the sentence made sense or not. Again, all other aspects of practice, memory portion, task structure, encouragement of 85% accuracy or higher on sentence verifications, recall, feedback, span size, randomization of span sizes, and partial scoring method were the same as in the OSPAN.
Automated Symmetry Span (SSPN) (Unsworth et al., 2009): In this task participants were required to recall a series of spatial locations while verifying the symmetry of other spatial displays. The structure was similar to the OSPAN and RSPAN in that participants first practiced with the memory portion, then practiced with the processing portion, then practiced with both the memory and processing portions combined, before moving on to the actual scored task that combined both memory and processing portions.

The memory portion consisted of participants being presented a 4 x 4 matrix of white squares, with one of the squares turning red for 650ms. At recall, participants were presented with a 4 x 4 matrix of white squares and had to click on the presented locations (i.e., previously presented red squares within the matrix) in the correct serial order. They had the option of marking BLANK if they could not remember a particular spatial location in a specific serial order position. The recall portion was untimed. The processing portion consisted of participants being presented with an 8 x 8 matrix of white squares, of which a number of squares of were colored black. Participants had to judge whether the grid was symmetrical along its vertical axis. As with the OSPAN and RSPAN, during practice of the processing portion participants were timed; their mean time + 2.5 SD became the maximum allowable time to make symmetry judgments when the memory and processing portions were combined. If participants exceeded this time on a given judgment, it was counted as a processing error. Participants were again encouraged to maintain at least 85% accuracy on the symmetry judgments during the scored task to ensure they were attending to this portion of the task instead of rehearsing the locations of the memory portion. During the scored task, 8 x 8 matrices presented during the processing portions were symmetrical half of the time.
The number of red squares to be maintained in memory during a given trial (i.e., span size) ranged from two to five, and each span size was presented three times. This resulted in 42 presented red squares, and therefore a total possible score of 42 (i.e., 42 red squares potentially recalled in the correct serial and spatial position). Again, except for the different memory (both type and span sizes) and processing portions, all other aspects of practice, task structure, encouragement of 85% accuracy or higher on processing portions, recall, feedback, randomization of span sizes, and partial scoring method were the same as in the OSPAN and RSPAN.

Procedure

For all lab sessions (Days 1 – 10), participants sat in one of five computer stations in a large, sound-attenuated laboratory. Each computer station was sectioned off by a curtain divider. When scheduling for Day 1 of the study, participants were informed that the study would examine the effects of cognitive training. On Day 1, participants read and signed informed consent and then scheduled their remaining lab sessions (i.e., Days 2 – 10). Participants then completed the OSPAN, RSPAN, and SSPAN in randomized order. Participants were randomly assigned to either the mindfulness training or cognitive training groups. On Days 2 – 9 participants completed their respective trainings (described below). On Day 10, participants again completed the OSPAN, RSPAN, and SSPAN in randomized order. Before each of these posttests, participants completed a brief training activity (described below). Upon completing all posttests, participants were paid, debriefed, and thanked for their participation.

Mindfulness Training
On Day 2, the mindfulness training group was provided with an overview of the intent and format of their training (see Appendix A). Adapted from Zeidan et al. (2010), as provided in Johnson, Gurr, David, and Currier (2015), the mindfulness training group was told that mindfulness training would train their minds to attend to their present moment experience in a nonjudgmental and non-elaborative way. This would be done by learning to become aware of one’s internal experience and the events in one’s environment, and by doing so enable better regulation of stress and emotional reactions. Participants could be mindful at any point during their day by taking a deep breath and attending to their internal and external experience. Lastly, participants would notice that their minds wandered during the upcoming training, and this was a normal part of training. Becoming aware of the mind and its tendency to wander would be part of mindfulness training. This overview was read every day during the first week of training, with the option to read each day during the second week.

For training on Days 2 through 9, participants listened via laboratory headphones to guided meditations led by experienced mindfulness practitioners and instructors. These meditations varied in time, and lasted approximately 15 to 25 minutes (for full meditation list, see Appendix B). Days 2, 4, 5, 7, and 9 were body scan meditations. Days 3, 6, and 8 were breathing meditations. Body scan meditations would instruct participants to attend to the present moment by exploring body sensations in a systematic way. For example, participants would attend to the sensations in their feet (e.g., how the floor felt, how their shoes felt, the stability of the ground) for a few moments. Then participants would be instructed to move their awareness to their calves, attending to any present sensations or just letting the mind be aware of this part of their body. This process would continue over regions of the entire body throughout practice. Breathing meditations would instruct participants to attend to the present moment by attending to
the physical sensations of breathing. An initial focal point was typically encouraged (e.g., the tip of the nose) for participants to be aware of, and then participants would gradually expand their awareness to other body sensations associated with breathing (e.g., sounds of breathing, feeling of air entering and leaving the nose, the expansion and contraction of the chest and abdomen). Throughout both types of meditations, participants were routinely reminded to be aware of any thoughts, feelings, or sensations that came to mind; to nonjudgmentally observe and note these experiences; to return their attention back to the current focus of the meditation (i.e., specific body sensation); and if their mind wandered away from the meditation or the present moment, to note what they had been thinking about and, without judgment or elaboration, return their attention back to current focus of the meditation.

Following each guided meditation on Days 2 – 9, participants completed a brief feedback form within a training log. First, they rated on a 5-point Likert scale how well they had followed the instructions of the meditation: 1-not at all, 3-somewhat, 5-completely. This was intended to serve as a manipulation check that participants had actually been trying to meditate. As meditation is an individualized, contextual, and subjective experience, we asked participants to rate how well they had followed the instructions of the meditation rather than how well they had meditated. If participants had followed the instructions, it was assumed they had meditated as best they could. In addition, the intent to meditate and the application of meditation instructions are often prioritized over any outcomes of meditation (Teasdale & Chaskalson, 2011a, 2011b). Second, participants were asked to “Please list any questions, comments, or general feedback about your experience during the meditation.” This was done to elicit feedback from participants to address any concerns or questions they had. As guided meditations are typically conducted with an instructor and include discussion time to assess the meditation and address questions, the
recorded format of this study’s meditations would not allow for this. Any questions listed by the participants were emailed to the lead author by research assistants to be immediately addressed. On Day 9, following the day’s meditation and feedback, participants were asked to describe their overall experience during the training and how, if applicable, the training affected them outside of the laboratory. This was done to elicit global feedback from participants about their meditation training and capture any subjective experiences of meditation impacting their life beyond the laboratory. This feedback was not analyzed and is not reported.

On Day 10 prior to each working memory capacity posttest (i.e., OSPAN, RSPAN, SSPAN), mindfulness training participants listened to a brief guided meditation. As in prior studies (Banks et al., 2015; Semple, 2010; Zeidan et al., 2010), participants completed brief meditations on the day of posttests to induce a mindful state and cue the attention control practices learned during mindfulness training (e.g., awareness of attention, disengaging from distractions, reorienting attention to task). Upon entering the lab on Day 10, participants listened to a 4 min 30 sec guided meditation, then completed their first working memory capacity posttest. Participants then listened to a 1 min 5 sec guided meditation, then completed their second working memory capacity posttest. Participants then listened to the same 1 min 5 sec guided meditation, then completed their third working memory capacity posttest.

Cognitive Training

On Day 2, the cognitive training group was provided with an overview of the intent and format of their training (see Appendix A). The overview mirrored that of the mindfulness training group’s overview, and differed according to the cognitive training group’s training. Participants were told that they were going to engage in cognitive training that may improve
their abilities across a range of tasks. Training would take the form of item span and executive tasks; the former requiring participants to remember as much as possible, and the latter requiring participants to work with distractions. Participants were to try to improve their performance throughout training by remembering more items in the item span tasks and maintaining accuracy while increasing speed in the executive tasks. Further, abilities tapped by these tasks are useful in day to day life: it is often helpful to remember more items on a grocery list or for an upcoming exam, or attend to some stimuli while ignoring others (e.g., attending to hitting the brake instead of the gas pedal at a red light or attending to reading a textbook instead of music while studying). Lastly, participants were told to improve as much as possible and not get discouraged if some tasks were hard or improvement came faster on some tasks than others. This overview was read every day during the first week of training, with the option to read each day during the second week.

On Days 2, 3, 4, 5, 8, and 9, cognitive training participants trained on various item span tasks (for full list of training tasks, see Appendix B). On Days 6 and 7, cognitive training participants completed different executive tasks. The item span tasks required recall of either digits or spatial locations, in either forward or reverse order. The executive tasks required participants to attend to specific task stimuli while ignoring task-irrelevant stimuli (e.g., during the Stroop task, to attend to the color of the printed color word while ignoring the written color word). All item span tasks began at 3 to-be-remembered items; participants were instructed to adapt their performance throughout each task by clicking on an “up” arrow to increase the number of to-be-remembered digits, and to do so whenever they were ready\(^5\). Participants were

\(^5\) The method of the cognitive training group’s adaptation differed in the present experiment from other working memory training research, but should not affect study conclusions. Here, there was no automatic increase or decrease in training task difficulty based on participants’ performance. The cognitive training group was told they may improve their cognitive abilities and performance by participating in training and adapting their performance.
instructed to adapt their performance throughout executive tasks by maintaining high accuracy while increasing their speed. Every cognitive training group task was timed to match the mindfulness training group’s training for the same day; participants wore laboratory headphones every day during training to be able to hear the timer that indicated that day’s training was over. Upon completion of every task, participants were provided feedback that they recorded in their training logs: for item span tasks, their longest and average span; for executive tasks, their fastest trial, average trial speed, and percentage correct for incongruent trials (i.e., trials where to-be-ignored stimuli conflicted with the to-be-attended stimuli; for example, in the Eriksen flanker task responding to a center arrow pointing left while all other arrows on screen pointed right). On Day 9, following the day’s training and feedback, participants were asked to describe their overall experience during the training and how, if applicable, the training affected them outside of the laboratory. This was done to elicit global feedback from participants about their cognitive training, and capture any subjective experiences of cognitive training impacting their life beyond the laboratory. This feedback was not analyzed and is not reported.

On Day 10 prior to each working memory capacity posttest, cognitive training participants completed a simple, brief drawing activity. This was done in the same manner (upon entering lab, prior to each working memory capacity posttest) and duration as the mindfulness training group’s Day 10 meditations. Participants were given a paper with a display of labeled boxes (e.g., A1, E6, B3, etc.) at the top, and a blank grid on the bottom (labeled A1, A2, A3, etc.). Cognitive training participants had to copy the design from a labeled box at the top of the page into the appropriately labeled box on the bottom. The finished picture on the bottom grid displayed a beach sunset. Cognitive training participants were told this would serve as a warmup for expectancy and motivation effects as the mindfulness training group was given similar expectations.
for their upcoming tasks, and to try to complete as much as possible during the allotted time. As on Days 2 – 9, participants wore laboratory headphones to hear a timer that indicated to stop drawing. This task was selected as it was an easy, undemanding task that would not fatigue the cognitive training participants before their working memory capacity posttests.
III. Results

The results of the current experiment suggest that mindfulness meditation training improved working memory performance. Descriptive statistics for all participants on the working memory capacity measures at pretest and posttest are presented in Table 1. As stated previously, the partial scoring method was used whereby participants were given credit for any memory span item recalled in the correct serial position. This allowed for a maximum of 75, 75, and 42 points on the operation (OSPAN), reading (RSPAN), and symmetry (SSSPAN) tasks, respectively. To obtain a composite measure of working memory capacity, the individual span task scores were first converted into a proportion correct score. These proportion correct scores were then averaged into a mean proportion correct; this mean proportion correct score became the working memory capacity composite score (see Table 1). No analyses were conducted on working memory capacity task processing scores. Participants scoring below 85% accuracy on the processing portion of working memory capacity tasks are often dropped from further analysis (Conway et al., 2005); however, this procedure may not be necessary as positive correlations between processing accuracy and memory span recall scores indicate no trade-offs between the two (Unsworth et al., 2009). In addition, working memory training studies using similar working memory capacity tasks have not reported dropping participant data due to processing scores (Harrison et al., 2013; Redick et al., 2013). Therefore, working memory capacity task recall data from all participants who completed the study were used for analyses.

Initial descriptive statistics for each group on the working memory capacity composite score are displayed in Table 2. Skewness (< 2) and kurtosis (< 4) values indicate that the data were normally distributed. Despite numeric differences, there were no significant group
Table 1.

Working Memory Capacity (WMC) Individual Task Scores and Proportion Correct, and WMC Composite Score.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Min.</th>
<th>Max.</th>
<th>M</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partial Score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSPAN Pretest</td>
<td>63</td>
<td>9</td>
<td>75</td>
<td>52.70</td>
<td>17.03</td>
<td>-1.017</td>
<td>.254</td>
</tr>
<tr>
<td>RSPAN Pretest</td>
<td>65</td>
<td>10</td>
<td>72</td>
<td>50.85</td>
<td>13.95</td>
<td>-.589</td>
<td>-.144</td>
</tr>
<tr>
<td>SSPAN Pretest</td>
<td>64</td>
<td>5</td>
<td>41</td>
<td>24.94</td>
<td>9.28</td>
<td>-.350</td>
<td>-.580</td>
</tr>
<tr>
<td>OSPAN Posttest</td>
<td>63</td>
<td>4</td>
<td>74</td>
<td>54.46</td>
<td>18.40</td>
<td>-1.329</td>
<td>.939</td>
</tr>
<tr>
<td>RSPAN Posttest</td>
<td>64</td>
<td>11</td>
<td>74</td>
<td>52.59</td>
<td>14.41</td>
<td>-.847</td>
<td>.186</td>
</tr>
<tr>
<td>SSPAN Posttest</td>
<td>65</td>
<td>5</td>
<td>42</td>
<td>27.17</td>
<td>8.99</td>
<td>-.688</td>
<td>-.100</td>
</tr>
<tr>
<td><strong>Proportion Correct</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSPAN Pretest</td>
<td>63</td>
<td>.12</td>
<td>1.00</td>
<td>.703</td>
<td>.227</td>
<td>-1.017</td>
<td>.254</td>
</tr>
<tr>
<td>RSPAN Pretest</td>
<td>65</td>
<td>.13</td>
<td>.96</td>
<td>.678</td>
<td>.186</td>
<td>-.589</td>
<td>-.144</td>
</tr>
<tr>
<td>SSPAN Pretest</td>
<td>64</td>
<td>.12</td>
<td>.98</td>
<td>.594</td>
<td>.221</td>
<td>-.350</td>
<td>-.580</td>
</tr>
<tr>
<td>OSPAN Posttest</td>
<td>64</td>
<td>.01</td>
<td>.99</td>
<td>.715</td>
<td>.259</td>
<td>-1.316</td>
<td>.824</td>
</tr>
<tr>
<td>RSPAN Posttest</td>
<td>64</td>
<td>.15</td>
<td>.99</td>
<td>.701</td>
<td>.192</td>
<td>-.847</td>
<td>.186</td>
</tr>
<tr>
<td>SSPAN Posttest</td>
<td>65</td>
<td>.12</td>
<td>1.00</td>
<td>.647</td>
<td>.214</td>
<td>-.688</td>
<td>-.100</td>
</tr>
<tr>
<td><strong>WMC Composite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>65</td>
<td>.26</td>
<td>.94</td>
<td>.659</td>
<td>.177</td>
<td>-.458</td>
<td>-.876</td>
</tr>
<tr>
<td>Posttest</td>
<td>65</td>
<td>.15</td>
<td>.95</td>
<td>.685</td>
<td>.189</td>
<td>-.872</td>
<td>.137</td>
</tr>
</tbody>
</table>

Differences at pretest (as revealed by a repeated measures analysis of variance, discussed later).

One mindfulness training participant’s posttest OSPAN score was dropped from their working memory capacity composite at posttest; their pretest OSPAN raw score was a 28 and their posttest OSPAN raw score was a 1 (both raw scores out of 75 possible points). Their RSPAN and SSPAN raw scores did not exhibit such a drop (RSPAN: pretest = 10, posttest = 21; SSPAN: pretest = 16, posttest = 11). As this drop was considerable and specific to one test, it may have reflected a failure to understand or follow instructions (this participant’s OSPAN was performed last at posttest) (Thompson et al., 2013).

---

6 Inclusion of this participant’s posttest OSPAN raw score into their posttest working memory capacity composite score changed the repeated measures analysis of variance test of within-subjects contrasts main effect of time to a non-significant value, F(1, 63) = 3.953, p = .051, ηp² = .059. This score inclusion did not change the results of the paired samples t-test for group differences on the working memory capacity composite from pretest to posttest; only the mindfulness training group significantly increased the working memory capacity composite score from pretest to posttest. Cohen’s d for the mindfulness training group’s pretest to posttest difference changed to d = .42.
Table 2.
*Descriptive Statistics for WMC Composite at Pretest and Posttest.*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Range</th>
<th>Min.</th>
<th>Max.</th>
<th>M</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>31</td>
<td>.52</td>
<td>.37</td>
<td>.89</td>
<td>.68</td>
<td>.16</td>
<td>-.411</td>
<td>-1.196</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>.52</td>
<td>.42</td>
<td>.94</td>
<td>.69</td>
<td>.15</td>
<td>-.272</td>
<td>-1.154</td>
</tr>
<tr>
<td>MT</td>
<td>34</td>
<td>.68</td>
<td>.26</td>
<td>.94</td>
<td>.64</td>
<td>.20</td>
<td>-.392</td>
<td>-.966</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>.79</td>
<td>.15</td>
<td>.95</td>
<td>.68</td>
<td>.22</td>
<td>-.959</td>
<td>-.112</td>
</tr>
</tbody>
</table>

CT = cognitive training group; MT = mindfulness training group

A repeated measures analysis of variance (ANOVA) was conducted to examine effects of training and differences between groups. Levene’s test of equality of error variances was non-significant at pretest and posttest, demonstrating equal variance of the error variance for the working memory capacity composite for the mindfulness training and cognitive training groups: pretest, $F(1, 63) = 1.48, p = .23$; posttest, $F(1, 63) = 3.84, p = .06$. Recall, it was hypothesized that the mindfulness training group would significantly improve their working memory capacity composite from pretest to posttest, whereas the cognitive training group would not. It was also hypothesized that the mindfulness training group would significantly outperform the cognitive training group on the working memory capacity composite at posttest. The test of between-subject effects demonstrated no significant differences between groups, $F < 1, \eta^2_p = .006$. The test of within-subject contrasts demonstrated a main effect of time, $F(1, 63) = 4.50, p = .04, \eta^2_p = .07$, but no time by group interaction, $F < 1, \eta^2_p = .014$. These results ran contrary to our second hypothesis, as there were no significant differences between the mindfulness training and cognitive training groups at posttest.

Examining the main effect of time (see Figure 1), both groups improved their working memory capacity composite score from pretest to posttest. Given the clear differences in slope, the change in the mindfulness training group appears to be a larger influence on the main effect of the
time. To examine the changes within each group more closely, two exploratory paired samples t-tests were conducted. As stated earlier, it was hypothesized that the mindfulness training group would significantly increase working memory capacity from pretest to posttest, whereas the cognitive training group would not improve. The cognitive training group did not display a significant difference in the working memory capacity composite score from pretest to posttest; mean difference = .014, $t(30) = .782, p = .44, d = .14, 95\% CI (-.05, .023)$. The mindfulness training group did display a significant difference in the working memory capacity composite score from pretest to posttest; mean difference = .037, $t(32) = 2.29, p = .029, d = .45, 95\% CI (.004, .07)$. The repeated measures ANOVA did not support our first hypothesis that the mindfulness training group, but not the cognitive training group, would significantly improve working memory capacity following training. The results from our exploratory follow-up analysis did support that the mindfulness training group significantly increased their working memory capacity composite score following training, whereas the cognitive training group did not.

Table 2 and Figure 1 display numeric – although non-significant – differences between the mindfulness training and cognitive training groups at pretest. A univariate ANOVA was run to examine the working memory capacity composite posttest differences between the
mindfulness training and cognitive training groups using the pretest as a covariate. Although there were numeric differences at posttest (cognitive training group $M = .68$, mindfulness training group $M = .70$) when using pretest ($M = .66$) as a covariate, there were no significant group differences between the mindfulness training and cognitive training groups, $F < 1$, $\eta^2_p = .011$.

Exploratory analyses were conducted to review the distribution of scores, change scores, and extreme scores in both groups. Of the 5 lowest scoring cognitive training participants at pretest, 3 were again in the bottom 5 scores at posttest; 2 out of 3 of these participants increased their scores and the lowest overall score increased (.37 to .42). Of the 5 lowest scoring mindfulness meditation participants at pretest, 4 were again in the bottom 5 scores at posttest; all 4 of these participants scored lower at posttest and the lowest overall score decreased (.26 to .15). These data suggest that several lower scoring participants in the mindfulness meditation group decreased performance at posttest, whereas the trend for the mindfulness meditation group was to score higher on the working memory capacity composite following training. This suggests that the lowest scoring participants in the mindfulness group were not compliant with instructions of the study (i.e., did not attempt to do well on the working memory capacity tasks), or a potential and counter-intuitive interaction that mindfulness meditation decreased working memory capacity for participants with lower working memory capacity.\(^7\)

Exploratory analyses were conducted on the working memory capacity composite scores without these low scoring participants in both groups, in the event that the low scoring individuals in the mindfulness training group were not complying with study instructions and

\(^7\) Of the 5 highest scoring participants for each group at pretest, 2 participants in each group were again in the top 5 scores at posttest; all 4 of these participants increased their scores at posttest. There were no differences between groups in scatterplots of each group’s pretest and posttest, except that 3 participants in the mindfulness training group with pretest scores around .45 to .55 increased by .22 to .27 at posttest.
therefore not reflective of mindfulness training’s effect on working memory capacity. The aforementioned repeated measures ANOVA, paired-samples t-test, and univariate ANOVA were rerun after dropping data from the three cognitive training group and four mindfulness training group participants just described. The results were unchanged: for the repeated measures ANOVA, only the within subjects effect of time was significant, $F(1, 56) = 6.77, p = .01, \eta^2_p = .11$; for the paired samples t-test, only the mindfulness meditation group significantly improved working memory capacity following training (see Table 3); and there were numeric but non-significant differences (cognitive training group $M = .71$, mindfulness training group $M = .75$; $F(1, 56) = 1.895, p = .17, \eta^2_p = .033$) on the working memory capacity composite posttest univariate ANOVA using the pretest ($M = .69$) as a covariate. The main change in results after dropping the low scoring participants in both groups is that the mindfulness training group surpassed the cognitive training group on the working memory capacity composite at posttest, although this difference was non-significant (see Figure 2).

Table 3.
*Paired Samples t-test for WMC Composite at Pretest and Posttest With Low-Scoring Participant Data Dropped.*

<table>
<thead>
<tr>
<th>Group</th>
<th>Test (n)</th>
<th>Pretest Mean</th>
<th>SD</th>
<th>Posttest Mean</th>
<th>SD</th>
<th>Mean Difference</th>
<th>SD</th>
<th>95% CI of Difference</th>
<th>t</th>
<th>df (2-tailed)</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>28</td>
<td>.70</td>
<td>.14</td>
<td>.72</td>
<td>.13</td>
<td>.02</td>
<td>.10</td>
<td>-.03</td>
<td>.06</td>
<td>27</td>
<td>.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.73</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.73</td>
<td></td>
</tr>
<tr>
<td>MT</td>
<td>30</td>
<td>.69</td>
<td>.16</td>
<td>.74</td>
<td>.16</td>
<td>.05</td>
<td>.09</td>
<td>.02</td>
<td>.09</td>
<td>29</td>
<td>.55</td>
</tr>
</tbody>
</table>

CT = cognitive training group; MT = mindfulness training group
The effect of mindfulness training on the working memory capacity composite score, representing working memory as a system, was the main focus of this study. Additional exploratory analyses were conducted to examine the effects of mindfulness training on performance on individual working memory capacity tasks; first, repeated measures ANOVAs were performed on the OSPAN, RSPAN, and SSPAN\(^8\). The dependent variable for each individual span task was the proportion correct. Levene’s test of equality of error variances was non-significant at pretest and posttest for all individual task repeated measures ANOVAs, demonstrating equal variance of the error variance for each task for the mindfulness training and cognitive training groups. As shown in Table 4, all repeated measures ANOVA tests were non-significant for the OSPAN and RSPAN; only the within-subjects effect of time test was significant for the SSPAN.

\(^8\) These, and all subsequent exploratory analyses, were conducted with the full data set. The only exception is the previously mentioned participant in the mindfulness training group whose posttest OSPAN was dropped from their posttest working memory capacity composite score.
Table 4.  
Repeated Measures ANOVA Tests of Individual WMC Tasks.

<table>
<thead>
<tr>
<th>ANOVA Tests</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>$\eta^2_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between-subjects</td>
<td>1, 60</td>
<td>1.457</td>
<td>.23</td>
<td>.024</td>
</tr>
<tr>
<td>OSPAN Effect of Time</td>
<td>1, 60</td>
<td>.164</td>
<td>.69</td>
<td>.003</td>
</tr>
<tr>
<td>Time X Group Interaction</td>
<td>1, 60</td>
<td>.225</td>
<td>.64</td>
<td>.004</td>
</tr>
<tr>
<td>Between-subjects</td>
<td>1, 62</td>
<td>1.026</td>
<td>.32</td>
<td>.016</td>
</tr>
<tr>
<td>RSPAN Effect of Time</td>
<td>1, 62</td>
<td>1.166</td>
<td>.28</td>
<td>.018</td>
</tr>
<tr>
<td>Time X Group Interaction</td>
<td>1, 62</td>
<td>.047</td>
<td>.83</td>
<td>.001</td>
</tr>
<tr>
<td>Between-subjects</td>
<td>1, 62</td>
<td>.862</td>
<td>.36</td>
<td>.014</td>
</tr>
<tr>
<td>SSPAN Effect of Time</td>
<td>1, 62</td>
<td>9.817</td>
<td>.00</td>
<td>.137</td>
</tr>
<tr>
<td>Time X Group Interaction</td>
<td>1, 62</td>
<td>.214</td>
<td>.65</td>
<td>.003</td>
</tr>
</tbody>
</table>

As exploratory paired samples $t$-tests had demonstrated significant improvement on the working memory capacity composite score following training only for the mindfulness training group, similar analyses were conducted in an exploratory manner on the individual span task proportion correct scores. Displayed in Table 5 and Figure 3 are the paired samples $t$-tests for the mindfulness training and cognitive training groups on the pretest and posttest OSPAN, RSPAN, and SSPAN. The mindfulness training group significantly increased performance from pretest to posttest on the SSPAN, whereas the cognitive training group did not significantly improve on any individual working memory capacity task. The cognitive training group scored numerically – but not significantly – higher than the mindfulness training on all pretests and posttests except for the SSPAN. The mindfulness training group also numerically – but not significantly – increased performance on the OSPAN and RSPAN more than the cognitive training group.
Table 5.
*Paired Samples t-tests on Individual WMC Tasks by Group at Pretest and Posttest.*

<table>
<thead>
<tr>
<th>Group</th>
<th>Test</th>
<th>Pretest Mean</th>
<th>SD</th>
<th>Posttest Mean</th>
<th>SD</th>
<th>Mean Difference</th>
<th>SD</th>
<th>95% CI of Difference</th>
<th>t</th>
<th>df</th>
<th>Sign. (2-tailed)</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSPAN</td>
<td>(30)</td>
<td>.75</td>
<td>.20</td>
<td>.75</td>
<td>.24</td>
<td>.002</td>
<td>.25</td>
<td>-.093</td>
<td>.090</td>
<td>.040</td>
<td>29</td>
<td>.969</td>
</tr>
<tr>
<td>CT</td>
<td>RSPAN</td>
<td>.71</td>
<td>.17</td>
<td>.72</td>
<td>.16</td>
<td>.015</td>
<td>.15</td>
<td>-.038</td>
<td>.068</td>
<td>.577</td>
<td>30</td>
<td>.568</td>
</tr>
<tr>
<td></td>
<td>(31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSPAN</td>
<td>(30)</td>
<td>.57</td>
<td>.22</td>
<td>.62</td>
<td>.20</td>
<td>.045</td>
<td>.14</td>
<td>-.008</td>
<td>.099</td>
<td>1.724</td>
<td>29</td>
<td>.095</td>
</tr>
<tr>
<td>OSPAN</td>
<td>(32)</td>
<td>.67</td>
<td>.25</td>
<td>.69</td>
<td>.29</td>
<td>.023</td>
<td>.15</td>
<td>-.031</td>
<td>.076</td>
<td>.863</td>
<td>31</td>
<td>.395</td>
</tr>
<tr>
<td>MT</td>
<td>RSPAN</td>
<td>.66</td>
<td>.20</td>
<td>.68</td>
<td>.22</td>
<td>.023</td>
<td>.13</td>
<td>-.025</td>
<td>.070</td>
<td>.970</td>
<td>32</td>
<td>.339</td>
</tr>
<tr>
<td></td>
<td>(33)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSPAN</td>
<td>(34)</td>
<td>.61</td>
<td>.23</td>
<td>.67</td>
<td>.23</td>
<td>.061</td>
<td>.13</td>
<td>.017</td>
<td>.105</td>
<td>2.789</td>
<td>33</td>
<td>.009</td>
</tr>
</tbody>
</table>

CT = cognitive training group; MT = mindfulness training group

Exploratory analyses on training scores for both groups were also conducted. On the 5-point Likert scale for how well mindfulness training participants followed the instructions of the guided meditation (1-not at all, 3-somewhat, 5-completely), the mindfulness group reported an average of 3.85. This indicates that mindfulness training participants were engaged in the meditations by following the instructions most of the time. Averaging across all item span tasks,
the cognitive training group had a mean of 7.74 for longest span and a mean of 4.99 for average span. Averaging across both executive tasks, the cognitive training group had a mean response time of 419.78ms for fastest incongruent time and a mean response time of 865.1ms for average incongruent time; cognitive training group participants were also 95% correct on all incongruent trials.

Exploratory regression analyses were conducted to determine if the above training scores predicted the working memory capacity composite score at posttest. Regression analysis was conducted separately for each group (mindfulness training, cognitive training) to allow regression of the working memory capacity composite score on the mindfulness and cognitive training groups’ training scores. As shown in Table 6, the mindfulness training group’s training score was not a significant predictor of the working memory capacity composite score at posttest. This would imply that there were problems with the scale used to record how well mindfulness training participants followed the guided meditation instructions, or that participants did not need to completely follow the guided meditation instructions to benefit from mindfulness meditation. For the cognitive training group, only participants’ longest and average span were predictors of the working memory capacity composite score at posttest. Interestingly, longest span was negatively related to the working memory capacity composite score. This would imply that processes above and beyond simple short-term storage capacity contribute to working memory capacity (Engle et al., 1999).
Table 6.  
ANOVA, Regression, and Multiple Regression Results for Predicting WMC Composite Score at Posttest From Training Scores.

<table>
<thead>
<tr>
<th>Group</th>
<th>$R^2$</th>
<th>$df$</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT</td>
<td>.078</td>
<td>1, 32</td>
<td>2.712</td>
<td>.109</td>
</tr>
<tr>
<td>Following Instructions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$b$</td>
<td>$b^*$</td>
<td>$t$</td>
<td>$p$</td>
</tr>
<tr>
<td></td>
<td>.106</td>
<td>.280</td>
<td>1.647</td>
<td>.109</td>
</tr>
<tr>
<td>CT</td>
<td>.409</td>
<td>5, 25</td>
<td>3.461</td>
<td>.016</td>
</tr>
<tr>
<td>Longest Span</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$b_i$</td>
<td>$b_{i*}$</td>
<td>$t$</td>
<td>$p$</td>
</tr>
<tr>
<td></td>
<td>-.076</td>
<td>-.616</td>
<td>-2.679</td>
<td>.013</td>
</tr>
<tr>
<td>Avg. Span</td>
<td>.231</td>
<td>.929</td>
<td>3.884</td>
<td>.001</td>
</tr>
<tr>
<td>Fastest Incongruent Time</td>
<td>.000</td>
<td>.330</td>
<td>1.929</td>
<td>.065</td>
</tr>
<tr>
<td>Avg. Incongruent Time</td>
<td>-.000037</td>
<td>-.055</td>
<td>-.326</td>
<td>.747</td>
</tr>
<tr>
<td>Percentage Incongruent Correct</td>
<td>-.012</td>
<td>-.302</td>
<td>-1.763</td>
<td>.090</td>
</tr>
</tbody>
</table>

MT = mindfulness training group; CT = cognitive training group
IV. Discussion

The results of the present study suggest that mindfulness meditation may improve working memory capacity. The present study investigated if mindfulness meditation could enhance the capacity of the working memory system using appropriate criteria for reaching such a conclusion: using multiple, valid indicators of working memory capacity different from the tasks participants trained on, and demonstrating improvement relative to an active, adaptive control group. It was hypothesized that the mindfulness meditation group would significantly improve working memory capacity from pretest to posttest, whereas the cognitive training group (i.e., active, adaptive control group) would not demonstrate such improvement. It was also hypothesized that the mindfulness meditation group would have a significantly higher working memory capacity at posttest than the cognitive training group.

The first hypothesis was confirmed as only the mindfulness meditation group significantly improved working memory capacity following training, whereas the cognitive training group did not. The second hypothesis was not supported, as the cognitive training group had a numerically but non-significantly higher working memory capacity than the mindfulness meditation group at posttest. When the data from the lowest scoring participants in both groups were dropped (due to those in the mindfulness meditation group presumably not following study instructions), the mindfulness meditation group numerically – although not significantly – surpassed the cognitive training group in working memory capacity at posttest. Exploratory analyses demonstrated that only the mindfulness meditation group significantly increased performance on an individual working memory task (symmetry span), the mindfulness meditation group numerically but non-significantly increased performance more than the
cognitive training group on all individual working memory tasks, the cognitive training group scored numerically but non-significantly higher than the mindfulness group on two individual working memory tasks at pretest and posttest (operation and reading span), and only the cognitive training group’s item span scores from training were significant predictors of working memory capacity at posttest.

These findings are important in several ways. Theoretically, the results demonstrate that the working memory system, a foundational psychological system that supports higher-order cognition, may be enhanced with training. This was demonstrated using stringent criteria that other studies reporting working memory capacity improvement have not met (Melby-Lervåg & Hulme, 2013; Shipstead, Hicks, & Engle, 2012; Shipstead, Redick, & Engle, 2012; Simons et al., 2016). The current experiment is the first study that used a well-controlled design and met (almost all) the requisite criteria for concluding working memory capacity was improved following training, and did so with comparatively brief and inexpensive training. Further, the results support models of working memory that posit attention control as a major determinant of working memory capacity (Baddeley, 2012; Cowan, 1999; Engle, 2002; Engle et al., 1999; Kane et al., 2007; Unsworth & Engle, 2007), as a method of learning to control attention (i.e., mindfulness meditation) was shown to improve working memory capacity. This latter point provides reciprocal and convergent support to the notion that mindfulness meditation is an effective means of enhancing attention control, as training in mindfulness meditation led to improvement on measures of a psychological system reliant on attention control (i.e., working memory capacity). Practically, these findings are significant in that it is possible – with brief and inexpensive training – to enhance a core aspect of human information processing, potentially leading to improvement on measures of higher-order cognition.
Before over stating the significance of these findings, it is important to reiterate that the mindfulness meditation group did not significantly differ from the cognitive training group at posttest. This implies that while mindfulness meditation improved working memory capacity, it did not differentiate from training that has not improved working memory capacity (Harrison et al., 2013). In addition, while attention control is a plausible explanation of how mindfulness mediation led to working memory capacity improvement, there were no direct measures of attention control to confidently conclude this. It is important to interpret the current findings considering prior research and limitations in the current design.

The present findings are like prior work demonstrating that mindfulness meditation may enhance working memory capacity and functioning, but not differentiate a mindfulness meditation group from an active control group on working memory capacity measures (Banks et al., 2015; Jha et al., 2010; Johnson et al., 2015; Morrison et al., 2013; Quach et al., 2016; but see Mrazek et al., 2013). The current and previous findings suggest that mindfulness meditation may enhance working memory functioning and capacity. Mindfulness meditation may be able to enhance working memory capacity enough to differentiate its effects from other interventions, but this is yet to be consistently demonstrated. A potential explanation for these results is that the duration of mindfulness training in the present and aforementioned studies was not sufficient to enhance working memory capacity to such a degree that group differences were apparent. For example, total mindfulness training time in the current study equaled just under 3 h of mindfulness training (~ 2 h 50 min). Mrazek et al. demonstrated enhanced working memory capacity following almost 3 h (~ 2 h 40 min) of in-class mindfulness meditation and an unknown amount of at-home mindfulness meditation⁹. The largest reported mean duration of mindfulness

⁹The amount of mindfulness meditation outside of class may have ranged from 1 h 20 min to 3 h 30 min. Mrazek et al. (2013) stated that participants were instructed to practice mindfulness meditation for 10 min per day outside of
training in the aforementioned studies was in Jha et al., with ~10.5 h for the high-practice mindfulness group. Chambers, Lo, and Allen (2007) reported that 10 days of an intensive mindfulness retreat (with up to 110 h of practice) significantly improved performance on a working memory measure, with a significant time by group interaction at posttest compared to a wait-list control group. However, the digit span backwards test used to assess working memory in this study was found to load on a short-term memory factor instead of a working memory factor in Engle et al. (1999). Thus, future research should examine how much mindfulness training is necessary and typically required to surpass an active control group on valid working memory capacity measures.

Although it was assumed that enhanced attention control following mindfulness meditation improved working memory capacity, the mechanism of mindfulness meditation’s effect was not measured within the current work. Improvements in cognitive performance following mindfulness training have also been attributed to reductions in mind-wandering (Mrazek et al., 2013), reductions in fatigue and anxiety (Zeidan et al., 2010), acceptance of present moment experience (Rahl, Lindsay, Pacilio, Brown, & Creswell, 2016), and moderation of negative affect (Banks et al., 2015). While future studies should examine the mediational role of attention control on mindfulness meditation’s effects on working memory capacity, previous literature suggests that enhanced attention control is a plausible mechanism of working memory capacity improvement.

For example, Mrazek and colleagues (2012, 2013) demonstrated that improvements in cognitive tasks, including a working memory capacity task, were mediated by reductions in mind
wandering. This reduction can be considered an instantiation of attention control, as those who sustained their attention longer on a task or reoriented attention back to the task more quickly after distraction were less prone to several measures of mind wandering. Further, mediational analyses in Jha et al. (2010) suggested that reductions in negative affect following mindfulness meditation training were mediated by enhanced working memory capacity, instead of improvements in working memory capacity following mindfulness meditation training being mediated by reduced negative affect. Rahl et al. (2016) found that mindfulness meditation that included acceptance of present moment experience (in addition to attention to the present moment) further reduced mind-wandering, more so than mindfulness meditation that only included attention to the present moment. In the present study, increases in acceptance may have reduced mind-wandering; this still supports that mindfulness meditation enhanced working memory capacity by improving attention control (albeit indirectly; future research can separate what effects, if any, mindfulness meditation with or without present moment focus or acceptance of experience is critical to affecting working memory capacity).

In contrast to these results on the role of attention control in improving cognition following mindfulness meditation, additional mechanisms have been suggested. Isbel and Mahar (2015) observed that mindfulness meditation experience was associated with enhanced decentering (i.e., detachment from thoughts and feelings) but not improved performance on attention control or attentional inhibition tasks. However, the authors acknowledged that the attention tasks used (e.g., alerting, orienting, and executive attention measures from the Attention Network Test; Stroop task) relied on task-driven, externally directed timed responses that may not have tapped the internally directed attention practices learned from mindfulness mediation. In a working memory capacity complex span task, for example, successful performance may
require participants to allocate internal attention as needed to maintain to-be-remembered items while balancing the demands of the interleaved processing task; if so, the current results support that improved internal attention control following mindfulness training may have mediated the effects of mindfulness meditation on working memory capacity. Alternatively, mindfulness meditation training may have reduced fatigue, anxiety, or negative affect in the current study to improve working memory capacity (Banks et al., 2015; Zeidan et al., 2010). If this is the case, it is unclear why the current data pattern was observed (i.e., mindfulness group scoring lower at pretest, equating cognitive training group at posttest with full data set, or surpassing the cognitive training group at posttest with low scoring data dropped), as both groups were randomly assigned and participated in the study during the same time points of the semester.

Beyond the potential mechanisms of working memory capacity enhancement following mindfulness meditation, it is also not clear what aspects of mindfulness meditation impacted these mechanisms. Mindfulness meditation practices can vary along multiple dimensions and qualities, such as object orientation, meta-awareness, dereification, focus of attention, aperture of attentional focus, clarity and vividness of experience, stability of attention and aspects of experience, effort to maintain mental state, physical posture during meditation, judgment or elaboration on thoughts, and ethics and purpose of practice (Lutz et al., 2015; Wallace, 1999). How these variations of mindfulness meditation, both within an individual guided meditation and between different guided meditations, impact working memory capacity directly and indirectly through other mechanisms (i.e., improved attention control; reductions in mind-wandering, fatigue, or anxiety; increased decentering) remain to be specified.

The present results also do not allow direct conclusions regarding whether the observed effects on working memory capacity following mindfulness meditation training are the result of
training per se or state effects induced during the Day 10 meditations. Engle (2002) stated that working memory capacity “…is not about individual differences in the number of items that can be stored per se but about differences in the ability to control attention to maintain information in an active, quickly retrievable state” (pg. 20). If mindfulness meditation can induce a state where attention is more focused and centered on the task at hand, this state may produce task results that look like enhanced working memory capacity. In support of the effects on working memory capacity being the result of at least several days of training, Johnson et al. (2015) and Watier and Dubois (2016) found that one session of mindfulness meditation was not enough practice to improve performance on multiple cognitive tasks relative to control groups. This, and other research showing working memory improvement following at least several days of mindfulness training (Mrazek et al., 2013; Zeidan et al., 2010), support the notion that the present working memory capacity improvements resulted from mindfulness meditation training. Within in these prior studies, however, there were no working memory capacity tasks like those used in the current study. Therefore, while it may be unlikely that ~6 min of mindfulness meditation during posttests could improve working memory performance, the current study cannot rule out the possibility of state effects.

An alternative explanation for the observed results were that trait mindfulness and previous mindfulness meditation experience were not assessed, nor was the amount of mindfulness training that may have occurred outside the lab. It may be possible that participants in the mindfulness group had higher levels of trait mindfulness and prior meditation experience, and the additional training in lab led to the increased working memory capacity at posttest. While not controlled for, this explanation is unlikely as it does not account for the lower mindfulness meditation group score at pretest. Further, participants were randomly assigned to groups, so the
probabilities of trait mindfulness and prior meditation experience were equally probable in the cognitive training group. Additionally, participants in the mindfulness meditation group may have practiced mindfulness outside of the laboratory during their two weeks of training, which gave them additional treatment that the control group did not receive. It was explained in the mindfulness group’s training overview that mindfulness can be practiced any time anywhere by focusing on the present moment. This is possible, and prior research is inconsistent with monitoring mindfulness practice outside of the laboratory; some studies have tracked and reported mindfulness practice outside of experimenter presence (Banks et al., 2015) and others have not (Mrazek et al., 2013; Quach et al., 2016; Zeidan et al., 2010). While it is equally possible that the cognitive training group practiced some form of cognitive training outside of the laboratory (as explained in their training overview about remembering as many items as possible and attending to some stimuli while ignoring others), training outside the laboratory should be measured or controlled for in future research.

Finally, this study used one category of working memory capacity measures (i.e., complex span tasks) to assess working memory capacity improvement following training. Many other types of working memory and working memory capacity tasks exist: running memory span, keeping track, visual arrays, n-back, content-embedded span, updating, and immediate free recall tasks\(^\text{10}\) are thought to tap the working memory system (Engle et al., 1999; Shipstead, Lindsey, Marshall, & Engle, 2014; Unsworth & Engle, 2007; Was, Rawson, Bailey & Dunlosky, 2011; Willhelm, Hildebrandt, & Oberauer, 2013). If working memory capacity is increased following a training intervention, increases in performance on a diverse array of working memory tasks should be observed. Future research should investigate how mindfulness

\(^{10}\) Immediate free recall tasks scored for primary and secondary memory.
meditation impacts working memory as measured by a broad range of valid working memory tasks. Despite the limitation of only one type of working memory capacity task, the current results do support that mindfulness meditation increased working memory capacity: complex span tasks are considered valid indicators of working memory capacity, multiple outcome measures were used, mindfulness meditation training did not resemble the structure or content of the complex span tasks, and improvement was demonstrated relative to an active, adaptive control group (i.e., to rule out expectancy or motivation confounds). Further, each of the current complex span tasks used different stimuli (e.g., verbal, visuospatial, numerical content) for the storage and processing portions of the tasks, which demonstrates that the observed working memory capacity improvement was general and not specific to any one modality.

As this study included a young adult sample, it is unclear whether training-related working memory capacity improvements in the mindfulness group would generalize to other populations that are typically studied in the working memory training literature (e.g., older adults, children, special populations). Differences in controlled attention have been shown to differentiate young adults on working memory capacity measures (Kane et al., 2007), whereas differences in processing speed and attentional inhibition have been shown to differentiate various age and clinical groups on working memory capacity measures (Conway et al., 2007). Future work can compare how mindfulness meditation training impacts working memory capacity in the various populations mentioned.

Additionally, the current study did not examine how mindfulness meditation affects different levels of baseline working memory capacity. Several participants in the mindfulness meditation group who scored low on the working memory capacity composite at pretest scored even lower at posttest. This is a counter-intuitive finding, as people with low working memory
capacity are theorized to have low attention control and should benefit from training known to enhance attention control (Engle, 2002; Mrazek et al., 2012; Mrazek et al., 2013; Semple, 2015). The current study could not rule out whether this drop was an interaction between low working memory capacity and mindfulness training or some participants not complying with study instructions. Additionally, three participants in the mindfulness training group with pretest scores ranging from .45 to .55 increased posttest scores by .22 to .27. How mindfulness meditation potentially interacts with a wide range of initial individual differences in working memory capacity should be explored further; this could demonstrate who may better benefit from mindfulness training and by how much.
Conclusions

The current study demonstrated that working memory capacity may be enhanced following mindfulness meditation training. This investigation met most of the criteria for validly concluding working memory capacity improvement (i.e., using multiple, valid measures of working memory capacity; using outcome measures different from training tasks; demonstrating improvement compared to an active, adaptive control group) that other studies in the working memory training literature have not met. The current results are significant as they demonstrate that a core cognitive system (i.e., working memory) that supports higher-order cognition may be improved following brief and inexpensive training. These results should encourage further exploration of how mindfulness meditation, and other forms of cognitive training, may enhance working memory, other core cognitive functions, and complex cognition while using similar well-controlled study designs.
References


Wilhelm, O., Hildebrandt, A. H., & Oberauer, K. (2013). What is working memory capacity, and how can we measure it?. *Frontiers in psychology, 4*, 433.

Appendix A
Training overviews provided to mindfulness and cognitive training groups

Mindfulness Training (MT) overview

Please read this page every day for the first week of training, as different parts will stand out to you on different days.

You will practice mindfulness training (MT) to cultivate awareness of yourself as well as your environment. MT also teaches you how to regulate your emotional responses to everyday stressful events. You will practice finding a balance between a relaxed state of mind and a highly attentive one. This involves learning to rest your mind in its natural awareness, uncluttered by the distractions of daily life, memories of the past, or concerns about the future.

We are going to be training you, just like you would train your biceps in a gym, to train your mind to attend to the present moment and to control the way it responds to stressors and different emotions. Therefore, MT is a practice that will teach you moment to moment awareness of all the things inside your mind.

Being mindful is something you can do at any point during your day, as many times as you would like. You simply take a deep breath, bring your attention to what is happening in the present moment, and observe what is going on in your mind, your body, and your environment.

You will likely notice that your mind is very busy and will wander off during MT. Mentally noting or becoming aware of how busy your mind can be is one of the most important aspects of MT. What you do is acknowledge when your mind has wandered, let the distraction go, and gently bring your attention back to the MT instructions. You simply start over. Most importantly, you do not judge yourself or get frustrated: you take it easy on yourself. You can start over hundreds to thousands of times. It is part of the training. You are training your mind.

Each time you practice, sit upright in a comfortable position with your back straight and your feet flat on the floor. You may close your eyes or keep them open; whatever feels comfortable to you.

Cognitive Training (CT) overview

Please read this page every day for the first week of training, as different parts will stand out to you on different days.

You will practice frequent cognitive training (CT) to develop your abilities across a range of tasks. By engaging in frequent and varied forms of CT, you may be able to improve your cognitive functioning. This may occur not only for the tasks you practice with, but may also transfer to other non-practiced tasks.

We are going to be training you, just like you would train your biceps in a gym, to train your mind to improve on various tasks. Try your best to be fully engaged in each task and complete it to the best of your current abilities. Different tasks will have different goals, such as remembering as many items as possible (i.e. item span tasks) or working with distractions (i.e. executive tasks). Your goal is to keep improving on each task; for example, in the item span tasks this means increasing the number of items you can remember. It is OK if you improve more or faster on some tasks than others, or even if you don’t improve at all on some tasks.

The tasks you will be training on involve skills and abilities you will likely find useful outside of the laboratory. As previously mentioned, your tasks will involve remembering as many items as possible or responding to certain stimuli instead of irrelevant stimuli. In your day to day life, you’ve likely noticed that it is often helpful to remember more things at a given time than less; for example, numbers in a phone number, items in a grocery list, or facts in a lecture. Similarly, it is often helpful to respond only to certain stimuli rather than others; for example, hitting the brakes for a red light rather than the gas pedal, reading your textbook rather than listening to music, or making healthy eating choices instead of ordering fast food.

The abilities you develop during CT may carry over into unpracticed tasks. Work as quickly and as accurately as possible. Do not be discouraged if a task seems difficult or if you don’t improve as much as on other tasks.
## Appendix B

Mindfulness meditation and cognitive training group activities, Days 2 – 9

Table 7. *Mindfulness Meditation Group’s Guided Meditation Trainings.*

<table>
<thead>
<tr>
<th>Training Day</th>
<th>Instructor</th>
<th>Title (Type of Meditation)</th>
<th>Time</th>
<th>Link (Homepage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>(unknown)</td>
<td><em>Mindfulness Guided Meditation for Beginners and Intermediate</em> (Body Scan)</td>
<td>20 m 52 s</td>
<td><a href="https://www.youtube.com/watch?v=rbg90A7POMo">https://www.youtube.com/watch?v=rbg90A7POMo</a> (<a href="https://www.youtube.com/channel/UCN4vvy6O4GiJXcXTlZQQ">https://www.youtube.com/channel/UCN4vvy6O4GiJXcXTlZQQ</a>)</td>
</tr>
<tr>
<td>3</td>
<td>Mark Bertin</td>
<td><em>Mindful Breathing Meditation</em> (Breathing)</td>
<td>14 m 33 s</td>
<td><a href="https://soundcloud.com/mindfulmagazine/breathing-meditation">https://soundcloud.com/mindfulmagazine/breathing-meditation</a>; (<a href="http://www.mindful.org/">http://www.mindful.org/</a>)</td>
</tr>
<tr>
<td>4</td>
<td>Mark Bertin</td>
<td><em>Mindful Body Scan Meditation</em> (Body Scan)</td>
<td>25 m 16 s</td>
<td><a href="https://soundcloud.com/mindfulmagazine/body-scan-meditation">https://soundcloud.com/mindfulmagazine/body-scan-meditation</a>; (<a href="http://www.mindful.org/">http://www.mindful.org/</a>)</td>
</tr>
<tr>
<td>5</td>
<td>Tara Brach</td>
<td><em>Meditation – In the Body</em> (Body Scan)</td>
<td>25 m 33 s</td>
<td><a href="https://www.tarabrach.com/guided-meditation-in-the-body/">https://www.tarabrach.com/guided-meditation-in-the-body/</a> (<a href="http://www.tarabrach.com/">http://www.tarabrach.com/</a>)</td>
</tr>
<tr>
<td>6</td>
<td>Dave Potter</td>
<td><em>Sitting Meditation</em> (Breathing)</td>
<td>19 m 59 s</td>
<td><a href="https://palousemindfulness.com/meditations/sittingmeditation20min.html">https://palousemindfulness.com/meditations/sittingmeditation20min.html</a> (<a href="https://palousemindfulness.com/index.html">https://palousemindfulness.com/index.html</a>)</td>
</tr>
<tr>
<td>7</td>
<td>Dave Potter</td>
<td><em>Body Scan</em> (Body Scan)</td>
<td>20 m 46 s</td>
<td><a href="https://palousemindfulness.com/meditations/bodyscan20min.html">https://palousemindfulness.com/meditations/bodyscan20min.html</a> (<a href="https://palousemindfulness.com/index.html">https://palousemindfulness.com/index.html</a>)</td>
</tr>
<tr>
<td>8</td>
<td>Gil Fronsdal</td>
<td><em>Guided Meditation on the Breath</em> (Breathing)</td>
<td>14 m 38 s</td>
<td><a href="http://www.audiodharma.org/talks/audio_player/363.html">http://www.audiodharma.org/talks/audio_player/363.html</a> (<a href="http://www.audiodharma.org/">http://www.audiodharma.org/</a>)</td>
</tr>
<tr>
<td>9</td>
<td>Gil Fronsdal</td>
<td><em>Guided Body Scan</em> (Body Scan)</td>
<td>24 m 57 s</td>
<td><a href="http://www.audiodharma.org/talks/audio_player/353.html">http://www.audiodharma.org/talks/audio_player/353.html</a> (<a href="http://www.audiodharma.org/">http://www.audiodharma.org/</a>)</td>
</tr>
</tbody>
</table>
Green Mountain at Fox Run  
Tara Brach

<table>
<thead>
<tr>
<th>Training Day</th>
<th>Name of Task (Description)</th>
<th>Type of Task</th>
<th>Time</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Visual Forward Digit Span</td>
<td>Item Span</td>
<td>20 m 52 s</td>
<td><a href="http://cognitivefun.net/test/7">http://cognitivefun.net/test/7</a></td>
</tr>
<tr>
<td></td>
<td>(participants are presented with a sequence of digits that they must type in the correct serial order)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Visual Backward Digit Span</td>
<td>Item Span</td>
<td>14 m 33 s</td>
<td><a href="http://cognitivefun.net/test/10">http://cognitivefun.net/test/10</a></td>
</tr>
<tr>
<td></td>
<td>(participants are presented with a sequence of digits that they must type in the correct reverse serial order; e.g. being shown “7 – 3 – 4 – 1” would be correctly entered as “1 – 4 – 3 – 7”)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Corsi Block Task</td>
<td>Item Span</td>
<td>25 m 16 s</td>
<td><a href="http://cognitivefun.net/test/27">http://cognitivefun.net/test/27</a></td>
</tr>
<tr>
<td></td>
<td>(participants are presented with 12 white squares; select squares sequentially turn black; participants must click on squares that turned black in the correct serial order)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Reverse Corsi Block Task</td>
<td>Item Span</td>
<td>25 m 33 s</td>
<td><a href="http://cognitivefun.net/test/28">http://cognitivefun.net/test/28</a></td>
</tr>
<tr>
<td></td>
<td>(participants are presented with 12 white squares; select squares sequentially turn black; participants must click on squares that turned black in the correct reverse serial order; i.e. the last square to turn black is selected first, continuing until the first square to turn black is selected last).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Eriksen Flanker Task</td>
<td>Executive Task</td>
<td>19 m 59 s</td>
<td><a href="http://cognitivefun.net/test/6">http://cognitivefun.net/test/6</a></td>
</tr>
<tr>
<td></td>
<td>(participants are shown a range of arrows – 3, 5, or 20 – pointing either left or right; participants press the appropriate arrow key – left or right arrow key – that matched the direction of the center arrow)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7 Stroop Task
(participants are shown a color word – e.g., RED – and have to indicate via key press the visual color of the displayed word – e.g., blue, if the word RED was printed in blue ink; the appropriate key to press was the first letter of displayed colors and words – e.g., “r” for red, “o” for orange, etc.)

8 Auditory Forward Digit Span
(participants hear a sequence of digits that they must type in the correct serial order)

9 Auditory Backward Digit Span
(participants hear a sequence of digits that they must type in the correct reverse serial order; e.g. hearing “7 – 3 – 4 – 1” would be correctly entered as “1 – 4 – 3 – 7”)

Executive Task 20 m 46 s http://cognitivefun.net/test/2

Item Span 14 m 38 s http://cognitivefun.net/test/9

Item Span 24 m 57 s http://cognitivefun.net/test/11

All cognitive training group tasks came from the following homepage: http://cognitivefun.net/