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Mindfulness meditation improves visual short-term memory

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Abstract

Research into the effects of mindfulness meditation (MM) on behavioural outcomes has received much interest in recent years, with benefits for both short-term memory (STM) and working memory identified. However, little research has considered the potential effects of brief MM interventions or the nature of any benefits for visual STM. Here, we investigate the effect of a single, eight-minute MM intervention, presented via audio recording, on a STM task for faces. In comparison with two control groups (listening to an audiobook or simply passing the time however they wished), our MM participants showed greater increases in visual STM capacity from pre- to post-intervention. In addition, only MM resulted in significant increases in performance. In conclusion, a single, brief MM intervention led to improvements in visual STM capacity for faces, with important implications regarding the minimum intervention necessary to produce measurable changes in STM tasks.

Keywords

Mindfulness; Meditation; Visual short-term memory; Faces; Intervention

Short title

Meditation improves short-term memory

Introduction

Working memory (WM) is a multicomponent system, bringing together short-term memory (STM) and attention (Cowan, 2016), and has a limited capacity, varying between individuals (Ortells, Noguera, Alvarez, Carmona, & Houghton, 2016). Having a particularly low or high capacity can affect people in many different ways, impacting daily life (Richmond, Redick, & Braver, 2015).

Low WM capacity has been linked to inattentive behaviour, which can increase the difficulty of everyday tasks and activities requiring sustained attention (Kofler et al., 2017; Zhang, Chang, Chen, Ma, & Zhou, 2018), while STM capacity may, for example, explain individual differences in learning (Frensch & Miner, 1994), mathematical performance (Swanson & Kim, 2007), and reading comprehension (Haarmann, Davelaar, & Usher, 2003). Specific courses designed to improve WM have been implemented using different techniques and with varying levels of success (Klingberg, Forssberg, & Westerberg, 2002; for a review, see Morrison & Chein, 2011). Methods targeting the improvement of STM specifically have included rehearsal (Broadley, MacDonald, & Buckley, 1994), visual imagery (de la Iglesia, Buceta, & Campos, 2005), creating stories from the information to be remembered (McNamara & Scott, 2001), and grouping of the items into conceptual categories (Carr & Schneider, 1991).

One promising avenue for improvement has been the introduction of mindfulness meditation (MM), gaining popularity in recent years and triggering substantial research (Keng, Smoski, & Robins, 2011). Mindfulness-based interventions have become common, owing to their affordability, ease of learning, and growing evidential support for benefits in mental health and cognitive function (Davis & Hayes, 2011). The term MM can describe several practices and states, with the main goal of reaching a state of awareness that maintains attention in the present moment (e.g., on changing sensory and mental states) while avoiding the intrusion of outside factors (Baltar & Filgueiras, 2018).

Chambers, Lo, and Allen (2008) assessed individuals after they had attended a ten-day MM camp, finding that WM capacity (specifically, backward digit memory span) had improved. Indeed, several studies have recently demonstrated similar improvements on various measures of WM, including the adaptive n-back task and operation span, although no improvements in STM (for example, forward digit span) were found (e.g., Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). In contrast, Lykins, Baer, and Gottlob (2012) found no improvements in WM (letter-number sequencing; Wechsler, 1997) while identifying group differences (experienced meditators versus controls) in measures of STM (both short delay free and cued recall; Delis, Kramer, Kaplan, & Ober, 1987).

While studies appear to have demonstrated relationships between MM and improved WM and STM capacities, the length of the MM intervention involved has been variable, ranging from one to eight weeks. Shorter intervention periods are generally preferred to longer ones due to their ease and convenience (Bergen-Cico, Possemato, & Cheon, 2013). However, there are some cases in which brief interventions have been shown to be marginally less effective than longer ones (Basso, McHale, Ende, Oberlin, & Suzuki, 2019). In terms of implementation, there is a clear demand for research surrounding the effectiveness of MM in even shorter sessions, such as a single sitting (Chiesa, Calati, & Serretti, 2011). It is also worth noting that the motivation to practice MM can decrease over time and across sessions (Hafenbrack & Vohs, 2018). As such, the main aim of our study was to investigate whether a single, brief session of MM could lead to a measurable improvement in STM capacity.

There are many ways to study the impact of MM on STM capacity, and the specific task used to quantify STM can vary. With previous research involving STM capacity focussing on verbal paradigms (e.g., Lykins et al., 2012), the effects of MM on visual STM have yet to be investigated, which is perhaps surprising since this can be assessed reliably and is critical for the online use of visual information. One method of testing visual STM is through a delayed nonmatching-to-sample paradigm, where participants are tasked with distinguishing between previously seen items and a novel item (e.g., using faces – Crook & Larrabee, 1992). As such, identification of the novel item requires that previously seen items are maintained in STM.

There are many explanations as to why MM improves memory, with the most widely accepted explanation being through a reduction of anxiety. For instance, Eysenck, Derakshan, Santos, and Calvo (2007) suggested that the attentional control aspect of the central executive is impaired by anxiety. Specifically, the inhibition function of the central executive can no longer effectively redirect attention away from task irrelevant stimuli. This, in turn, means that people find difficulty in completing tasks that require sustained attention as they become distracted. A link between attentional control and memory has been established as a result of this, due to the completion of memory tasks requiring effective attentional control in order to maintain attention to goal-relevant information (Shipstead, Lindsey, Marshall, & Engle, 2014).

Researchers have suggested that attention and memory processes are closely related forms of cognitive control, with both likely to be influenced by MM (Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010). Further, both short- and long-term memory are largely dependent on present-moment direction of attention (Cowan, 1997). Therefore, in line with previous work (Lykins et al., 2012), it is important to determine whether MM can improve performance on STM tasks. In the current study, we utilise a single, brief MM intervention, lasting only a few minutes. In addition, we focus on visual STM specifically, given the lack of previous research investigating this particular domain.

Method

Participants

Ninety undergraduate students (age range, 18-25 years; 61 women; 83 self-reported as White) participated in exchange for course credits. Data from one additional participant were excluded due to a failure to complete all tasks. Sample size ($N = 30$ per group) was chosen to be comparable with previous research in this area (for a systematic review, see Chiesa et al., 2011).

The university's research ethics committee approved the experiment presented here, which was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki. Participants provided written, informed consent before taking part, and were given both a written and verbal debriefing upon completion.

Materials

Participants completed two measures of mindfulness during everyday life. The Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003) consists of 15 items that are rated on a 6-point Likert scale from 1 (almost always) to 6 (almost never), where the mean rating across all items represents the final score, with higher scores reflecting greater mindfulness. The Five-Factor Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006) consists of 39 items that are rated on a 5-point Likert scale from 1 (never or very rarely true) to 5 (very often or always true). Mean ratings (after reverse scoring specific items) are calculated for each of five facets: observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience. Again, higher scores reflect greater mindfulness.

Given that the FFMQ is derived from a factor analysis of several questionnaires including the MAAS, we would predict at least some correlation between participants' scores on these instruments. However, since such relationships are far from perfect (Baer et al., 2006) and both measures remain popular, we decided to include both questionnaires in the current study.

In the listening task, participants in the audiobook group listened to the beginning of 'The Hobbit' (Shaw, 2005). Those in the meditation group listened to a 'mindfulness of body and breath' exercise (Williams & Penman, 2011) designed to focus their attention on the movement of the breath in the body. We selected an audiobook for comparison since it requires a similar amount of attention and concentration to the meditation task, although the focus of attention in the two tasks was necessarily, and importantly, different. Both of these audio segments have featured in previous research (e.g., Kramer, Weger, & Sharma, 2013). Finally, for the control group, participants were simply asked to sit quietly and fill their time however they wished. (In the majority of cases, this involved the use of personal smartphones.) The audio recordings were presented using closed-back headphones.

For the face memory task, 450 images of White faces (225 women) were downloaded from an online database (www.facity.com), which contained around two thousand high quality photographs of faces, taken front-on and with neutral expressions, hair pulled back, and minimal make-up. We selected only faces with no jewellery and that were aged approximately 18-40 (year of birth was available in the majority of cases). Images were already cropped below the hairline, and we additionally cropped them just below the chin, and close to the sides of the faces, using Adobe Photoshop CS software.

Procedure

Participants were tested individually in a quiet laboratory room, first completing both questionnaires, along with demographic information. Following this, participants performed a face memory task adapted from previous work (Crook & Larrabee, 1992), presented on a desktop computer using custom MATLAB software. On each trial, a single facial photograph was initially displayed onscreen, which the participant was instructed to select with the mouse. Next, this face and a second face appeared onscreen, and the participant was required to select the new face. If the correct response was given, this process would continue, each time introducing a new face, until a maximum of 45 faces were displayed (see Figure 1). Within each trial, all faces were of the same sex. Trials terminated when an incorrect response was given, and the number of correct responses was recorded. Importantly, after every response, the new display of faces was randomised with respect to spatial position onscreen, meaning that participants could not use location information to inform their decisions. Participants completed five trials in the first session, with the sex of faces alternating across trials. No face appeared in more than one trial.

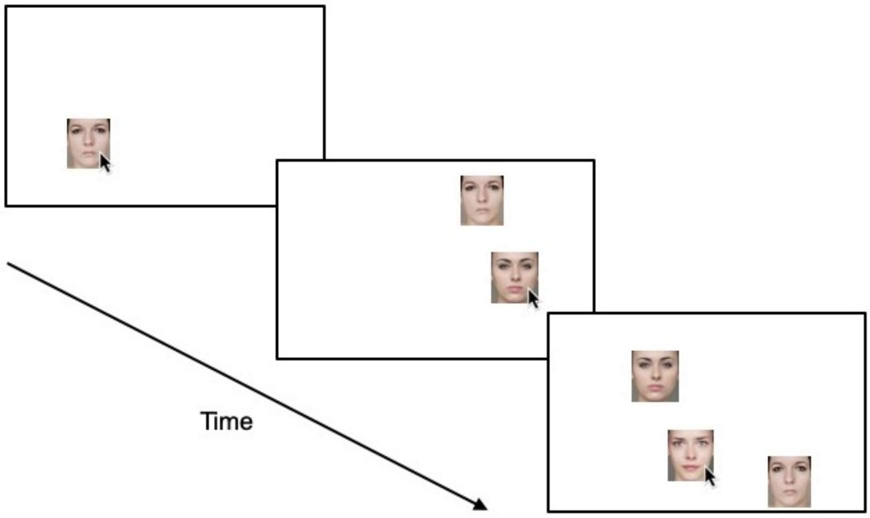

Figure 1. Illustration depicting the face memory task. In this example trial, the participant responds correctly to the first three displays. (Images not to scale.)

Upon completion, participants were randomly allocated to one of three groups. Those in the audiobook (11 men, 19 women) and meditation (12 men, 18 women) groups then listened to an 8 min audio recording with instructions to follow along as best they could, and to inform the experimenter when it finished. Those in the meditation group were presented with a breathing exercise while those in the audiobook group listened to a neutral recording. Participants in the control group (6 men, 24 women) were instructed to fill their time however they wished, and were given 8 mins for this task. In all cases, the experimenter remained in the room but did not interact with the participant. The assignment of participants to groups was randomised.

After the listening/control task, participants completed the face memory task again (second session). The procedure was identical to earlier although only face images that had not appeared in the first session were presented.

Results

Preliminary analyses

Participants' scores on the MAAS and FFMQ were calculated, and the associations between these measures are summarised in Table 1. As expected, we found some significant overlap between the two questionnaires, as well as among the five facets of the FFMQ. Most notably, we found a large positive relationship between scores on the MAAS and the 'acting with awareness' facet of the FFMQ.

Table 1

Correlations between questionnaire measures

Questionnaire	1	2	3	4	5
1. MAAS	-				
2. FFMQ: Observing	-0.05	-			
3. FFMQ: Describing	0.32**	0.20	-		
4. FFMQ: Acting with awareness	0.69***	-0.15	0.19	-	
5. FFMQ: Non-judging	0.42***	-0.30**	0.19	0.41***	-
6. FFMQ: Non-reactivity	0.16	0.17	0.19	0.08	0.32**

Note. *$p < .05$; **$p < .01$; ***$p < .001$. MAAS = Mindful Attention Awareness Scale; FFMQ = Five-Factor Mindfulness Questionnaire.

In addition, we compared participants across the three groups. We found no group differences in FFMQ Describing scores, FFMQ Non-judging scores, and FFMQ Non-reactivity scores (in all cases, $F < 2.64$, $p > .077$, $\eta^2_p < 0.06$).

However, we found a significant difference in MAAS scores, $F(2, 87) = 4.28$, $p = .017$, $\eta^2_p = 0.09$, with post hoc tests (Dunn-Šidák corrected here and below) revealing that participants in the control group ($M = 3.82$, $SD = 0.61$) showed higher scores than those in the audiobook group ($M = 3.38$, $SD = 0.63$; $p = .021$). No other comparisons were significant (both *p*s > .087). Groups also differed in FFMQ Observing scores, $F(2, 87) = 4.15$, $p = .019$, $\eta^2_p = 0.09$, with participants in the meditation group ($M = 3.31$, $SD = 0.54$) showing higher scores than those in the control group ($M = 2.83$, $SD = 0.72$; $p = .017$). No other comparisons were significant (both *p*s > .200). Finally, group differences were also found in FFMQ Acting with Awareness scores, $F(2, 87) = 4.44$, $p = .015$, $\eta^2_p = 0.09$, with participants in the control group ($M = 3.26$, $SD = 0.55$) showing higher scores than those in the audiobook group ($M = 2.82$, $SD = 0.62$; $p = .011$). No other comparisons were significant (both *p*s > .302).

In two of these results, group differences suggested higher baseline mindfulness in the control than in the audiobook participants, which had no bearing on the hypothesised benefit of our mindfulness task over the other two groups. However, we also found that participants in the meditation group scored higher on baseline FFMQ Observing in comparison with control participants prior to any listening task. Perhaps reassuringly, this difference comprised only 0.48 on a 1-5 scale, and we found no difference between the meditation and audiobook groups. As such, we could be confident that any benefit for the mindfulness meditation group during the listening task was not the result of baseline differences between the three groups. In addition, we included these scores as covariates in our analyses (see below).

Improvements in face memory

For each participant, we calculated the mean score across the five trials of the memory task for each session separately. We then calculated the difference between sessions (second minus first), providing us with a measure of the improvement due to the listening (or control) task. The difference scores were then analysed as follows.

Initial consideration of the difference scores revealed nine data points (meditation group – 1; audiobook group – 4; control group – 4) that were classified as outliers (identified using boxplots produced with IBM's SPSS Statistics software v25), defined as values further than 1.5 times the interquartile range from the nearer edge of that range. It is worth noting that four of these outliers showed extreme negative difference scores while the remaining five demonstrated extreme positive differences, suggesting no particular pattern of performance across this subsample. As a result of identifying these outliers, we decided to carry out two types of analyses on our data.

Parametric analysis: One-way ANOVA

Since both the group means and variances are sensitive to outliers, their presence violates the assumptions of an analysis of variance (ANOVA) by reducing the validity of the results. We therefore excluded the above-mentioned nine data points and then carried out a one-way (Group: control, audiobook, meditation) between-subjects ANOVA. We found a main effect of group, $F(2, 78) = 9.83$, $p < .001$, $\eta^2_p = 0.20$, with post hoc tests (again, Dunn-Šidák corrected) revealing larger difference scores for participants in the meditation group (M = 2.08, SD = 2.41) in comparison with those in the audiobook group (M = -0.18, SD = 1.79; p < .001) and the control group (M = 0.18, SD = 1.82; p = .003). These latter two groups did not differ from each other (p = .887; see Figure 2).

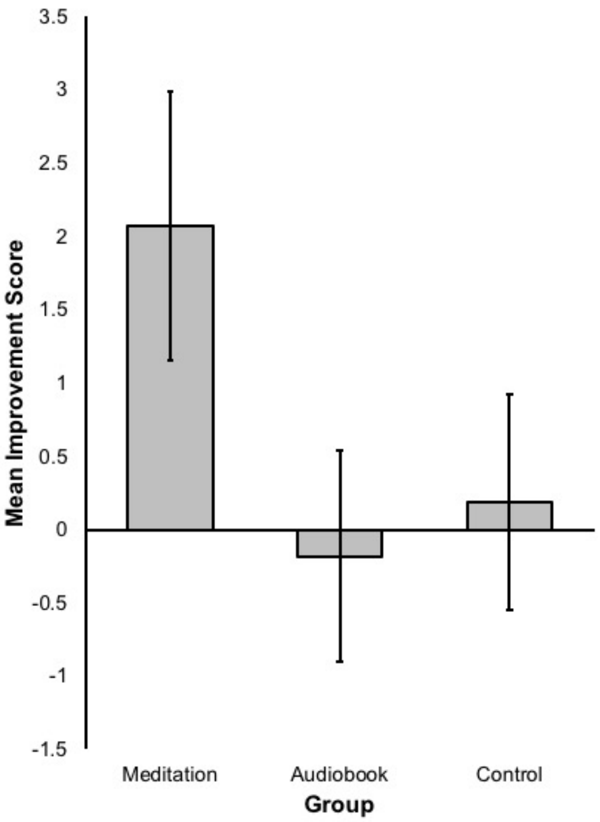

Figure 2. Mean improvement scores for the three groups. Error bars represent 95% confidence intervals.

In addition, we compared mean improvement scores to a value of zero for each group separately. For the meditation group, we found a non-zero improvement, $t(28) = 4.63$, $p < .001$, Cohen's $d = 0.86$. In contrast, improvements did not differ from zero for both the audiobook group, $t(25) = 0.53$, $p = .603$, Cohen's $d = 0.10$, and control group, $t(25) = 0.52$, $p = .609$, Cohen's $d = 0.10$.

Our preliminary analyses revealed significant differences between participants across our three groups with regard to three of their questionnaire scores: MAAS, FFMQ Observing, and FFMQ Acting with Awareness. As such, we repeated the above analysis while including these three scores as covariates. Again, we found a main effect of group, $F(2, 75) = 10.66$, $p < .001$, $\eta^2_p = 0.22$, with post hoc tests (again, Dunn-Šidák corrected) revealing larger difference scores for participants in the meditation group in comparison with those in the audiobook group ($p < .001$) and the control group ($p = .001$). These latter two groups did not differ from each other ($p = .998$).

Nonparametric analysis: Kruskal-Wallis test

We also carried out a nonparametric equivalent of the above analysis, allowing us to include all data points since ranked data are far less sensitive to outliers. The Kruskal-Wallis test found a significant difference between groups, $H(2) = 7.74$, $p = .022$.[1] Follow-up comparisons using Mann-Whitney tests[2] showed larger difference ranks for participants in the meditation group in comparison with those in the audiobook group, $U = 285.50$, $z = 2.43$, $p = .015$, $r = 0.31$. In addition, those in the meditation group also showed higher difference ranks than those in the control group, $U = 294.50$, $z = 2.30$, $p = .020$, $r = 0.30$. These latter two groups did not differ from each other, $U = 406.50$, $z = 0.64$, $p = .525$, $r = 0.08$.

Discussion

The goal of this research was to investigate whether a single, brief MM intervention could improve STM capacity. Our results demonstrated a significant improvement in visual STM for our MM group. In contrast, those who listened to an audiobook or filled their time however they wished failed to show an improvement. The increase in performance on the face memory task as a result of MM extends previous research demonstrating that MM can improve various components of STM (Lykins et al., 2012).

[1] Monte Carlo estimate of significance based on 10,000 samples.
[2] Significance values calculated using exact methods.

That an eight-minute MM intervention was effective is an important result, building upon earlier research showing that MM sessions as brief as ten minutes can improve attentional control and reduce psychological stress (Norris, Creem, Hendler, & Kober, 2018), two aspects considered important in WM performance (Kane, Bleckley, Conway, & Engle, 2001; Schoofs, Preuß, & Wolf, 2008). Our results are also consistent with research showing that time spent on a MM task may not be correlated with the strength of subsequent improvements, suggesting that the majority of MM benefits may occur early on in one's practice (Carmody & Baer, 2009).

One explanation as to why MM might improve STM capacity is that during task performance, part of STM is occupied by task-irrelevant information. MM could then improve (relevant) STM capacity by reducing this information, freeing up cognitive resources to be put to work on the task at hand. Previous research has shown that anxiety can inhibit central executive processes (Berggren, Curtis, & Derakshan, 2016; Park, Wood, Bondi, Del Arco & Moghaddam, 2016), and with MM reducing anxiety (Hoge et al., 2014), this could provide a potential mechanism through which MM can improve STM. In addition, MM encourages the acceptance, rather than avoidance, of thoughts and emotions as they pass through awareness. Evidence suggests that MM improves the acceptance of emotional states, resulting in greater executive control (Teper & Inzlicht, 2013; for a review, see Malinowski, 2013). Again, this may be why our MM participants showed increases in visual STM in the current experiment. However, we acknowledge that the specific mechanism through which MM affects STM has yet to be identified.

Here, for practical reasons, we presented an audio recording for our MM intervention rather than a face-to-face session. Along similar lines, recent evidence has suggested that participants can benefit from completing their own MM practices via the use of a smartphone application (Walsh, Saab, & Farb, 2019), representing the possibility that a greater proportion of the population might benefit from access to MM through solo practice. If further research supports this idea, more people might be willing to incorporate MM into their daily routines if additional costs and time constraints, typically associated with organised classes and sessions, are not required.

To conclude, this study demonstrates that a single, brief MM intervention improves performance on a STM task. Our focus on visual STM, as well as the use of only minimal MM with our participants, represent important extensions to the literature with regard to measurable effects that MM has on behavioural outcomes.

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Declaration of Conflicting Interest

The authors declare that there is no conflict of interest.

References

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13*, 27-45.

Baltar, Y. C., & Filgueiras, A. (2018). The effects of mindfulness meditation on attentional control during off-season among football players. *SAGE Open*, *8*(2), 215824401878189.

Basso, J. C., McHale, A., Ende, V., Oberlin, D. J., & Suzuki, W. A. (2019). Brief, daily meditation enhances attention, memory, mood, and emotional regulation in non-experienced meditators. *Behavioural Brain Research*, *356*, 208-220.

Bergen-Cico, D., Possemato, K., & Cheon, S. (2013). Examining the efficacy of a brief mindfulness-based stress reduction (Brief MBSR) program on psychological health. *Journal of American College Health, 61*(6), 348-360.

Berggren, N., Curtis, H. M., & Derakshan, N. (2016). Interactions of emotion and anxiety on visual working memory performance. *Psychonomic Bulletin & Review*, *24*(4), 1274-1281.

Broadley, I., MacDonald, J., & Buckley, S. (1994). Are children with Down's syndrome able to maintain skills learned from a short-term memory training programme? *Down Syndrome Research and Practice, 2*(3), 116-122.

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84*, 822-848.

Carmody, J., & Baer, R. A. (2009). How long does a mindfulness-based stress reduction program need to be? A review of class contact hours and effect sizes for psychological distress. *Journal of Clinical Psychology*, *65*(6), 627-638.

Carr, M., & Schneider, W. (1991). Long-term maintenance of organizational strategies in kindergarten children. *Contemporary Educational Psychology, 16*(1), 61-72.

Chambers, R., Lo, B. C. Y., & Allen, N. B. (2008). The impact of intensive mindfulness training on attentional control, cognitive style, and affect. *Cognitive Therapy and Research*, 32(3), 303-322.

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical Psychology Review*, *31*(3), 449-464.

Cowan, N. (1997). *Attention and memory: An integrated framework*. Oxford: Oxford University Press.

Cowan, N. (2016). The many faces of working memory and short-term storage. *Psychonomic Bulletin & Review*, *24*(4), 1158-1170.

Crook, T. H., III, & Larrabee, G. J. (1992). Changes in facial recognition memory across the adult life span. *Journal of Gerontology, 47*(3), P138-P141.

Davis, D. M., & Hayes, J. A. (2011). What are the benefits of mindfulness? A practice review of psychotherapy-related research. *Psychotherapy*, *48*(2), 198-208.

de la Iglesia, C. J. F., Buceta, J. M., & Campos, A. (2005). Prose learning in children and adults with Down syndrome: The use of visual and mental image strategies to improve recall. *Journal of Intellectual and Developmental Disability, 30*(4), 199-206.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). *California verbal learning test: Adult version manual*. San Antonio, TX: The Psychological Corporation.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*(2), 336-353.

Frensch, P. A., & Miner, C. S. (1994). Effects of presentation rate and individual differences in short-term memory capacity on an indirect measure of serial learning. *Memory & Cognition, 22*(1), 95-110.

Haarmann, H. J., Davelaar, E. J., & Usher, M. (2003). Individual differences in semantic short-term memory capacity and reading comprehension. *Journal of Memory and Language, 48*(2), 320-345.

Hafenbrack, A. C., & Vohs, K. D. (2018). Mindfulness meditation impairs task motivation but not performance. *Organizational Behavior and Human Decision Processes, 147*, 1-15.

Hoge, E. A., Bui, E., Marques, L., Metcalf, C. A., Morris, L. K., Robinaugh, D. J., …Simon, N. M. (2014). Randomized controlled trial of mindfulness meditation for generalized anxiety disorder: Effects of anxiety and stress reactivity. *Journal of Clinical Psychiatry*, *74*(8), 786-792.

Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion, 10*(1), 54-64.

Kane, M. J., Bleckley, M. K., Conway, A. R., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130*(2), 169.

Keng, S. -L., Smoski, M. J., & Robins, C. J. (2011). Effects of mindfulness on psychological health: A review of empirical studies. *Clinical Psychology Review*, *31*(6), 1041-1056.

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *24*(6), 781-791.

Kofler, M. J., Sarver, D. E., Harmon, S. L., Moltisanti, A., Aduen, P. A., Soto, E. F., & Ferretti, N. (2017). Working memory and organizational skills problems in ADHD. *Journal of Child Psychology and Psychiatry*, *59*(1), 57-67.

Kramer, R. S. S., Weger, U. W., & Sharma, D. (2013). The effect of mindfulness meditation on time perception. *Consciousness and Cognition, 22*(3), 846-852.

Lykins, E. L. B., Baer, R. A., & Gottlob, L. R. (2012). Performance-based tests of attention and memory in long-term mindfulness meditators and demographically matched nonmeditators. *Cognitive Therapy and Research, 36*(1), 103-114.

Malinowski, P. (2013). Neural mechanisms of attentional control in mindfulness meditation. *Frontiers in Neuroscience, 7*, 8.

McNamara, D. S., & Scott, J. L. (2001). Working memory capacity and strategy use. *Memory & Cognition, 29*(1), 10-17.

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review, 18*(1), 46-60.

Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. *Psychological Science, 24*(5), 776-781.

Norris, C. J., Creem, D., Hendler, R., & Kober, H. (2018). Brief mindfulness meditation improves attention in novices: Evidence from ERPs and moderation by neuroticism. *Frontiers in Human Neuroscience*, *12*, 315.

Ortells, J. J., Noguera, C., Álvarez, D., Carmona, E., & Houghton, G. (2016). Individual differences in working memory capacity modulates semantic negative priming from single prime words. *Frontiers in Psychology*, *7*, 1286.

Park, J., Wood, J., Bondi, C., Del Arco, A., & Moghaddam, B. (2016). Anxiety evokes hypofrontality and disrupts rule-relevant encoding by dorsomedial prefrontal cortex neurons. *Journal of Neuroscience, 36*(11), 3322-3335.

Richmond, L. L., Redick, T. S., & Braver, T. S. (2015). Remembering to prepare: The benefits (and costs) of high working memory capacity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(6), 1764-1777.

Schoofs, D., Preuß, D., & Wolf, O. T. (2008). Psychosocial stress induces working memory impairments in an n-back paradigm. *Psychoneuroendocrinology, 33*(5), 643-653.

Shaw, M. (Speaker). (2005). The Hobbit (Digital recording). London, UK: HarperCollins Audiobooks.

Shipstead, Z., Lindsey, D. R. B., Marshall, R. L., & Engle, R. W. (2014). The mechanisms of working memory capacity: Primary memory, secondary memory, and attention control. *Journal of Memory and Language*, 72, 116-141.

Swanson, L., & Kim, K. (2007). Working memory, short-term memory, and naming speed as predictors of children's mathematical performance. *Intelligence, 35*(2), 151-168.

Teper, R., & Inzlicht, M. (2013). Meditation, mindfulness and executive control: The importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive and Affective Neuroscience, 8*(1), 85-92.

Walsh, K. M., Saab, B. J., & Farb, N. A. (2019). Effects of a mindfulness meditation app on subjective well-being: Active randomized controlled trial and experience sampling study. *JMIR Mental Health, 6*(1), e10844.

Wechsler, D. (1997). *Wechsler adult intelligence scale: Administration and scoring manual* (3rd ed.). New York: Oxford University Press.

Williams, M., & Penman, D. (2011). *Mindfulness: An eight-week plan for finding peace in a frantic world (Track 1)*. Oxford: Piatkus.

Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and Cognition, 19*(2), 597-605.

Zhang, H., Chang, L., Chen, X., Ma, L., & Zhou, R. (2018). Working memory updating training improves mathematics performance in middle school students with learning difficulties. *Frontiers in Human Neuroscience*, *12*, 154.