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Mindfulness improves verbal learning and memory through enhanced encoding

Adam Lueke[1] · Niloufar Lueke[1]

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Abstract

Recent research has begun to demonstrate the effectiveness of mindfulness in improving certain cognitive abilities, including verbal learning and memory. However, no research has investigated the potential mechanism by which mindfulness may improve verbal learning and memory. We examined encoding, consolidation, and retrieval as potential mechanisms by which learning and memory may be increased on a list learning test (Rey Auditory Verbal Learning Task; RAVLT). After dividing participants into either a mindfulness or a control condition, in which they listened to a 10-min audio tape, results found that the mindfulness condition significantly outperformed the control condition on every RAVLT trial. Using the Item-Specific Deficit Approach, we discovered that this enhanced verbal learning and memory was specifically due to a significantly enhanced encoding process for the mindfulness group, which fully mediated the relationship between the mindfulness condition and performance on the RAVLT. There were no differences between the conditions on consolidation or retrieval. Furthermore, these improvements were not accompanied by improvements in verbal fluency or attention. In a second study, we presented a mindfulness or control audio before the first RAVLT delayed free-recall trial and another one before the second RAVLT delayed free-recall trial in order to better determine the effect of mindfulness on consolidation and retrieval. The results replicated Study 1, in that neither consolidation nor retrieval were significantly affected by mindfulness. This research indicates that mindfulness may primarily improve verbal learning and memory through improved encoding processes.

Keywords Mindfulness · Learning · Memory · Encoding · Verbal

Introduction

Mindfulness is a state of being characterized by present-moment awareness of the unfolding of experience in a nonreactive way. This simple practice has been shown to have a myriad of benefits for its practitioners, despite the science of mindfulness being a relatively new field. Much of the early work on mindfulness focused on its ability to improve individual well-being through its ameliorative effects on stress, anxiety, and depression (Baer, Carmody, & Hunsinger, 2012; Ciesla, Reilly, Dickson, Emanuel, & Updegraff, 2012; Davidson et al., 2003; Desrosiers, Vine, Klemanski, & Nolan-Hoeksema, 2013; Lagor, Williams, Lerner, & McClure, 2013). Furthermore, mindfulness has also been shown to be effective in improving the healing process (Davidson et al. 2003; Kabat-Zinn et al., 1998) and helping clinical populations cope with painful medical conditions (Brown & Jones, 2013). In addition to personal well-being, mindfulness has also been demonstrated to be an effective tool in improving interpersonal relationships (Hopthrow, Hooper, Mahmood, Meier, & Weger, 2017; Langer, Bashner, & Chanowitz, 1985; Lueke & Gibson, 2015, 2016; Parks, Birtel, & Crisp, 2014; Pratscher, Rose, Markovitz, & Bettencourt, 2017; Ramsey & Jones, 2015). Among all of these positive benefits from the practice of mindfulness, there is also a burgeoning literature on the ability of this practice to enhance cognitive ability. The focus of the current article is to indicate a particular cognitive faculty that can be improved through brief mindfulness training – verbal learning and memory, while also demonstrating the mechanism by which verbal learning and memory is improved. Concurrently, we look to rule out other potential explanations for improved learning and memory – namely attentional processes.

✉ Adam Lueke
aklueke@bsu.edu

Niloufar Lueke
nassar@bsu.edu

[1] Department of Psychological Science, Ball State University, Muncie, IN 47306, USA

Recent work with mindfulness indicates that verbal learning and memory can be positively affected by mindfulness practice. Participants assigned to a 2-week mindfulness class demonstrated improved ability on a reading comprehension measure, whereas control participants did not. This effect was particularly pronounced in individuals whose mind-wandering significantly decreased due to the mindfulness class (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013). Other research has also indicated that mindfulness can help reduce mind-wandering (Killingsworth & Gilbert, 2010; Rahl, Lindsay, Pacilio, Brown, & Creswell, 2017). While it is possible that mindfulness may help to free up cognitive resources necessary for peak verbal learning and memory performance that would otherwise be engaged in task-unrelated thoughts, the avenue by which mindfulness may positively impact verbal learning and memory is currently uncertain.

One potential explanation for improvements observed in verbal learning and memory could be due to increased attention, but currently the research is mixed as to whether mindfulness increases attentional capabilities or not (Anderson, Lau, Segal, & Bishop, 2007; Chambers, Lo, & Allen, 2008; Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2012; Josefsson & Broberg, 2011; Kerr et al., 2011). Indeed, recent research has found that long-term meditators were significantly better on a measure of verbal learning and memory compared to non-meditators, even though they found no significant differences between the two groups in terms of attention or attention switching (Lykins, Baer, & Gottlob, 2012). We propose that rather than altering attention, mindfulness may improve verbal learning and memory via its effect on the encoding process of learning, which allows for enhanced memory for new information over time.

List-learning and parsing out memory process capabilities

List-learning is a common neuropsychological device that can help measure general verbal learning and memory capabilities. Typically, these tests provide participants with several learning trials to practice a list of words, followed by an interference trial before a free-recall trial. Another longer delay is then presented, followed by another free-recall trial, and then a recognition trial. For example, the Rey Auditory Verbal Learning Test (RAVLT) has participants listen to and recall the same list of words over five consecutive trials. With repetition, it is expected that participants improve across trials. This is then followed by a single presentation and recall test of a new list of words, which is used as interference to the previous word list. A free-recall test of the first list that the participants had learned is then administered immediately after the free-recall test of the interference list, and then again after a delay period of approximately 20 min. Finally, a recognition test of the word list is administered.

List-learning measures such as the RAVLT also attempt to make distinctions in ability regarding encoding, consolidation, and retrieval. Previous research has shown that the RAVLT can measure encoding, consolidation, and retrieval (Vakil & Blachstein, 1993), and there is evidence from similar list-learning tests that immediate recall during the five learning trials is associated with encoding, while the two delayed-recall trials are associated with consolidation and retrieval (Delis et al., 1991). However, the way in which these memory processes are distinguished with these list-learning measures may lack precision and potentially could be confounded by other factors, and therefore may not accurately reflect the measurement of these processes. For instance, encoding is generally measured as the improvement in recall across learning trials in a list-learning task (Delis, Kramer, Kaplan, & Ober, 2000). However, this improvement may simply be due to a lack of attention during early trials that is mitigated through repeated practice. Thus, any improvements in recall across trials may not accurately reflect encoding capabilities.

Likewise, consolidation is usually measured by comparing performance on the final learning trial to performance on a delayed free-recall trial (Delis, et al., 2000). Consolidation difficulties are said to occur when words that were recalled on the final learning trial are not recalled on the delayed free-recall trial, as this indicates rapid loss of previously learned information. However, it is certainly possible that poor performance on the delayed free-recall trial may indicate a retrieval rather than consolidation deficit. Similarly, retrieval is typically measured by comparing a recognition trial to a delayed free-recall trial, with retrieval deficits said to occur when recognition is better than delayed free-recall (Delis et al., 2000). However, recall and recognition represent different processes (Aggleton & Brown, 2006), which may not be ideal to compare in order to adequately measure retrieval capabilities.

A relatively new approach has been developed to more accurately distinguish and isolate encoding, consolidation, and retrieval processes with regard to list-learning measures such as the RAVLT – the Item-Specific Deficit Approach (ISDA). The ISDA is a psychometrically valid means of parsing out these processes that otherwise would be unable to be measured adequately. Additionally, the ISDA was developed in order to eliminate, or at least minimize, the confounding effects of inattention on encoding, consolidation, and retrieval, thus allowing a process-specific measure that is not influenced by attentional capabilities. This feature of the ISDA can help us identify any improvement in encoding due to mindfulness regardless of whether or not attention is also improved. Additionally, the ISDA measures consolidation and retrieval in a manner that better accounts for their potential overlap and eliminates the use of recognition trials, which may include confounding processes (Wright et al., 2009).

The ISDA must be applied to a list-learning measure that utilizes multiple learning trials and at least two delayed free-recall trials. Recognition trials are not utilized with the ISDA. The encoding index is determined by identifying the number of items that are not correctly recited on more than half of all learning trials. The RAVLT has five learning trials, meaning that an encoding error would be the inability to recall a specific word on at least three of the learning trials. By calculating encoding as the tendency to neglect certain words across trials, rather than by examining the improvement of performance on successive trials, the ISDA protects against the confounding effects of inattention on any one trial (Wright et al., 2009).

The consolidation index is calculated by identifying the words recalled during list learning that were not recalled on either delayed free-recall trial. This value is then divided by the total number of words that were recalled during list learning. For example, if someone recalled 13 out of 15 words in total over the course of the list learning trials, but two of those 13 words were not recalled on either delayed free-recall trial, then the consolidation index would be calculated by dividing 2 by 13. This helps control for encoding differences during list learning. The inability to recall previously learned items across both delayed free-recall trials indicates a deficit in consolidation more likely than with retrieval (Wright et al., 2009).

The retrieval index is calculated by identifying the words recalled during list learning that were inconsistently recalled across multiple delayed free-recall trials. This value is then divided by the total number of words that were recalled during list learning. For example, if someone recalled 11 of 15 words over the course of the list learning trials, but three of those 11 words were recalled on only one of the two delayed free-recall trials, then the retrieval index would be calculated by dividing 3 by 11. This helps control for encoding differences during list learning. Since the retrieval index identifies the inconsistency of recall across multiple trials, it indicates a problem with retrieval more likely than with consolidation (Wright et al., 2009).

Research using the RAVLT and ISDA has shown that patients with a traumatic brain injury demonstrate deficits in encoding and consolidation in comparison with controls (Wright & Schmitter-Edgecombe, 2011). Likewise, research with amyotrophic lateral sclerosis patients using these same measures indicates impairment within the encoding and consolidation but not retrieval stages in comparison with controls (Christidi, Zalonis, Smyrnis, & Evdokimidis, 2012). Additionally, the ISDA has also revealed that HIV-positive patients indicate impaired encoding processes in comparison with controls, whereas HIV-positive patients who did not adhere well to treatment also indicated deficits in retrieval processes (Wright et al., 2011).

If verbal learning and memory performance on the RAVLT was better for a mindfulness group in comparison with a control group, the ISDA could determine the memory process(es) responsible for this improvement, while also controlling for potential differences in attention. There is reason to suspect that the encoding process is particularly affected by a mindful state. Recent research has indicated that mindfulness reduces inattentional blindness (Schofield, Creswell, & Denson, 2015), which implies that people who are mindful are better able to encode information that others may simply not see or be aware of.

Additionally, research has shown that a primary brain region responsible for the encoding of verbal information, the left parahippocampal gyrus (Dolan & Fletcher, 1999; Fernandez et al., 1998; Strange et al., 2002), is more active within people with higher dispositional mindfulness (Kong, Wang, Song, & Liu, 2016). This overlap may indicate that the higher activity in this region among mindful individuals concurrently facilitates the encoding of verbal information. Relatedly, mindfulness training has been shown to increase volume in the left hippocampus, which reduced proactive interference and thus improved memory (Greenberg et al., 2018). Proactive interference is a major impediment to encoding, but factors such as higher working memory capacity can minimize the effects of proactive interference (Kliegl, Pastotter, & Bauml, 2015), and thus improve encoding processes. Mindfulness (even brief experience) has been shown to be related to greater working memory capacity (Dubert et al., 2016; Jha et al., 2010; Mrazek et al., 2013; Quach, Mano, & Alexander, 2016), which in turn would minimize proactive interference and increase encoding processes. Other research has demonstrated that interference often takes place specifically during the encoding process (i.e., encoding interference; Gordon, Hendrick, & Johnson, 2001, 2004; Villata, Tabor, & Franck, 2018), which implies that large memory gains can be achieved through an intervention that reduces encoding interference.

Other research has reported that mindfulness improves verbal memory through increased "encoding" (Bonamo, Legerski, & Thomas, 2015); however, the results only illustrated improved recall of learned verbal information, not an actual improvement in encoding. There was no measure of the separate memory processes, including the encoding process, so there was no evidence to suggest that encoding specifically was responsible for the improved verbal memory. Similarly, research with trait mindfulness has indicated that people higher on trait mindfulness tend to have an external "encoding" process (Herndon, 2008), but the measure used (Lewicki's Internal/External encoding styles; Lewicki, 2005) merely measured the tendency to attend to information in the internal or external world. It was not a measure of encoding as a learning and memory process. Our study is the first to directly measure memory processes that are potentially enhanced by mindfulness and that subsequently improve verbal learning and memory.

Our central hypothesis is that participants who engage in mindfulness will perform significantly better on a measure of verbal learning and memory (the RAVLT) than control participants, and that this improvement will be due to an enhanced encoding memory process. This encoding process should mediate the relationship between the mindfulness condition and performance on the RAVLT. This relationship would designate mindfulness as a useful tool for learning new verbal information, which would aid in future recall, and not necessarily in remembering previously learned verbal information.

As mindfulness is expected to work primarily on improving encoding, we would not expect increased performance on a measure that relied on previously learned verbal information. For this reason, we hypothesize that mindfulness participants will not perform better than others on a measure of verbal fluency that relies on recall of words that begin with specified letters (thus word-knowledge stored in long-term memory) within a limited timeframe.

Finally, we expect improvement in verbal learning and memory without improvements in selective attention or attention switching, which would mirror the results of Lykins, Baer, and Gottlob (2012). This would indicate that brief mindfulness works to improve verbal learning and memory by specifically enhancing encoding processes, and not due to increases in general attention abilities. To test this hypothesis, we included the Color-Word Interference Test (CWIT; a Stroop-like task that measures selective attention) and the Trail Making Test (a measure of attention switching). All tasks used in this study are commonly used and well validated neuropsychological measures.

Method

Participants

The total number of participants was 94, but four participants were excluded due to a technical error (i.e., no condition number), and another five were excluded due to having recently completed the neuropsychological tests used in this experiment. This was necessary because naïvety is crucial for measures like the RAVLT, in which participants are supposed to be unaware of the final delayed free-recall trial. With previous experience taking the RAVLT, participants know to rehearse before the final delayed free-recall trial in order to increase performance. Additionally, since the 15 target words on the RAVLT never change, these participants had recently memorized the words that they were given in this study, thus making them easier to relearn. Therefore, our final sample was comprised of 85 undergraduate university students (50 females and 35 males; 46 mindfulness condition and 39 control condition) of traditional college age who were recruited from a large Midwestern university. The final sample size was determined by a power analysis for independent samples t-tests, with the desire to achieve a 95% probability of detecting a large effect ($d = .80$), which required approximately 35 participants per condition.

Measures

Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003)

The MAAS is a measure of trait mindfulness that consists of 15 items measured on a 6-point scale (1 – Almost always, to 6 – Almost never) that asks participants about how they normally go through activities in their daily lives (e.g., "I rush through activities without being really attentive to them").

State Mindfulness Scale (SMS; Tanay & Bernstein, 2013)

The SMS is a measure of state mindfulness that consists of 15 items on a 5-point Likert scale (0 – Not at all, to 4 – Very much) that asks participants to rate their experiences during an audio recording immediately preceding the scale (e.g., "I tried to pay attention to pleasant and unpleasant sensations").

Rey Auditory-Verbal Learning Test (RAVLT; Strauss, Sherman, & Spreen, 2006)

The RAVLT measures verbal learning and memory. A 15-noun word list (List A) was read aloud to the participant, in a fixed order and with a 1-s interval between words, for five consecutive trials, with recall instructions repeated at the start of each trial. Each of the five trials was followed by a free-recall test, for which the participant was asked to repeat as many of the words as possible, in any order. Responses were tracked, and feedback was not provided. Upon completion of Trial 5 free-recall, a single presentation and free-recall test of a second (new) list of 15 words (List B; interference list; Trial 6) was administered. Immediately after the free-recall test of List B, and without an additional presentation of List A, a short-delayed recall of the first list (List A; Trial 7) was assessed. After a 20-min delay period (with no other verbal memory tests administered during this time interval), the long-delayed free-recall of List A (Trial 8) was assessed, again without an additional presentation of List A. Immediately after Trial 8, a recognition test (Trial 9) was administered by providing the participant with a matrix array of 50 words containing both List A and List B words, in addition to 20 words that were phonemically or semantically similar to those in both lists, and requesting the identification of List A words only.

The RAVLT is a sensitive test of verbal learning and memory (see Schoenberg et al., 2006, for a review), and provides scores for examination of immediate memory span, new verbal learning, susceptibility to interference, retention of information after a delay, and memory recognition (Magalhães & Hamdan, 2010; Strauss et al., 2006).

Controlled Oral Word Association Test (COWAT; FAS version: phonemic verbal fluency; Benton, Hamsher, & Sivan, 1994)

The FAS measures verbal fluency with the spontaneous oral generation of words that begin with a specified letter during a prescribed timeframe, while adhering to the following restrictions: no proper nouns (no names of people or places), no numbers, and no variants of the same word (saying the same word using a different ending). Following the abovementioned guidelines, participants were asked to provide as many words as possible that begin with the letters F, A, and S, for 60 s each (thus a total of three trials were administered, one per letter). Performance was measured by calculating the sum of all admissible words for the three letters, minus the errors (e.g., proper nouns, variations, repetitions, wrong words).

A recent factor-analytic study found that the FAS loaded exclusively onto the language factor, and not the executive functioning factor, implicating verbal fluency as primarily a language-processing measure (Whiteside et al., 2016). Word-knowledge (Ruff et al., 1997; Whiteside et al., 2016) as well as auditory attention and long-term memory, but not short-term memory, have also been suggested to be the most important determinants for FAS performance (Ruff et al., 1997).

Trail Making Test (TMT; Reitan & Wolfson, 1993)

The TMT is an attention-switching measure and consists of two parts: Part A and Part B. Part A measures the speed at which participants sequentially connect, by making pencil lines, 25 encircled numbers that are variously spread across a page. Part B measures the speed at which participants connect 25 encircled, and variously spread, numbers and letters in sequential, but alternating order (i.e., 1-A-2-B-3-C and so on). For each part, participants were instructed to draw the line as fast as they can. If errors occurred, they would be pointed out as per standard procedure, and error-correction would subsequently influence the total time taken to complete each part. A practice trial was provided prior to the administration of each part. While the primary variables of interest were the total time in seconds taken to complete each of the two parts, a ratio score (Part B/Part A) was also calculated in order to control for general processing speed when interpreting Part B performance.

While visual search and scanning abilities as well as speeded performance are required by both parts, Part B also requires divided attention (alteration of operations), and it is sensitive to cognitive flexibility (Strauss et al., 2006). The derived ratio score (Part B/Part A) is thought to serve as an index of complex divided attention – in other words, the B/A ratio score is thought to be the best indicator of attentional control processes required for rapid alternation between two tasks (e.g., Arbuthnott & Frank, 2000).

Color-Word Interference Test (CWIT) from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001)

The CWIT is a subtest from D-KEFS, and an extension of the classic Stroop procedure (Stroop, 1935). It is comprised of four conditions: (1) *color naming,* consisting of rows of colored patches (red, blue, and green) on a white surface. The participant was asked to name the colors aloud as fast and as accurately as possible; (2) *word reading,* consisting of rows of the words "red," "green," and "blue" printed in black ink on a white surface. The participant was asked to read the words aloud as fast and as accurately as possible; (3) *inhibition,* consisting of rows of the same three words as before, but this time the words were written in an incongruent ink color. The participant was asked to *not* read the words (thus inhibit the automatic response of word reading), and instead say aloud the color of the ink in which each word was printed in (e.g., say "red" when the word "green" is printed in red ink) as fast and as accurately as possible; (4) *inhibition/switching,* consisting of rows of the same three words, with half of the words enclosed within boxes. The participant was asked to switch between naming aloud the color of the ink in which the word was printed (same as the *inhibition* condition), and actually reading the word (and not naming the ink color) if the word was enclosed within a box, as fast and as accurately as possible. The aim of this last condition is to measure both inhibition and switching. Performance on this test is primarily assessed via the total completion time in seconds for each of the four conditions. Optional measurements include error analysis: the total number of uncorrected and self-corrected errors per condition.

Performance on the CWIT measures selective attention with the integration of processing speed, inhibitory control, and cognitive set-switching/attention shifting. *Color naming* (condition 1) and *word reading* (condition 2) are thought to reflect baseline low-level cognitive measures that are required for the subsequent high-level cognitive functions (e.g., inhibition and cognitive flexibility) that are assessed in *inhibition* (condition 3) and *inhibition/switching* (condition 4). In the *inhibition* condition, the participant is presented with interference in the form of competing responses, and their ability to inhibit a dominant and automatic response (word reading) in order to provide an intentional one (naming the ink color) is assessed. In the *inhibition/switching* condition, the participant is required to switch back and forth between the automatic response (reading the word, when the word is enclosed in a box), and the intentional response (not reading the word, but instead naming the ink color that the word is printed in); thus it not only measures inhibition, but also cognitive flexibility or the ability of set switching (Delis et al., 2001).

In order to obtain pure measures of inhibition and cognitive flexibility (Delis et al., 2001; Yu et al., 2018), lower level factors such as basic processing speed (as captured by conditions 1 and 2) were controlled for by calculating contrast scores: *inhibition* (inhibition minus color-naming completion time), inhibition/cognitive flexibility (inhibit/switching minus color-naming completion time), and cognitive flexibility (inhibit/switching minus inhibit completion time).

Procedure

All participants entered the lab and first completed the MAAS in order to assess trait mindfulness. They were then instructed to listen to a 10-min audiotape, which was either a mindfulness audio tape that directed the participant to concentrate on their breath and bodily sensations while remaining nonjudgmental about their experience, or a control audio tape that described an English countryside. These audios have been used in previous research a number of times, and the mindfulness audio has been shown to reliably increase mindfulness over the control condition (Cropley, Ussher, & Charitou, 2007; Lueke & Gibson, 2016). Participants alerted the experimenter when the audio had finished, and then completed the SMS.

Participants then completed the neuropsychological tests in the same order regardless of condition. First, they completed the CWIT, followed by the FAS, and then the RAVLT (except for the second-delayed recall trial and the recognition test). Participants then completed the TMT and a filler task in order to have enough time elapse (about 20-min) before the second part of the RAVLT was administered (the second delayed free-recall, followed by the recognition test). The filler task was the Wisconsin Card Sorting task, which was chosen for its length and reliance on nonverbal processes. The order of presentation was determined by the need to present the audio manipulation before all subsequent neuropsychological tests. The neuropsychological tests were ordered with the primary goal of achieving approximately a 20-min delay using tasks that were not reliant on verbal activity between the first and second delayed free-recall RAVLT trials. The TMT was administered during the RAVLT's delay interval since it was a nonverbal task, as was our filler task. The CWIT and FAS were presented before the RAVLT so as not to bury them at the end of the experiment. After all tasks were completed, participants were debriefed and left the experiment.

Results

Preliminary results

We first investigated whether our two conditions were similar in terms of trait mindfulness before any intervention had taken place. An independent t-test analysis on the MAAS indicated that the mindfulness and control conditions were not significantly different in trait mindfulness, ($t < 1$).

Additionally, as a manipulation check we measured state mindfulness after the intervention to ensure that our audio intervention did increase self-reported feelings of mindfulness. An independent t-test analysis on the SMS indicated that the mindfulness condition (M = 49.54, SD = 14.34) did report significantly greater state mindfulness than the control condition (M = 41.18, SD = 10.95), $t(83)$ = 2.98, p = .004, d = .66.

RAVLT analyses for verbal learning and memory

We first examined our hypothesis that verbal learning and memory would be better for individuals in the mindfulness condition than the control condition. In order to do this, we performed two independent samples t-tests – one for the combined performance on the five learning trials and one for the combined performance on the two delayed free-recall trials. One participant did not complete the RAVLT so was not included. A second participant had to leave before the second delayed free-recall could be administered so was not included in that specific analysis or subsequent ISDA analyses. Overall, results revealed significant support for the hypothesis that mindfulness improves verbal learning and memory, as the mindfulness condition (M = 53.31, SD = 7.33) performed significantly better than the control condition (M = 48.51, SD = 7.20) on the learning trials, $t(82)$ = 3.02, p < .002, d = .66, and delayed free-recall trials, $t(81)$ = 2.19, p < .02, d = .48 (Mindfulness: M = 22.38, SD = 4.25; Control: M = 20.26, SD = 4.54). All individual trial comparisons were also significant, including a recognition trial (Fig. 1).

ISDA for memory processes

In order to examine what aspect of memory may have been enhanced in the mindfulness condition, we utilized the ISDA to analyze encoding, consolidation, and retrieval processes. Following the instructions of Wright et al. (2009), we used the five learning trials to calculate encoding errors, and the two delayed free-recall trials to calculate consolidation and retrieval. Independent t-tests were used to determine any differences between mindfulness and control conditions for all three memory processes. Results indicated significantly more encoding errors for the control group (M = 4.47, SD = 2.30) than for the mindfulness group (M = 3.11, SD = 2.18), $t(81)$ = 2.77, p = .004, d = .61. The consolidation index was not quite significantly different between the groups, $t(81)$ = 1.53, p = .07, d = .34. The retrieval process was also not significantly different between the groups, $t(81)$ = 1.24, p = .11, d = .27. Both indices trended toward being better in the mindfulness condition.

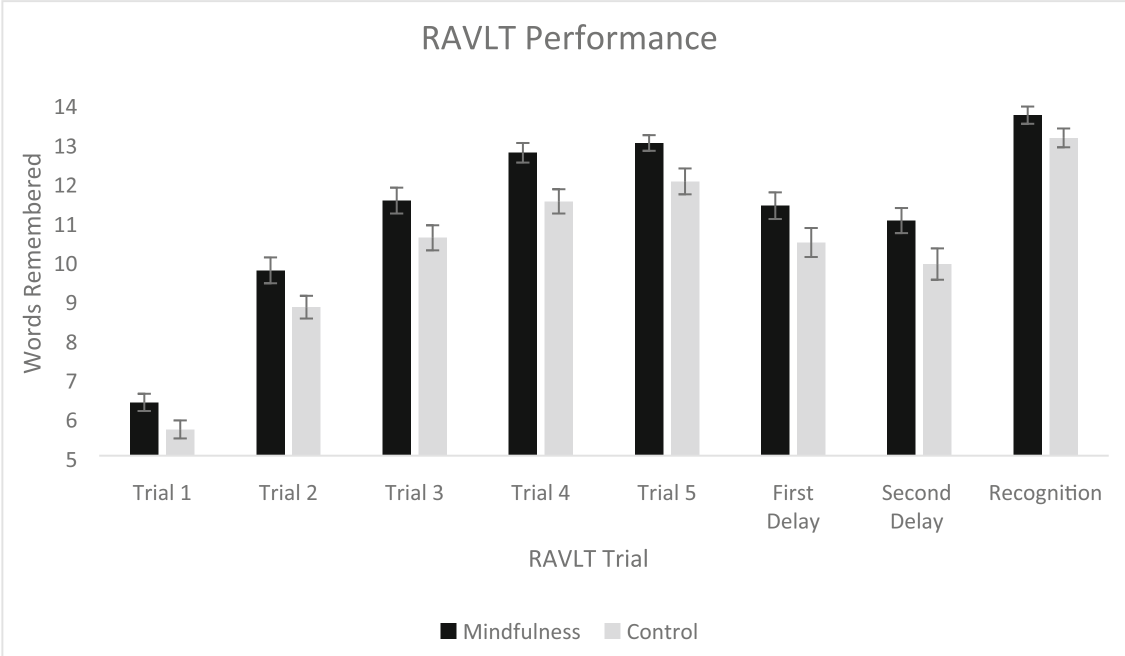

Fig. 1 Verbal learning and memory performance for both conditions on each Rey Auditory Verbal Learning Task (RAVLT) trial. All comparisons are significant

We then conducted a mediational analysis to determine if the improvements in verbal learning and memory in the mindfulness condition were due to increased encoding capabilities. Using PROCESS macro, model 4 (Hayes, 2017), we used the audio condition as our X variable, encoding as our M variable, and the combined delayed free-recall trials as our Y variable. We found that the overall model for X predicting Y was significant, $F(1, 81) = 4.79$, $p = .032$, $R^2 = .06$, as the mindfulness condition remembered more words on the delayed free-recall trials, $b = 2.11$, $t(81) = 2.19$, $p = .032$. Next, we found a significant effect of X on M, as the overall model was significant, $F(1, 81) = 7.67$, $p = .007$, $R^2 = .09$, with the mindfulness group showing greater encoding capabilities, $b = 1.36$, $t(81) = 2.77$, $p = .007$. Finally, we looked at X and M together predicting Y. The overall model was significant, $F(2, 80) = 19.83$, $p < .0001$, $R^2 = .33$. The effect of M on Y was also significant, $b = 1.06$, $t(80) = 5.74$, $p < .0001$, and the effect of X on Y was no longer significant, $b = .67$, $t(80) = .78$, $p = .44$. A Sobel test confirmed that there was a significant difference between the prediction of X on Y based on the involvement of M, $Z = 2.49$, $p = .01$.

We were unable to run the consolidation and retrieval indices as part of a multi-mediational analysis along with encoding to determine their combined effects on the delayed free-recall trials due to the nature of how these indices are calculated. Both the consolidation and retrieval indices exclusively utilize performance on the delayed free-recall trials to calculate ability within these processes. Thus, it would be inappropriate and meaningless to use these indices as a potential mediator for performance on the delayed free-recall trials. On the other hand, the encoding index only uses performance on the learning trials to calculate ability on this process, thus making it appropriate to use as a mediator for performance on the delayed free-recall trials.

General verbal fluency

We further expected that mindfulness would not improve general verbal ability even though it improved verbal learning and memory. The ability of mindfulness to improve encoding should help people learn verbal information, but this should not affect verbal information that had already been learned previous to the intervention, which would simply need to be retrieved. We tested this by examining any differences between the mindfulness and control conditions in terms of performance on the FAS, which measures verbal fluency through the timed recall of words that begin with the letters F, A, and S. An independent samples t-test confirmed that there was no difference between the mindfulness and control conditions in the number of words recalled that began with those letters, $t(83) = 1.20$, $p = .12$ (Mindfulness: $M = 37.89$, $SD = 10.27$; Control: $M = 35.10$, $SD = 11.17$).

Attention

We then examined the possibility that mindfulness may improve attentional capabilities. It is possible that any improvements in encoding were largely derived from improvements of attention. If there are no differences, it provides support for our hypothesis that mindfulness improves learning and memory specifically through enhanced encoding and not necessarily through increased attention.

Independent samples t-tests were used in order to examine any differences with regard to two different measures of attention: the CWIT (selective attention measure) and the TMT (attention switching measure). We examined several different measures available within the CWIT, including the time it took to complete each trial, and the number of errors that were either self-corrected or uncorrected by the participant. Results indicated that there were no differences between the mindfulness and control groups in terms of the time taken to complete any of the four CWIT trials, or the two critical trials combined (trials 3 and 4), or the combined time among all four trials (all *t*s < 1). Likewise, there were no significant differences in the number of errors of either type (self-corrected or uncorrected) for either critical trial or the total number of errors from both trials (all *t*s < 1.17). The total number of uncaught errors from both critical trials combined was also not significant, $t(83) = 1.40$, $p = .08$. The total number of caught errors from both critical trials combined was not significantly different ($t < 1$). Additionally, we isolated more pure assessments of inhibition and cognitive flexibility on the CWIT as outlined in previous research (see Yu et al., 2018), and found no significant differences among the three independent samples t-tests (all *t*s < 1).

Three independent samples t-tests were performed on the length of time to complete each of two parts on the TMT, as well as their combined time. We also conducted a fourth independent samples t-test for the ratio between Part B over Part A, which is thought to be a purer assessment of attention switching (Arbuthnott & Frank, 2000). Results indicated that none of these four comparisons indicated a significant difference (all *t*s < 1.21). Taken together, our results indicated that the mindfulness condition did not affect selective attention or attention switching. This provides support for the hypothesis that encoding is likely enhanced without necessarily increasing attention (see Table 1 for all attention comparisons).

Discussion

Our results strongly supported our central hypothesis that mindfulness improves verbal learning and memory through the enhancement of the encoding process, which mediated the relationship between mindfulness and recall at both delayed free-recall trials. Furthermore, this improved encoding capability was not due to increases in attention, as there were no differences in attention between the mindfulness and control groups. This means that encoding is enhanced by mindfulness without necessarily affecting attentional processes. Additionally, general verbal ability was left unaffected by brief mindfulness training, providing evidence that mindfulness is particularly effective for learning new verbal information through improved encoding processes, rather than helping to retrieve previously learned verbal information, or improving verbal ability more generally. However, questions remain regarding whether the mindfulness induced by the manipulation lasted until the final delayed free-recall, or even the measure of attention switching (i.e., TMT). It is possible that certain measures were not significant due to mindfulness having worn off over the course of the experiment. In order to address these questions, we conducted a second study to ensure that some of our null results were not due to dissipated mindfulness.

Study 2

In Study 1, the mindfulness audio was administered before the RAVLT learning trials. The ISDA calculates its encoding index using these learning trials, whereas the consolidation and retrieval indices are calculated using the two delayed free-recall trials. It is possible that the mindfulness produced by the initial mindfulness induction improved encoding during these learning trials but then dissipated over time and was no longer present during one or both of the delayed free-recall trials. Indeed, in Study 1 the consolidation and retrieval indices were not significant, but they did trend toward significance in favor of the mindfulness condition. If this is the case, then a mindfulness induction before the delayed free-recall trials but after the learning trials could improve consolidation and retrieval while leaving encoding untouched. We would then expect the delayed free-recall trials to be better for the mindfulness condition over the control, while the learning trials would indicate no difference.

On the other hand, if mindfulness truly improves verbal learning and memory through enhanced encoding, then without a mindfulness induction before the learning trials, we would expect no differences in verbal learning and memory with regard to the learning trials or delayed free-recall trials, even if participants were exposed to a mindfulness induction before the two delayed free-recall trials. Furthermore, we would expect no differences between conditions in terms of their consolidation and retrieval indices, even with the audio manipulations placed immediately before the delayed free-recall trials. In Study 2 we made these adjustments to test for these possibilities.

Finally, it is also possible that mindfulness wore off before participants reached our measure of attention switching (i.e., TMT) in Study 1, thus leading to null results. Had mindfulness been active during this measure, we may have found a difference. To test this, we moved the TMT closer to the mindfulness induction in Study 2.

Table 1 Descriptive statistics for all attention comparisons

Test	Mindfulness	Control
CWIT		
Time (in seconds)		
Time 1	26.17 (4.74)	26.92 (4.74)
Time 2	19.96 (3.78)	20.69 (4.35)
Time 3	45.58 (12.67)	45.15 (8.49)
Time 4	55.09 (11.45)	54.36 (10.75)
Total Time	146.69 (27.88)	147.13 (22.88)
Times 3 and 4	100.40 (21.21)	99.51 (16.69)
Errors		
Total	4.04 (3.26)	4.77 (3.39)
Trial 3 Uncorrected	.37 (1.04)	.67 (1.30)
Trial 3 Corrected	1.04 (1.30)	.90 (1.10)
Trial 4 Uncorrected	1.11 (1.58)	1.54 (1.93)
Trial 4 Corrected	1.52 (1.81)	1.67 (1.56)
Trials 3 and 4 Uncorrected	1.48 (1.93)	2.21 (2.82)
Trials 3 and 4 Corrected	2.57 (2.59)	2.56 (1.83)
Pure processes		
Inhibition	19.33 (9.49)	18.23 (6.79)
Cognitive Flexibility	9.24 (11.51)	9.21 (9.85)
Inhibition/Cog. Flexibility	28.91 (9.52)	27.44 (9.86)
Trail-Making Test (in seconds)		
Trail A	19.72 (5.60)	20.26 (8.79)
Trail B	44.26 (16.60)	48.62 (21.15)
Trails A and B	63.98 (19.25)	68.87 (27.10)
Ratio B/A	2.33 (.86)	2.56 (.88)

Note. Data are given as means and standard deviations (in parentheses) for all non-significant tests examined with regard to selective attention (CWIT) and attention switching (Trail-Making Test)

Method

Participants

Participants were 57 college students (35 females and 22 males; 31 mindfulness and 26 control) of traditional college age who were recruited from a large Midwestern university. The final sample size was determined by a power analysis for independent samples t-tests, with the desire to achieve a 90% probability of detecting a large effect ($d = .80$), which required approximately 27 participants per condition.

Measures

All measures were identical to Study 1 and were administered in the same manner except for the SMS. Instead of the SMS, we used three questions to measure state mindfulness. Two questions came from the SMS and were presented on a 5-point scale (0 – Not at all, to 4 – Very much; e.g., "During the audio, I felt closely connected to the present moment"), while the other was the one-question State MAAS (Ostafin & Kassman, 2012), presented on a 12-point scale (0 – Strongly disagree, to 11 – Strongly agree; "At this moment I feel like I will rush through activities without being really attentive to them").

Procedure

The procedure had a few key differences from Study 1. First, the mindfulness and control audios were administered before the RAVLT in Study 1, whereas Study 2 placed these audios after the RAVLT learning trials and interference trial but before the first delayed free-recall trial. Second, in Study 2 we added a novel second audio (which varied by condition and were similar to the audios used in Study 1) before the second RAVLT delayed free-recall trial, given that there were approximately 20 min in between delayed free-recall trials, and there still existed the possibility of mindfulness dissipating before the second delayed free-recall trial. Third, to account for the addition of the second 10-min audio and the reordering of the RAVLT in relation to the audio trials, we eliminated the filler task and placed the remaining tests in an order designed to provide approximately a 20-min gap between the two RAVLT delayed free-recall trials.

All manipulations and measures were presented in the following order: MAAS, RAVLT learning trials and interference trial, first 10-min audio tape (mindfulness/control), state mindfulness questions, first RAVLT delayed-recall trial, CWIT, TMT, second 10-min audio tape (mindfulness/control), state mindfulness questions, second RAVLT delayed free-recall trial and recognition trial, FAS, and demographic questions.

Results

Preliminary results

An independent samples t-test revealed no differences between the mindfulness and control groups in trait mindfulness before any audio manipulation, ($t < 1$). However, state mindfulness was significantly higher for the mindfulness condition after the first audio, $t(55) = 4.06$, $p < .001$, $d = 1.06$ (Mindfulness: $M = 12.48$, $SD = 2.82$; Control: $M = 8.81$, $SD = 4.00$) and the second audio $t(55) = 2.38$, $p = .01$, $d = .63$ (Mindfulness: $M = 12.39$, $SD = 3.30$; Control: $M = 10.27$, $SD = 3.39$).

RAVLT and ISDA analyses for verbal learning and memory

We then examined whether the mindfulness and control conditions were different on the combined performance for all five learning trials (which were completed before any audio manipulation), as well as the combined performance on the two delayed free-recall trials (which were all completed after an audio manipulation). There were no differences with regard to the learning trials (higher numbers means better performance), $t(55) = 1.24$, $p = .11$ (Mindfulness: $M = 47.32$, $SD = 7.46$; Control: $M = 49.77$, $SD = 7.44$), or the delayed free-recall trials, $t(55) = 1.34$, $p = .09$ (Mindfulness: $M = 19.03$, $SD = 5.01$; Control: $M = 20.69$, $SD = 4.22$) Fig. 2. As this study predicted that the null hypothesis would be supported for both of these analyses, we calculated a Bayes factor for each using the mean differences from Study 1 as an estimate of the effect we should see if the mindfulness and control conditions are different from each other. This mean difference was used as the SD of a half normal (Dienes, 2014). As per Jeffrey (1939), we interpret a Bayes factor above 3 as providing substantial evidence for the alternative hypothesis, whereas a Bayes factor below 1/3 providing substantial evidence for the null hypothesis. The learning trials provided support for the null hypothesis, $B_{H(0,\ 4.80)} = .19$, as did the delayed recall trials, $B_{H(0,\ 2.12)} = .25$.

To follow up with the ISDA, we examined the potential difference between mindfulness and control conditions in terms of their encoding, consolidation, and retrieval. The encoding index was calculated using the five learning trials, which were completed before any manipulation and therefore were expected to be similar. This was the case, as there was no significant difference between conditions, ($t = 1.00$). Again, we used the mean difference between conditions regarding encoding from Study 1 as an estimate of the effect in order to calculate a Bayes factor to determine whether or not the null hypothesis was supported. Results indicated support for the null hypothesis, $B_{H(0,\ 1.36)} = .23$.

We then examined any potential consolidation or retrieval benefits of mindfulness, as these indices were calculated using the two delayed free-recall trials, each of which followed an audio manipulation. Higher numbers on each index indicates a greater deficit. There were no significant differences between the mindfulness and control conditions for the consolidation index, $t(55) = 1.49$, $p = .07$ (Mindfulness: $M = .34$, $SD = .25$; Control: $M = .25$, $SD = .18$), or retrieval index, $t(55) = 1.31$, $p = .10$ (Mindfulness: $M = .14$, $SD = .11$; Control: $M = .17$, $SD = .09$). Once again, we calculated a Bayes factor with the results from Study 1 as an estimate for the effect regarding consolidation and retrieval. Results indicated some support for the null hypothesis regarding consolidation, $B_{H(0,\ .0456)} = .43$, but no support for the null hypothesis regarding retrieval, $B_{H(0,\ .0278)} = 1.80$.

General verbal fluency and attention

Similar to Study 1, we found no significant differences between the mindfulness and control conditions on our verbal fluency measure (i.e., FAS), $t < 1$. Furthermore, our measure of attention switching (i.e., TMT) also indicated no significant differences among the four possible comparisons, (all ts < 1). Our selective attention measure (CWIT) also found no significant differences among its comparisons, (all ts < 1). Tab. 2

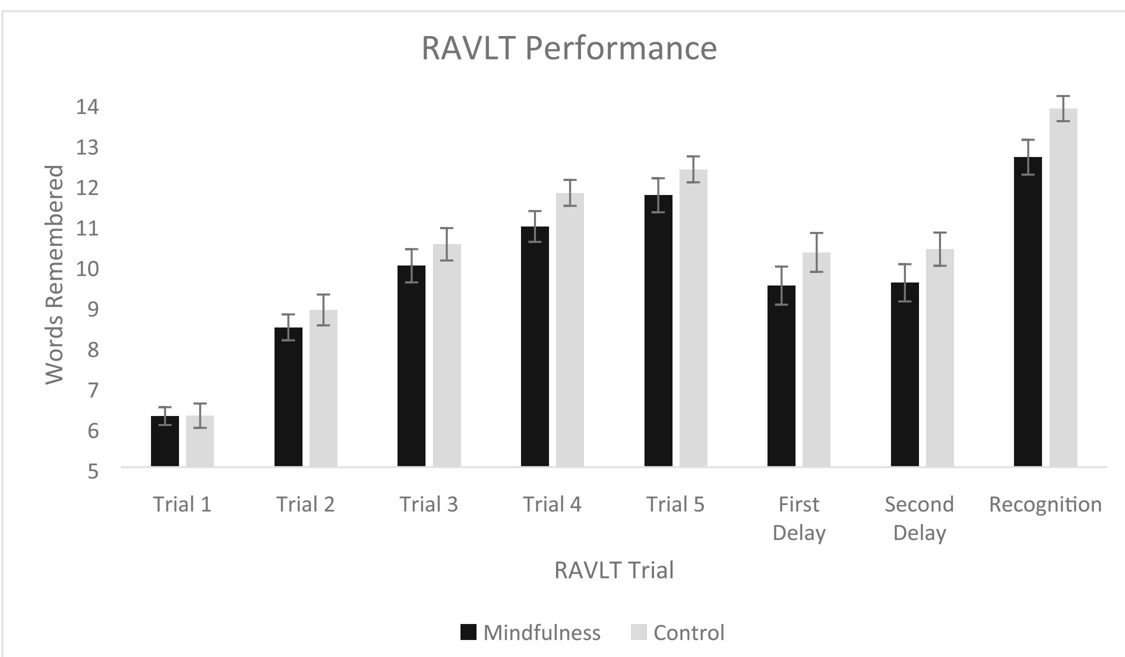

Fig. 2 Verbal learning and memory performance for both conditions on each Rey Auditory Verbal Learning Task (RAVLT) trial in Study 2. None of the comparisons are significant at $p = .05$ except Recognition

Discussion

Study 2 found further support for the idea that mindfulness improves verbal learning and memory through enhancing the encoding process of memory rather than the consolidation and retrieval processes. Without mindfulness during the learning trials, the mindfulness condition did not perform any better on the learning trials or delayed free-recall trials, even when given a mindfulness induction before both delayed free-recall trials. This indicates that mindfulness must be present during the learning process in order to enhance the encoding process and subsequently recall the new verbal information at a later time. Alternatively, it appears as though mindfulness is not particularly effective at improving consolidation and retrieval processes if instituted after a learning phase has already ended.

Additionally, we again found no effect of mindfulness on general verbal fluency, indicating further that mindfulness is particularly effective at helping to learn new verbal information, rather than giving greater access to and retrieval of previously learned verbal material. Finally, the results of Study 2 reflected those of Study 1 with regard to attention. The mindfulness condition did not enhance selective attention or attention-switching capabilities. As the attention-switching task was placed much closer to the mindfulness induction in Study 2, this indicates the null result found in Study 1 was not due to mindfulness wearing off by the time participants reached that task. Instead, we found evidence that mindfulness did not alter selective attention or attention switching in either study.

Table 2 Descriptive statistics for all attention comparisons in Study 2

Test	Mindfulness	Control
CWIT		
Time (in seconds)		
Time 1	26.11 (3.72)	25.89 (2.25)
Time 2	19.69 (3.19)	19.30 (3.69)
Time 3	45.56 (11.46)	46.63 (8.20)
Time 4	53.50 (12.68)	54.19 (10.06)
Total Time	144.94 (26.12)	146.36 (15.56)
Times 3 and 4	99.08 (21.62)	100.82 (15.10)
Errors		
Total	3.77 (3.45)	4.20 (4.19)
Trial 3 Uncorrected	.77 (2.01)	.92 (1.85)
Trial 3 Corrected	1.00 (1.13)	1.16 (1.40)
Trial 4 Uncorrected	1.23 (1.91)	.84 (1.21)
Trial 4 Corrected	1.03 (1.22)	1.28 (1.43)
Trials 3 and 4 Uncorrected	1.70 (2.58)	1.76 (2.60)
Trials 3 and 4 Corrected	2.07 (1.82)	2.44 (2.62)
Pure processes		
Inhibition	19.45 (9.41)	20.55 (8.01)
Cognitive Flexibility	7.91 (11.23)	7.56 (10.44)
Inhibition/Cog. Flexibility	27.46 (11.32)	28.11 (10.12)
Trail-Making Test (in seconds)		
Trail A	21.51 (8.78)	20.57 (5.05)
Trail B	56.81 (17.38)	59.52 (19.74)
Trails A and B	78.32 (21.20)	80.20 (22.64)
Ratio B/A	2.89 (1.18)	2.91 (.85)

Note. Data are given as means and standard deviations (in parentheses) for all non-significant tests examined with regards to selective attention (CWIT) and attention switching (Trail-Making Test)

General discussion

Participants who engaged in mindfulness for a mere 10 min exhibited improved verbal learning and memory through enhanced encoding. This demonstrates that even brief periods of mindfulness can help people improve important areas of learning with relatively little investment before the learning process begins, such as learning vocabulary, reading comprehension, listening comprehension, etc. Furthermore, it seems likely that experienced meditators who generally maintain a mindful state throughout their day would exhibit higher encoding capabilities without the need to have recently engaged in meditation. In this way, long-term meditators may indicate a greater general capacity to learn, understand, and remember verbal information within their environment throughout the course of the day. Indeed, long-term meditators have shown better verbal learning and memory performance on a task similar to the RAVLT without having recently meditated (Lykins, Baer, & Gottlob, 2012). It is important to understand if these long-term meditators achieve these enhanced results due to increased encoding capabilities as well, which would be a fruitful area for future research. If so, it would elevate mindfulness as an extremely important tool to actively improve verbal learning and memory processes through enhancing the ability to encode new information.

This elevated learning through mindfulness should be able to improve almost anyone's verbal learning and memory capability without the need for invasive or difficult learning techniques that may be off-putting or time-consuming for people to incorporate into their lives. This seems particularly useful for children, as learning progresses rapidly through early school years. A number of school subjects may benefit from enhanced verbal learning, such as learning vocabulary, learning a new language, understanding reading assignments, remembering important historical events, and many more. Recent research with children has shown some promising early signs regarding the benefits that mindfulness can have on academic success (Ksendzov, 2017; Lu, Huang, & Rios, 2017). Research with children and the potential for increased learning through mindfulness should be an area of primary importance for future research.

Additionally, our research demonstrated that mindfulness increases encoding capabilities despite not improving attentional capabilities, which implies that mindfulness may be a particularly effective learning tool for people regardless of their attentional capacity. While attention is important for learning, and improving its capacity is valuable for the learning process, the ability of mindfulness to strengthen encoding processes by bypassing attentional constraints can be incredibly valuable in its own right. This may especially be the case for those who struggle to pay attention, as this research implies that mindfulness can improve verbal learning and memory despite these difficulties. In this way, children or adults who are vulnerable to distraction may still be able to improve their ability to learn and recall new verbal information through enhancing their encoding skills through mindfulness. Perhaps this may even be true of clinical populations, such as in people with Alzheimer's disease whom show certain impairments in encoding (Millet, Le Goff, Bouisson, Dartigues, & Amieva, 2010). On the other hand, individuals whose attentional capabilities are excellent, without much room for improvement, may still be able to enhance their verbal learning and memory capabilities by further improving their encoding capacity through mindfulness. Theoretically, this may work regardless of whether individuals show learning difficulties or not, which could potentially be another very fertile area for future research.

While we found evidence that encoding enhancement was not due to increases in attention, it is possible that other measures of attention may have been more likely to have been affected by mindfulness, and therefore could have helped mediate the relationship between mindfulness and RAVLT performance. We utilized measures of attention switching and selective attention, but other attention measures (such as focused attention measures) could have been more likely to have been enhanced by mindfulness. Future research should look at these other attention measures as possible mediators between mindfulness and improved verbal learning and memory.

Similarly, while we found that a brief mindfulness induction does not improve consolidation or retrieval processes, it is possible that long-term practice may benefit these memory processes. Taken together with our results, this would mean that even a short mindfulness practice can help increase encoding processes, which increases verbal learning and memory, but long-term mindfulness practice could also strengthen consolidation and retrieval, which would then enhance verbal learning and memory even more greatly. Future research should examine whether consolidation and retrieval processes are better in long-term meditators than controls.

Additionally, the current study demonstrated that mindfulness improved learning and memory in the verbal domain, but it is possible that nonverbal learning capabilities may also benefit from mindfulness. Future work will need to assess whether visuo-spatial learning and memory is also enhanced by a brief mindfulness practice. If it is the case that mindfulness can improve visuo-spatial learning and memory, this would provide evidence that mindfulness can enhance general learning capabilities, regardless of the modality in which learning occurs. Preliminary evidence in this domain has shown that mindfulness can enhance the recognition of visual objects (Brown, Goodman, Ryan, & Analayo, 2016) and improve visuo-spatial processing (Zeidan et al., 2010)

On the other hand, it could be that mindfulness is specifically good for verbal learning and memory, as perhaps the enhanced encoding in this domain is produced by removing cognitive load from the phonological loop – an essential aspect of working memory that holds and manipulates auditory information (Baddeley & Hitch, 1994). Activities that engage the phonological loop do not necessarily impede with performance in non-verbal tasks, such as spatial tasks, while spatial tasks also do not necessarily impede with verbal tasks. For instance, Baddeley (1992) reported an attempt to have participants memorize chess-piece locations, a visuo-spatial task, while loading either the phonological loop or the visuospatial sketchpad. Compared to a control group, memory was impaired when the visuo-spatial sketchpad was loaded but not when the phonological loop was loaded (also see Burnham, Sabia, & Langan, 2014). When people allow their thoughts to slip away from the current task into thoughts that are unrelated to the task, this internal verbalization (or inner speech) likely interferes with the task that currently requires the phonological loop, which would negatively affect cognitive performance. Alternatively, this internal verbalization may not have any impact on other learning capabilities as long as the task does not heavily involve the phonological loop. It is for this reason that mindfulness may be particularly suited to improve verbal learning and memory but not general learning capabilities.

This hypothesis is derived from the ability of mindfulness to help people disengage from their thoughts, including decreasing rumination (Kumar, Felman, & C.H.S, 2008), even after a stressful event (Key, 2010). Similarly, low levels of trait mindfulness are related to elevated levels of rumination (Ciesla, Reilly, Dickson, Emanuel, & Updegraff, 2012), and higher trait and state mindfulness have also been shown to be associated with lower rumination (Eisenlohr-Moul, Peters, Pond, & DeWall, 2016). Similarly, mind-wandering is a natural phenomenon (Killingsworth & Gilbert, 2010) that can be alleviated through mindfulness (Mrazek et al., 2013; Rahl et al., 2017). Mind-wandering can be thought of as a form of cognitive load, as it negatively impacts working memory through its apparent recruitment of working memory resources (Kam & Handy, 2014). By allowing the mind to let go and disengage from thoughts, it perhaps reduces cognitive load by clearing the phonological loop, thereby providing more resources for verbal learning and memory tasks, but not necessarily for other non-verbal learning tasks. If this is indeed the case, then mindfulness may not lead to any improvements in visuo-spatial learning tasks. Future research should examine this possibility.

Tremendous resources have been exhausted in the attempt to improve learning capabilities and enhance the ability to remember important information. The present research demonstrates strong support for mindfulness as an important, effective, and easily utilized tool for improved verbal learning and memory through its specific enhancements of the encoding process. These improvements likely transcend age groups, establishing mindfulness as a valuable learning tool that can be started during childhood and maintained and fostered throughout adulthood. Furthermore, the ease of implementation and limited requirements for practicing mindfulness make it a method of learning enhancement that is approachable and easily able to be incorporated into daily life. While there still needs to be much investigation within this field, early indications are promising that the more you practice mindfulness, the more you know.

Author Notes Both authors were equally involved in the development of this research. As such, both authors share first authorship, and both are corresponding authors. Data are available upon email request.

Data Availability Data are available through email request. Neither study was pre-registered.

References

Aggleton, J. P., & Brown, M. W. (2006). Interleaving brain systems for episodic and recognition memory. *Trends in Cognitive Sciences, 10*(10), 455-463. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.tics.2006.08.003

Anderson, N. D., Lau, M. A., Segal, Z. V., & Bishop, S. R. (2007). Mindfulness-based stress reduction and attentional control. *Clinical Psychology & Psychotherapy, 14*(6), 449-463. http://dx.doi.org.cmich.idm.oclc.org/10.1002/cpp.544

Arbuthnott, K. & Frank, J. (2000). Trail making test, part B as a measure of executive control: validation using a set-switching paradigm. *Journal of Clinical Experimental Neuropsychology, 22*, 518–528.

Baddeley, A. D. (1992). Is working memory working? The fifteenth Bartlett lecture. *The Quarterly Journal of Experimental Psychology, 44A*, 1–31.

Baddeley, A. D., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology, 8*(4), 485-493. http://dx.doi.org.cmich.idm.oclc.org/10.1037/0894-4105.8.4.485

Baer, R. A., Carmody, J., & Hunsinger, M. (2012). Weekly change in mindfulness and perceived stress in a mindfulness-based stress reduction program. *Journal of Clinical Psychology, 68*, 755–765. doi:https://doi.org/10.1002/jclp.21865

Benton, A. L., de Hamsher, K. S., & Sivan, A. B. (1994). Multilingual Aphasia Examination-Third Edition. Iowa City, IA: AJA Associates.

Bonamo, K. K., Legerski, J., & Thomas, K. B. (2015). The influence of a brief mindfulness exercise on encoding of novel words in female college students. *Mindfulness, 6*(3), 535-544. http://dx.doi.org.cmich.idm.oclc.org/10.1007/s12671-014-0285-3 Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/1508428013?accountid=10181

Brown, K. W., Goodman, R. J., Ryan, R. M., & Anālayo, B. (2016). Mindfulness enhances episodic memory performance: Evidence from a multimethod investigation. *PLoS ONE, 11*(4), 19. Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/1898077554?accountid=10181

Brown, C. A., & Jones, A. K. P. (2013). Psychobiological correlates of improved mental health in patients with musculoskeletal pain after a mindfulness-based pain management program. *The Clinical Journal of Pain, 29*, 233-244. doi:https://doi.org/10.1097/AJP.0b013e31824c5d9f

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.

Burnham, B. R., Sabia, M., & Langan, C. (2014). Components of working memory and visual selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 40*(1), 391-403. http://dx.doi.org.cmich.idm.oclc.org/10.1037/a0033753

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. http://dx.doi.org.cmich.idm.oclc.org/10.1007/s10608-007-9119-0

Christidi, F., Zalonis, I., Smyrnis, N., & Evdokimidis, I. (2012). Selective attention and the three-process memory model for the interpretation of verbal free recall in amyotrophic lateral sclerosis. *Journal of the International Neuropsychological Society, 18*(5), 809-18. http://dx.doi.org.cmich.idm.oclc.org/10.1017/S1355617712000562

Ciesla, J., Reilly, L., Dickson, K., Emanuel, A., & Updegraff, J. (2012). Dispositional mindfulness moderates the effects of stress among adolescents: Rumination as a mediator. *Journal of Clinical Child and Adolescent Psychology, 41*, 760-770. doi:https://doi.org/10.1080/15374416.2012.698724

Cropley, M., Ussher, M., & Charitou, E. (2007). Acute effects of a guided relaxation routine (body scan) on tobacco withdrawal symptoms and cravings in abstinent smokers. *Addiction, 102*, 989–993. doi:https://doi.org/10.1111/j.1360-0443.2007.01832.x

Davidson, R. J., Kabat-Zinn, J., Schumacher, J., Rosenkranz, M., Muller, D., Santorelli, S. F., … Sheridan, J. F. (2003). Alterations in brain and immune function produced by mindfulness meditation. *Psychosomatic Medicine, 65*, 564-570. doi:https://doi.org/10.1097/01.PSY.0000077505.67574.E3

Delis D. C., Kaplan E., Kramer J. H.. Delis–Kaplan Executive Function System (D-KEFS): Examiner's manual, 2001, San Antonio, TX. The Psychological Corporation

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, E. (2000). *California Verbal Learning Test–II*. San Antonio, TX: Psychological Corporation.

Delis, D. C., Massman, P. J., Butters, N., Salmon, D. P., Cermak, L. S., & Kramer, J. H. (1991). Profiles of demented and amnesic patients on the california verbal learning test: Implications for the assessment of memory disorders. *Psychological Assessment, 3*(1), 19-26. http://dx.doi.org.cmich.idm.oclc.org/10.1037/1040-3590.3.1.19

Desrosiers, A., Vine, V., Klemanski, D. H., & Nolen-Hoeksema, S. (2013). Mindfulness and emotion regulation in depression and anxiety: Common and distinct mechanisms of action. *Depression and Anxiety, 30*(7), 654-61. http://dx.doi.org.cmich.idm.oclc.org/10.1002/da.22124

Dienes, Z. (2014). Using Bayes to get the most out of non-significant results. *Quantitative Psychology and Measurement, 5*, 781. doi:https://doi.org/10.3389/fpsyg.2014.00781.

Dolan, R. J., & Fletcher, P. F. (1999). Encoding and retrieval in human medial temporal lobes: An empirical investigation using functional magnetic resonance imaging (fMRI). *Hippocampus, 9*(1), 25-34. doi:3.0.CO;2-4" TARGET="_blank">http://dx.doi.org.cmich.idm.

oclc.org/10.1002/(SICI)1098-1063(1999)9:1<25::AID-HIPO3>3.0.CO;2-4

Dubert, C. J., Schumacher, A. M., Locker, L., Jr., Gutierrez, A. P., & Barnes, V. A. (2016). Mindfulness and emotion regulation among nursing students: Investigating the mediation effect of working memory capacity. *Mindfulness, 7*(5), 1061-1070. http://dx.doi.org.cmich.idm.oclc.org/10.1007/s12671-016-0544-6

Eisenlohr-Moul, T., Peters, J. R., Pond, R. S., Jr., & DeWall, C. N. (2016). Both trait and state mindfulness predict lower aggressiveness via anger rumination: A multilevel mediation analysis. *Mindfulness, 7*(3), 713-726. http://dx.doi.org.cmich.idm.oclc.org/10.1007/s12671-016-0508-x

Fernández, G., Weyerts, H., Schrader-Bölsche, M., Tendolkar, I., Smid, H. G. O. M., Tempelmann, C., … Heinze, H. (1998). Successful verbal encoding into episodic memory engages the posterior hippocampus: A parametrically analyzed functional magnetic resonance imaging study. *The Journal of Neuroscience, 18*(5), 1841-1847. Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/619293424?accountid=10181

Gordon, P. C., Hendrick, R., and Johnson, M. (2001). Memory interference during language processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition. 27*, 1411–1423. doi: https://doi.org/10.1037/0278-7393.27.6.1411

Gordon, P. C., Hendrick, R., and Johnson, M. (2004). Effects of noun phrase type on sentence complexity. *Journal of Memory and Language, 51*, 97–114. doi: https://doi.org/10.1016/j.jml.2004.02.003

Greenberg, J., Romero, V. L., Elkin-Frankston, S., Bezdek, M. A., Schumacher, E. H., & Lazar, S. W. (2018). Reduced interference in working memory following mindfulness training is associated with increases in hippocampal volume. *Brain Imaging and Behavior,* http://dx.doi.org.cmich.idm.oclc.org/10.1007/s11682-018-9858-4

Hayes, A. F. (2017). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. New York, NY: Guilford Press.

Herndon, F. (2008). Testing mindfulness with perceptual and cognitive factors: External vs. internal encoding, and the cognitive failures questionnaire. *Personality and Individual Differences, 44*(1), 32-41. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.paid.2007.07.002

Hopthrow, T., Hooper, N., Mahmood, L., Meier, B. P., & Weger, U. (2017). Mindfulness reduces the correspondence bias. *The Quarterly Journal of Experimental Psychology, 70*(3), 351-360. http://dx.doi.org.cmich.idm.oclc.org/10.1080/17470218.2016.1149498

Jeffreys, H. (1939/1961). The Theory of Probability, 1st/3rd Edn. Oxford: Oxford University Press.

Jensen, C. G., Vangkilde, S., Frokjaer, V., & Hasselbalch, S. G. (2012). Mindfulness training affects attention—Or is it attentional effort? *Journal of Experimental Psychology: General, 141*(1), 106-123. http://dx.doi.org.cmich.idm.oclc.org/10.1037/a0024931

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. http://dx.doi.org.cmich.idm.oclc.org/10.1037/a0018438

Josefsson, T., & Broberg, A. (2011). Meditators and non-meditators on sustained and executive attentional performance. *Mental Health, Religion & Culture, 14*(3), 291-309. http://dx.doi.org.cmich.idm.oclc.org/10.1080/13674670903578621

Kabat-Zinn, J., Wheeler, E., Light, T., Skillings, A., Scharf, M. J., Cropley, T. G., … Bernhard, J. D. (1998). Influence of a mindfulness meditation-based stress reduction intervention on rates of skin clearing in patients with moderate to severe psoriasis undergoing phototherapy (UVB) and photochemotherapy (PUVA). *Psychosomatic Medicine, 60*(5), 625-632. http://dx.doi.org.cmich.idm.oclc.org/10.1097/00006842-199809000-00020

Kam, J. W. Y., & Handy, T. C. (2014). Differential recruitment of executive resources during mind wandering. *Consciousness and Cognition, 26*, 51-63. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.concog.2014.03.002

Kerr, C. E., Jones, S. R., Wan, Q., Pritchett, D. L., Wasserman, R. H., Wexler, A., … Moore, C. I. (2011). Effects of mindfulness meditation training on anticipatory alpha modulation in primary somatosensory cortex. *Brain Research Bulletin, 85*(3-4), 96-103. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.brainresbull.2011.03.026

Key, B. L. (2010). *The influence of rumination, distraction and mindfulness on cardiovascular recovery from stress* (Order No. NR69488). Available from ProQuest Dissertations & Theses Global. (848965766). Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/848965766?accountid=10181

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science, 330*, 932.

Kliegl, O., Pastötter, B., & Bäuml, K. T. (2015). The contribution of encoding and retrieval processes to proactive interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(6), 1778-1789. http://dx.doi.org.cmich.idm.oclc.org/10.1037/xlm0000096

Kong, F., Wang, X., Song, Y., & Liu, J. (2016). Brain regions involved in dispositional mindfulness during resting state and their relation with well-being. *Social Neuroscience, 11*(4), 331-343. http://dx.doi.org.cmich.idm.oclc.org/10.1080/17470919.2015.1092469

Ksendzov, E. (2017). *Associative relationship among mindfulness, academic grades, and affective outcomes in adolescence* (Order No. AAI10164953). Available from PsycINFO. (1910931448; 2017-01058-262). Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/1910931448?accountid=10181

Kumar, S. M., Feldman, G. C., & Hayes, S. C. (2008). Changes in mindfulness end emotion regulation in an exposure based cognitive therapy or depression. *Cognitive Therapy & Research, 32*, 734−744.

Lagor, A. F., Williams, D. J., Lerner, J. B., & McClure, K. S. (2013). Lessons learned from a mindfulness-based intervention with chronically ill youth. *Clinical Practice in Pediatric Psychology, 1*, 146-158. doi:https://doi.org/10.1037/cpp0000015

Langer, E. J., Bashner, R. S., & Chanowitz, B. (1985). Decreasing prejudice by increasing discrimination. *Journal of Personality and Social Psychology, 49*, 113-120. doi: https://doi.org/10.1037/0022-3514.49.1.113

Lewicki, P. (2005). Internal and external encoding style and social motivation. In J. P. Forgas, K. D. Williams & S. M. Laham (Eds.), *Social motivation: Conscious and unconscious processes; social motivation: Conscious and unconscious processes* (pp. 194-209, Chapter xx, 386 Pages) Cambridge University Press, New York, NY. Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/620554589?accountid=10181

Lu, S., Huang, C., & Rios, J. (2017). Mindfulness and academic performance: An example of migrant children in China. *Children and Youth Services Review, 82*, 53-59. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.childyouth.2017.09.008 Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/1976695701?accountid=10181

Lueke, A., & Gibson, B. (2015). Mindfulness meditation reduces implicit age and race bias: The role of reduced automaticity of responding. *Social Psychological and Personality Science, 6*(3), 284-291. http://dx.doi.org.cmich.idm.oclc.org/10.1177/1948550614559651

Lueke, A., & Gibson, B. (2016). Brief mindfulness meditation reduces discrimination. *Psychology of Consciousness: Theory, Research, and Practice, 3*(1), 34-44. http://dx.doi.org.cmich.idm.oclc.org/10.1037/cns0000081

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. http://dx.doi.org.cmich.idm.oclc.org/10.1007/s10608-010-9318-y Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/964200583?accountid=10181

Magalhaes, S., & Hamdan, A. C. (2010). The Rey Auditory Verbal Learning Test: Normative data for the Brazilian population and analysis of the influence of demographic variables. *Psychology & Neuroscience*, *3*, 85-91.

Millet, X., Le Goff, M., Bouisson, J., Dartigues, J., & Amieva, H. (2010). Encoding processes influence word-stem completion priming in alzheimer's disease: A meta-analysis. *Journal of Clinical and Experimental Neuropsychology, 32*(5), 494-504. http://dx.doi.org.cmich.idm.oclc.org/10.1080/13803390903224936

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. http://dx.doi.org.cmich.idm.oclc.org/10.1177/0956797612459659

Ostafin, B. D., & Kassman, K. T. (2012). Stepping out of history: Mindfulness improves insight problem solving. *Consciousness and Cognition, 21*, 1031–1036.

Parks, S., Birtel, M. D., & Crisp, R. J. (2014). Evidence that a brief meditation exercise can reduce prejudice toward homeless people. *Social Psychology, 45*(6), 458-465. http://dx.doi.org.cmich.idm.oclc.org/10.1027/1864-9335/a000212

Pratscher, S. D., Rose, A. J., Markovitz, L., & Bettencourt, A. (2017). Interpersonal mindfulness: Investigating mindfulness in interpersonal interactions, co-rumination, and friendship quality. *Mindfulness,* http://dx.doi.org.cmich.idm.oclc.org/10.1007/s12671-017-0859-y

Quach, D., Mano, K. E. J., & Alexander, K. (2016). A randomized controlled trial examining the effect of mindfulness meditation on working memory capacity in adolescents. *Journal of Adolescent Health, 58*(5), 489-496. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.jadohealth.2015.09.024

Rahl, H. A., Lindsay, E. K., Pacilio, L. E., Brown, K. W., & Creswell, J. D. (2017). Brief mindfulness meditation training reduces mind wandering: The critical role of acceptance. *Emotion, 17*(2), 224-230. http://dx.doi.org.cmich.idm.oclc.org/10.1037/emo0000250

Ramsey, A. T., & Jones, E. E. (2015). Minding the interpersonal gap: Mindfulness-based interventions in the prevention of ostracism. *Consciousness and Cognition, 31*, 24-34. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.concog.2014.10.003

Reitan, R., & Wolfson, D. (1993). The halstead-reitan neuropsychological test battery: Theory and clinical applications. Tucson, AZ: Neuropsychology Press.

Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1997). The psychological construct of word fluency. *Brain and Language, 57*, 394–405. doi:https://doi.org/10.1006/brin.1997.1755

Schoenberg, M.R., Dawson, K.A., Duff, K., Patton, D., Scott, J.G., & Adams, R.L. (2006). Test performance and classification statistics for the Rey Auditory Verbal Learning Test in selected clinical samples. *Archives of Clinical Neuropsychology, 21*, 693-703.

Schofield, T. P., Creswell, J. D., & Denson, T. F. (2015). Brief mindfulness induction reduces inattentional blindness. *Consciousness and Cognition: An International Journal, 37*, 63-70. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.concog.2015.08.007 Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/1803818840?accountid=10181

Strange, B. A., Otten, L. J., Josephs, O., Rugg, M. D., & Dolan, R. J. (2002). Dissociable human perirhinal, hippocampal, and parahippocampal roles during verbal encoding. *The Journal of Neuroscience, 22*(2), 523-528. Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/619830312?accountid=10181

Strauss E.H., Sherman E.M., & Spreen O. (2006). A compendium of neuropsychological tests: administration, norms, and commentary. New York, NY: Oxford University Press.

Stroop J. R. (1935). Studies of interference in serial verbal reactions, *Journal of Experimental Psychology, 18*, 643-666.

Tanay, G., & Bernstein, A. (2013). State Mindfulness Scale (SMS): Development and initial validation. *Psychological Assessment, 25,* 1286–1299. doi:https://doi.org/10.1037/a0034044

Vakil, E., & Blachstein, H. (1993). Rey auditory-verbal learning test: Structure analysis. *Journal of Clinical Psychology, 49*(6), 883-890. doi:3.0.CO;2-6" TARGET="_blank">http://dx.doi.org.cmich.idm.oclc.org/10.1002/1097-4679(199311)49:6<883::AID-JCLP2270490616>3.0.CO;2-6

Villata, S., Tabor, W., & Franck, J. (2018). Encoding and retrieval interference in sentence comprehension: Evidence from agreement. *Frontiers in Psychology, 9*, 16. http://dx.doi.org.cmich.idm.oclc.org/10.3389/fpsyg.2018.00002

Whiteside, D. M., Kealey, T., Semla, M., Luu, H., Rice, L., Basso, M. R. and Roper, B., (2016). Verbal fluency: language or executive function measure? *Applied Neuropsychology, 23*, 29–34.

Wright, M. J., & Schmitter-Edgecombe, M. (2011). The impact of verbal memory encoding and consolidation deficits during recovery from moderate-to-severe traumatic brain injury. *The Journal of Head Trauma Rehabilitation, 26*(3), 182-191. http://dx.doi.org.cmich.idm.oclc.org/10.1097/HTR.0b013e318218dcf9

Wright, M. J., Woo, E., Foley, J., Ettenhofer, M. L., Cottingham, M. E., Gooding, A. L., … Hinkin, C. H. (2011). Antiretroviral adherence and the nature of HIV-associated verbal memory impairment. *The Journal of Neuropsychiatry and Clinical Neurosciences, 23*(3), 324-31. Retrieved from http://cmich.idm.oclc.org/login?url=https://search-proquest-com.cmich.idm.oclc.org/docview/916301253?accountid=10181

Wright, M.J., Woo, E., Schmitter-Edgecombe, M., Hinkin, C.H., Miller, E.N., & Gooding, A.L. (2009). The item-specific deficit approach to evaluating verbal memory dysfunction: Rationale, psychometrics, and application. *Journal of Clinical and Experimental Neuropsychology, 31*, 790–802.

Yu, K., Seal, M. L., Reyes, J., Godfrey, C., Anderson, V., Adamson, C., ... Catroppa, C. (2018). Brain volumetric correlates of inhibition and cognitive flexibility 16 years following childhood traumatic brain injury. *Journal of Neuroscience Research, 96*, 642–651.

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: An International Journal, 19*(2), 597-605. http://dx.doi.org.cmich.idm.oclc.org/10.1016/j.concog.2010.03.014