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Evaluating the effects of brief mindfulness practice on attentional control and episodic memory

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ABSTRACT
Mindfulness refers to a mental state of present awareness that involves non-judgmental acceptance of current cognitions and emotions. Building on reported clinical benefits (e.g. reduced anxiety/depression), minfulness engagement may similarly facilitate attention and memory processes as practitioners repetitively inhibit distracting thoughts and direct attention to the present moment. Experiment 1 gauged the relationships between trait mindfulness and practice frequency and performance on attention and episodic memory tasks. Experiment 2 evaluated attention and memory performance following a brief mindfulness intervention consisting of two 5-minute mindfulness sessions. No consistent relationships were found between trait mindfulness and practice frequency and attention and memory performance in Experiment 1. Further, brief engagements in mindfulness failed to benefit attention and memory versus a control group in Experiment 2. Engagement in brief mindfulness sessions do not appear to produce short-term improvements in attention and memory, suggesting that cognitive benefits following mindfulness may only emerge following long-term practice.

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Mindfulness practice refers to the act of attending and being fully conscious of the present moment while maintaining non-judgmental acceptance of any cognitions or emotions that occur (Marlatt & Kristeller, 1999). Though there is much variability in mindfulness techniques, common practices include focused deep breathing, self-reflection, and attending to bodily sensations. Mindfulness practices are relatively new within Western society, but date back millennia, originating in East Asia from practitioners of Theravada and Mahayana Buddhism (Kabat-Zinn, 1982). Original practitioners emphasised rhythmic breathing to achieve a sense of inner peace, to contemplate life events, and self-reflect. While mindfulness originated as a religious practice, accumulating research over the past few decades has shown that secular mindfulness can produce psychological benefits including general stress reduction (Baer et al., 2012; Ciesla et al., 2012; Lagor et al., 2013), reductions in anxiety and depression, (Desrosiers et al., 2013) pain management (Zeidan et al., 2012), and treatment of eating disorders (Kristeller et al., 2014; see too Schumer et al., 2018, for a meta-analysis of general mindfulness effects). Additionally, mindfulness practice has been shown to produce physiological changes such as reductions in heart rate, blood pressure, and skin conductance (Goleman & Schwartz, 1976). Given the broad and successful therapeutic benefits of mindfulness, a related question is whether mindfulness practice may affect basic cognitive processes such as controlled attention and episodic memory, the latter of which requires a well-tuned attentional system to effectively encode and retrieve information.

The present study evaluates the relationships between trait mindfulness, mindfulness practice, attention, and memory by examining the frequency of mindfulness states and practice in a large sample and the potential benefits following brief mindfulness-practices. Trait mindfulness, also termed dispositional mindfulness, refers to one's inherent capacity to focus on and be fully present in the moment with a nonjudgmental and accepting mindset (Brown & Ryan, 2003). Like other forms of skill acquisition, mindfulness practitioners regularly engage in mindfulness practice with a goal of more efficiently and effectively achieving a mindful state. Although there are many approaches that have been used to achieve a mindful state (see Van Dam et al., 2018, for review), mindfulness practice can generally be grouped into one of two relatively comprehensive groups: Focused attention (FA; i.e. concentration-based

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approach) and open monitoring (OM; i.e. mindfulness-meditation approach; Baer, 2003; Lutz et al., 2008).

FA is generally categorised as the instruction of participants to direct attention to a specific stimulus throughout the session, such as a word, sound, or phrase. When mindwandering occurs, the practitioner redirects attention to the focal stimulus, and no attention is paid to the nature of the thought that occurred during mindwandering (Lutz et al., 2008). To exemplify focused mindfulness practice, one may meditate to alleviate stress. During the mindfulness practice they could focus on a mantra and silently repeat the phrase "this shall pass" throughout the session. When mindwandering occurs, attention is shifted back to the phrase and the process is repeated until the session is over. Although there are several different FA practices, this mantra-focused meditation exemplifies the general framework of FA practice in which attention is directed to a target stimulus.

Separately, OM is centralised on the experiences evoked within the individual when mindfulness practice begins, such as emotions and thoughts, and this mindfulness practice type emphasises the non-judgmental acceptance of cognitions as they occur rather focusing on a specific stimulus (Baer, 2003). It is paramount that the practitioner be conscious of the present moment to achieve a mindful state. For example, a practitioner may be engaged in mindfulness practice with focus on the present moment, only to spontaneously recollect an argument with a romantic partner from the previous week. Rather than labelling the event as positive or negative, the practitioner should merely acknowledge the thought and reengage with the present moment. Kabat-Zinn (1994) relates this state of mindfulness as sitting near a flowing stream in which one's thoughts represent the flowing water. Regardless of whether this stream is raging or calmly flowing, one should merely observe the thoughts moving by rather than being in the stream's current, as individuals often are in daily life.

The primary differences between the two mindfulness approaches are therefore whether meditation directs attention towards a specific stimulus (FA) versus redirecting attention towards the present moment (OM). While there are clear distinctions between the FA and OM mindfulness approaches, it is important to avoid viewing them mutually exclusive practices. Instead, FA and OM approaches may be better understood as points along a spectrum of mindfulness techniques (Lutz et al., 2015). This perspective acknowledges the nuanced variations within mindfulness practices while emphasising their interconnectedness. Additionally, it suggests a functional overlap between FA and OM approaches, wherein aspects of each contribute to the cultivation of mindfulness.

Given the importance of attention in both mindfulness approaches, our research question of interest is whether trait mindfulness and mindfulness practice be linked to enhanced cognition and if cognitive benefits emerge following short-term engagement of mindfulness practice. Because sustained attention and inhibition of irrelevant distractions are cognitive processes that are prioritised under most types of mindfulness practice, it is possible that individuals who engage in mindfulness practice may show enhanced attention which may spillover to other tasks that require controlled attentional processes, such as episodic memory (Anderson et al., 1998; Wagner, 2002).

Attentional control and mindfulness

Attentional control systems involve the activation of relevant information and the control/inhibition of irrelevant information which can support many aspects of cognition including memory and language (Balota & Duchek, 2014). Attentional control refers to an individual's unique ability to selectively process specific attributes (either internally or externally) for additional processing while simultaneously inhibiting competing attributes which may be more salient and include working memory processes (Aschenbrenner & Balota, 2019; Jaeggi et al., 2003; Posner & Petersen, 1990). Given limits in the cognitive resources that are available to process environmental demands, the integrity of one's attentional control system is critical for ensuring task completion. This coordination of selection/maintenance and inhibition processes operate in tandem to ensure accurate and efficient behavioural functions. Thus, mindfulness practice may support the recruitment of attentional processes via controlled selection and inhibition.

Relatedly, working memory is a multi-component memory system which involves a capacity-limited memory store and an attentional process designed to prioritise information that is most relevant to the present (Baddeley & Hitch, 1974; Baddeley, 1986; 1993; Engle, 2002). Individual differences in the capacity of this memory system are evident, as some individuals are more likely to hold a greater capacity of information after a delay. This ability to maintain information for use requires the ability to inhibit off-task thoughts created endogenously and non-related events that occur in the external environment (Unsworth & Engle, 2007; Engle, 2018; Mashburn et al., 2020).

Several studies have shown that tasks that are generally thought to measure attentional control are strongly related to working memory tasks. For instance, the Stroop colour naming task (Stroop, 1935), which utilises processes such as inhibition and goal maintenance, has been shown to be sensitive to differences in working memory capacity (Kane & Engle, 2003). Participants with higher working memory capacity typically show faster latencies and higher accuracy for incongruent trials than those with lower working memory capacity. A converging pattern has been reported by Hutchison (2007) who found that Stroop performance loaded on the same factor as working memory capacity using a principal components analysis. Relatedly, studies on mindwandering have also shown sensitivities to differences in working memory capacity. Specifically, high (vs. low) working memory capacity participants were more likely to produce on-task thoughts when asked to report their cognitions at random over a one-week testing period (Kane et al., 2007).

Relevant to the present study, some positive relationships have also been reported between working memory capacity and mindfulness practice. Quach et al. (2016) reported an increase in working memory capacity indexed by the auto-OSPAN, in adolescents who completed eight 45-minute sessions of mindfulness-based stress reduction (MBSR) over a 4-week period. The working memory increase was argued to occur due to MBSR increasing attentional maintenance on the present experience while inhibiting off-task thoughts. Additionally, other studies support an increased working memory benefit by deploying regular mindfulness practice programmes for military populations (Jha et al., 2010).

Moore and Malinowski (2009) analysed the relations between mindfulness, meditation, and cognitive flexibility and compared attention differences between mindfulness meditators and non-meditators. Results indicated that meditators performed better on both measures of attention (the Stroop task and the d2-concentration and endurance test) versus non-meditators. However, the meditator group consisted of Buddhist meditators who had minimally completed a 6-week mindfulness practice programme (and likely considerable mindfulness practice), whereas non-meditators were office workers with no reported mindfulness experience. Additionally, a meta-analysis by Fox et al. (2014) reported that neuroanatomical structures such as the orbitofrontal cortex, frontopolar cortex, and hippocampus – structures that are related to controlled processes including attention and episodic memory (Svoboda et al., 2006) – can be altered through long-term mindfulness practice.

Similar benefits of mindfulness practice have also been reported with relatively shorter mindfulness programmes. Mrazek et al. (2013) compared a group of mindfulness trainees who completed a 2-week mindfulness programme resembling MBSR therapy to a control group who completed a 2-week nutrition education programme. In the mindfulness group, participants were instructed on how to reach a mindful state via mindfulness practice in sessions that occurred four times per week in which each session lasting 10–20 minutes Additionally, participants were instructed to partake in 10-minutes of mindfulness outside of class daily and encouraged to incorporate mindfulness into daily activities. Relative to the nutrition-education control, mindfulness practice produced improvements in working memory (via the OSPAN task), GRE reading comprehension, and reductions in mindwandering. In sum, long-term mindfulness practice (i.e. weeks or longer) may produce attention-related benefits which may reflect changes in functional connectivity in brain areas associated with attention and memory.

Although engagement in mindfulness may produce some cognitive benefits, these patterns are not always consistent. For example, Lueke and Lueke (2019) compared attentional control differences between brief mindfulness and control groups. In the mindfulness group, participants were instructed to listen and follow along to a mindfulness practice audiotape for 10-minutes which emphasised breathing and physical sensations in the present moment. For the control group, individuals listened to a 10-minute audio clip describing an English countryside. Attentional control was measured using a selective attention measure (colour-word interference test) and a task-switching measure (trail-making test). The mindfulness group produced no improvements in either attention measures versus the control group, indicating that a single brief mindfulness intervention may not benefit selective attention or task-switching.

There have been a few meta-analytic findings that further support the idea that long-term mindfulness practice enhances certain aspects of attentional control such as selective attention, working memory, executive control, and inhibition (Chiesa et al., 2011; Eberth & Sedlmeier, 2012; Sumantry & Stewart, 2021). Although, as mentioned throughout the meta-analyses, there are great differences within the methodologies of included studies such as study design, study duration, mindfulness programme duration, type of subject populations, sample sizes, mindfulness practice types, etc. This variability suggests large differences not only in study approaches, but also in the quality of the mindfulness induction procedures and cognitive tasks used which could affect the quality of the conclusions made from the meta-analyses.

More germane to the current study, Gill et al. (2020) also conducted a meta-analysis examining the effects of brief mindfulness practice on cognition and assessed the methodological quality of the included studies. Although the findings of individual studies were mixed, meta-analytic results indicated that brief mindfulness inductions result in small improvements to higher-order functions (e.g. verbal reasoning, judgement/decision making, creativity) but not memory, attention, and executive functioning. Although the authors define mindfulness induction as follows, "Mindfulness induction is a single and brief session of mindfulness training, designed to induce a temporary state of mindfulness", the average duration of these brief inductions varied widely, ranging from as short as 3 minutes (Calvillo et al., 2018) to as long as 30 minutes (Gorman & Green, 2016) per session, indicating a lack of consensus on what constitutes brief mindfulness practice. Of the 34 studies analysed, most lacked methodological quality (i.e. Poor quality: 32 studies; Fair quality: 2 studies; Good quality: 0 studies) Poor quality studies were described as those that lacked active control comparisons, proper randomisation to conditions, small samples, and/or case-controls with expert mindfulness practitioners. Given these quality concerns across many of the studies designed to examine mindfulness interventions on cognitive processes, it is possible that these issues may contribute to the inconsistent findings on whether brief mindfulness practice facilitates cognitive function.

Episodic memory and mindfulness

In addition to attentional control and working memory processes, mindfulness practice has also been examined in the context of long-term episodic memory, a type of declarative memory which allows individuals to mentally "time travel" to past events (Tulving, 1983, 2002; Moscovitch et al., 2016). A key component of episodic memory is the recollection of contextual details that accompany a retrieved event. Recollections of contextual details from episodic memory are sensitive to individual differences in working memory and attentional control with source accuracy improving in high working memory individuals and in younger versus older adults (Wahlheim & Huff, 2015; Wahlheim et al., 2016). High-integrity attentional systems facilitate the encoding of contextual information at study by increasing the binding between context and event and aid retrieval by improving monitoring of episodic events for correct contextual information at test (Brown & Craik, 2000). Insufficient attention may increase the likelihood of context-related errors in episodic memory.

In a recent review, Levi and Rosenstreich (2019) described the effects of mindfulness on episodic memory in four domains: Attentional processes, sensitivity, dual memory processes, and false memory. In terms of attentional processes, mindfulness may be associated with higher selective attention under conditions that require elevated levels of focus. Rosenstreich and Ruderman (2016) had participants complete a mindfulness questionnaire (i.e. FFMQ-SF) to gauge trait-based mindfulness followed by recognition for two separate lists of words. Full attention was used for the first set of words but divided attention at encoding was used for the second set. When attention was divided, correct recognition scores decreased, however, a negative correlation between the non-judgmental facet of mindfulness and false alarms was found under full attention. This pattern suggests that non-judgmental acceptance may be associated with attention. Thus, how strongly one associates positive or negative emotions to an idea or event may negatively affect attention, whereas the ability to maintain a neutral emotional state likely benefits this process.

Studies that evaluate mindfulness using the signal-detection approach evaluate memory processes on sensitivity or discriminability. Results regarding whether mindfulness consistently affects signal-detection parameters have been mixed. For instance, a brief 15-minute mindfulness induction was completed before participants encountered a DRM list of semantically associated words and a decrease in source monitoring and increased false-recall were found (Wilson et al., 2015). However, in Calvillo et al. (2018) the opposite pattern emerged when a brief 3-minute mindfulness induction is conducted after encoding DRM false memory lists. This resulted in lower rates of false recognition and increased source monitoring. Thus, the effect of brief mindfulness practice on memory sensitivity remains unclear.

Finally, mindfulness appears to affect memory processes through the reduction in retrieval errors. Proactive interference – interference resulting from previously learned information (Keppel & Underwood, 1962) – may be particularly affected by mindfulness. Research has shown that the hippocampus plays a role in resolution of proactive interference (Caplan et al., 2007), which is consistent with other evidence showing hippocampal/medial temporal lobe recruitment in episodic contexts, especially when stimuli are complex (see Ranganath, 2010, for review). Greenberg et al. (2019) examined whether proactive interference could be mitigated by mindfulness interventions and concurrently analysed changes in hippocampal volume and activation. Participants either took part in a 4-

week web-based mindfulness intervention or a creative writing control programme, and interventions were visited five times a week by participants. A reduction in proactive interference errors was found on the Recent Probes task (Jonides & Nee, 2006) in the mindfulness intervention group versus the control, suggesting that mindfulness engagement may assist in resolving proactive interference via increased hippocampal volume and activation.

Further, a meta-analysis by Millett et al. (2021) was conducted to observe how group-based mindfulness interventions might benefit cognition by focusing on studies that implemented long-term intervention and measured cognition through executive functioning (i.e. classified as attentional inhibition, working memory, attention switching, and verbal fluency). Overall, group-based mindfulness training was found to have a small overall benefit to executive functioning. Additional analyses on some sub-facets of executive functioning across studies were conducted which also indicated small benefits to inhibition, working memory, and verbal fluency, though no mindfulness effects were found for attention switching. Similar meta-analytic findings were reported by C´asedas et al. (2020) who reported a small effect size benefit to executive functioning across 13 studies and Mirabito and Verhaeghen (2023) who reported small benefits to attention, long-term memory, and visuospatial processing following mindfulness in both healthy older adults and older adults with diagnoses of mild cognitive impairment.

In summary, mindfulness practice may facilitate attentional control/working memory processes and promote episodic memory via familiarity-based processes, promoting discriminability, and/or reducing interference. Despite the reported patterns, studies examining the effects of mindfulness on attentional control and episodic memory remain inconsistent due, in part, to several factors including task differences across studies, using a single task to measure a cognitive process (vs. a comprehensive battery of tasks), and differences in methodology such as control group types. Additionally, most studies do not examine the effects of mindfulness on attentional control and episodic memory concurrently.

Current study

The purpose of Experiment 1 was to examine the relationship between trait mindfulness and the frequency with which individuals practice mindfulness spontaneously in their everyday lives and attentional control and episodic memory performance. Trait mindfulness was assessed through two questionnaires, the 15-item Five Facets of Mindfulness Questionnaire (FFMQ-15; Baer et al., 2008) and the Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003), to measure self-reported qualitative aspects of mindfulness practice and the tendency to be in a mindful state. The FFMQ-15 was chosen as a measure of mindfulness because of its assessment of five separate aspects of mindfulness that can be quantified. As these aspects of mindfulness may have been disproportionately related to cognitive variables it seemed like an appropriate avenue for analysis. Whereas the MAAS was chosen as a measure due to its approach from a different perspective that being the view of mindfulness as a single construct, the presence of attention to and awareness of what is occurring in the present moment. Thus, both measures complement each other by assessing unique aspects of the same construct, which is mindfulness. Additionally, the FFMQ-15 and MAAS are commonly used measures throughout the mindfulness literature and have been cited vastly, with over 3,800 and 18,000 respective empirical citations to date exemplifying the proclivity of the measures. The estimated frequency and duration of mindfulness practice with which an individual partakes in was also assessed with a brief question. To assess attentional control and working memory, participants completed the Stroop colour-naming task (Spieler et al., 1996) and the operation span task (OSPAN; Foster et al., 2015). Finally, participants completed the dual-list interference paradigm (Wahlheim & Huff, 2015), an episodic memory task that evaluates both proactive and retroactive interference. Given the reported relationship between mindfulness and proactive interference (Greenberg et al., 2019), the dual-list paradigm may be sensitive towards subject-level differences in engagement in mindfulness practice. Relationships between attentional control, episodic memory, and spontaneous mindfulness practice were measured.

Experiment 2 experimentally evaluated the efficacy of brief mindfulness interventions on attentional control/working memory and episodic memory by comparing participants who completed two brief 5-minute mindfulness-based breathing exercises relative to a control group who listened to an audio recording of Bob Ross painting which were similarly divided into two 5-minute sessions. Participants then completed the attentional control battery used by Hutchison (2007), which included the Stroop task, the OSPAN, and the antisaccade visual search task (Kane et al., 2001), in which participants must visually inhibit a distractor to search for a target. Additionally, participants completed the consonant–vowel/odd-even (CVOE) switch task (Minear & Shah, 2008). The CVOE task presents participants with a bivalent stimulus (e.g. B-06) in which participants must classify the letter as a consonant or vowel or the number as odd or even in which the classification instructions change across trials.

Participants completed a block of trials that contained only a single task set (CV or OE) termed the pure block, and a block of trials in which the CV and OE trials switch randomly termed the switch block. Response latencies and errors typically increase when trials switch from one task set to another compared to repeated non-switch trials in the switch block, a difference termed the local switch cost. Separately, the difference in latencies and errors between nonswitch and pure trials is termed the global switch cost (Belleville et al., 2008; Tse et al., 2010). Local switch costs are typically accounted for as a task-set reconfiguration cost as individuals adjust to changing task sets, whereas the global switch cost reflects the additional processing due to maintaining two task sets even though the task set was repeated (Rogers & Monsell, 1995; Wylie & Allport, 2000). Although switch costs have been shown to be sensitive to attention-related population differences including the presence of Alzheimer's disease pathologies (Huff et al., 2015), our focus was directed towards errors on switch trials, which are most sensitive to attention-related differences. Thus, if mindfulness practice improves attentional control, switch errors would likely be reduced. Therefore, Experiment 2 experimentally evaluated whether brief exposures to mindfulness practice could produce immediate benefits to attention and memory processes.

Experiment 1: relationships between mindfulness practice and cognition

Participants were instructed to complete two questionnaires measuring trait mindfulness and mindfulness practice frequency followed by assessments of attentional control/working memory (via Stroop and OSPAN) and episodic memory (via dual-list recall). Given that the previous literature indicates potential relationships between mindfulness, attentional control, and episodic memory, a positive relationship was expected between attentional control/working memory, and performance on the dual-list recall task. This prediction was based on Wahlheim et al. (2019) who found a positive relationship between memory accuracy and working memory based on a reduction in interference for high working memory individuals. Additionally, it was expected that individuals who practice mindfulness regularly and with higher quality (i.e. deeper mindfulness practice, longer mindfulness practice, etc., as indicated on the mindfulness questionnaires) would show improved performance on attention and episodic memory tasks.

Method

Participants

One-hundred-fifty participants were recruited for the study which consisted of 100 undergraduate students from The University of Southern Mississippi and 50 individuals recruited from Prolific ($n = 50$; Palan & Schitter, 2018). Prolific participants were required to have a minimum high school education to approximate the education level of the undergraduate participants. Student participants were recruited both online ($n = 43$) or in-person ($n = 57$) and were compensated with course credit[1]. Prolific participants completed the study online and were compensated with $6.00 to complete the study. Due to a technical error, data was unavailable for one student participant in two tasks (the Stroop and dual-list task) and thus this participant was only included in analyses in which the tasks were available. The sample size chosen for Experiment 1 was based on a sensitivity analysis conducted using G*Power (Faul et al., 2007) which indicated that a sample size of 150 would have adequate power (.80) to detect small relationships of $r = .22$ and greater (two-tailed), and a recent review by Tang and Braver (2020) examining individual differences in mindfulness in which our sample size met or exceeded the 11 studies that were reviewed.

Materials

Mindfulness questionnaires

Self-report questionnaires on mindfulness practice were used to gauge the likelihood of engaging in a mindful state in daily life and the frequency and duration of mindfulness practice. Specifically, participants completed the MAAS (Brown & Ryan, 2003), a 15-item Likert-type assessment that measures levels of trait mindfulness by asking participants questions regarding how they respond to stimuli or experiences in their daily life (e.g. "I do jobs or tasks automatically, without being aware of what I'm doing".). Responses are made using a 1–6 Likert scale. Participants further completed the FFMQ-15 (Baer et al., 2008), a short-form version of the FFMQ-39 designed to assess five distinct facets of

[1]Testing location (online vs. in-person) occurred due to the COVID-19 pandemic. Location was tested as a covariate in all results reported and was not found to be a reliable covariate. All analyses collapse across testing location.

dispositional mindfulness as follows: Observing (ability to pay attention to one's feelings and surroundings), describing (ability to communicate thoughts and/or feelings), acting with awareness (degree one's aware of sensations and stimuli within oneself and environment), non-judging (acceptance of thoughts and cognitions as they are – neutrality), and non-reactivity (ability to inhibit thoughts, emotional expressions, and physical actions). Responses are made using a 1–5 Likert scale. Finally, a separate assessment had participants estimate the frequency in which they practice mindfulness-based mediation as well as the duration of practice in hours per week. The frequency assessment was as follows: "In the box below, please estimate the amount of time you engage in mindfulness practice per week. For example, if you practice for only 30 minutes a week Type .5, or if you practice for an hour a week Type 1. If you do not practice mindfulness regularly, please Type 0 in the box below".

OSPAN task

The OSPAN task from Foster et al. (2015) was used. In this task, participants viewed and were instructed to read aloud mathematical strings (e.g. $(5 \times 4) - 6 = ?$) and compute answers silently to themselves. Once a solution was computed, participants then clicked the mouse which directed them to another screen with a solution (e.g. 13) with instructions to select "yes" if the solution was correct, and "no" if the solution was incorrect. Once a response to a solution was made, a single letter was displayed for 1000 ms (e.g. K) followed by another mathematical string. This procedure was repeated for 2–7 mathematical strings/letters (i.e. spans) and followed by a serial recall test in which letters were recalled in the order in which they appeared by clicking on letter-labelled boxes on the screen. This procedure was repeated for two blocks containing 7 trials, with each span length tested once per block. Span lengths were presented randomly for each participant. Participants were instructed to place equal emphasis in mathematics/memorisation portions of the task and required to maintain an 85% accuracy on the math portion. Accuracy feedback on math problems was provided at the end of each trial.

Stroop color-naming task

Stroop stimuli were taken from Spieler et al. (1996) and included four colour words (green, red, blue, and yellow) and four neutral words (bad, deep, legal, and poor) that were presented in one of the four colours. Participants were asked to identify the colour that each word was presented in. Responses were made via key press in which four keys corresponded to each of the colours which are spaced evenly across the keyboard ("z", "v", "m", and "/"). Response latencies were assessed when the key was depressed (vs. released) and accuracy was computed based on the proportion of trials with a correct colour classification. A total of 130 trials were presented which included 10 practice trials and 120 experimental trials. Practice trials consisted of 3 incongruent trials (word/colour mismatch), 4 congruent colours (word/colour match), and 3 neutral trials (words unrelated to colour). Experimental trials consisted of 48 neutral trials (each neutral trial displayed 12 times in each colour), 36 congruent trials (each colour word presented 9 times in each colour), and 36 incongruent trials (each colour word presented 12 times in the other incongruent colour). Practice and experimental trials were presented in a once randomised order that was fixed across participants. Additionally, to minimise participant fatigue, experimental trials were parsed into 30 blocks of 40 trials and spaced by a self-paced rest break.

Dual-List recall task

The dual-list recall task was based on Wahlheim and Huff (2015). In this task, participants studied 2 lists taken from the same semantic category with each list containing 8 words. Each word was displayed for 2 s. Participants were asked to remember each word for a later recall memory test. A screen labelled "List 1" preceded the first list and a screen labelled "List 2" immediately followed List 1 and preceded the second list. Both screens were presented for a 2 s duration. Following the presentation of the second list, participants were immediately presented with instructions to recall words from either List 1 (to assess retroactive interference) or List 2 (to assess proactive interference). Participants were given 1 minute to recall as many words from the queried list as possible in any order. After completing the recall task, participants were instructed to repeat this procedure for an additional 7 sets of lists (8 total) in which 4 sets tested List 1, and 4 sets tested List 2. Lists were taken from the Battig and Montague (1969) categorical word norms and consisted of items from the four-footed animals, furniture, utensils, profession, sports, building, fruits, and birds, categories.

Procedure

The study was administered online and in-person using both Collector (Garcia et al., 2015) to collect responses to the mindfulness questionnaires and demographics, and E-Prime GO (Psychology Software Tools, 2020) to collect response latencies and accuracy for the attentional control and episodic memory tasks. Following informed consent, participants completed a brief demographics questionnaire (gender, age, years of education, and ethnicity) and the mindfulness measures (MAAS, FFMQ-15, and estimated frequency of mindfulness practice). Then participants completed the OSPAN task, Stroop task, and the dual-list recall task. The order was the same across participants, and participants clicked a link in the Collector programme which redirected them to E-Prime GO to begin each task. For the OSPAN task, participants were provided with task instructions, a brief training on how to complete the task, followed by the experimental trials. Following the OSPAN task, participants completed the Stroop task, which included a brief description of the task with instructions to classify the colour for each of the words as quickly as possible without compromising accuracy by pressing one of 4 colour-mapped keys. Participants then completed the dual-list task in which participants were instructed in advance that they would study two lists but would randomly be tested on one only after both lists were presented. Following completion of the cognitive tasks, participants were provided with a debriefing screen consisting of study information as well as the purpose of the study and then received compensation for their participation. The study lasted approximately 35–45 minutes.

Results

In addition to standard null-hypothesis significance testing, we supplement analyses with Bayesian hypotheses testing using the open-source statistical programme JASP (JASP Team, 2022). The Bayes factors provided indicate the predictive capacity of the null hypothesis model (H_0) in relation to the alternative hypothesis model (H_1), and the subscript in the BF corresponds to hypothesis that the BF favours. Evidence in the alternative hypothesis (H_1) over the null (H_0) is denoted by BF_{10}, whereas evidence for H_0 over H_1 is denoted by BF_{01}. Several interpretive criteria have been suggested, but here we follow the criteria reported by van Doorn et al. (2021). For alternative hypothesis evidence, BF_{10}s greater than 10 propose strong evidence for the alternative, BF_{10}s between 3 and 10 propose moderate evidence for the alternative, and BF_{10}s between 1 and 3 propose weak evidence for the alternative. For null hypothesis evidence, BF_{01}s greater than 10 propose strong evidence for the null, BF_{01}s between 3 and 10 propose moderate evidence for the null, and BF_{01}s between 1 and 3 propose weak evidence for the null. However, the authors warn against using these criteria as "all-or-none" cutoffs for making data conclusions.

Mindfulness measures

FFMQ-15 scores were scored by averaging the total scores for the 15 questions. Questions were rated on a 5-point Likert scale (1 – never or very rarely true, 5 – very often or always true). Items 3, 4, 7, 8, 9, 13, and 14 were presented in reverse scales and were transformed before data analysis. The FFMQ-15 had a mean score of 2.95 (*Range* = 2.39–3.53) and had acceptable reliability ($\alpha = .61$). MAAS scores were scored by simply computing a mean of the 15 items, with higher scores reflecting higher levels of trait mindfulness. Questions were rated on a 6-point Likert scale (1 – almost always, 6 – almost never). The MAAS score had a mean of 3.28 (*Range* = 2.74–3.64) and had acceptable reliability ($\alpha = .81$; see Table 1 for each of the mean scores and standard deviations across questionnaires and tasks).

Attentional control tasks

OSPAN scores were computed as the total number of letters correctly recalled in serial order for each of the 2–7 span trials (i.e. partial span) across 2 blocks resulting in a possible maximum span score of 54 (*Range* = 1-50). Performance was not conditionalised based on math performance, though few of the participants scored lower than the 85% correct criterion specified in the instructions. Stroop analyses computed reaction times (RTs) and percent errors for the three trial types

Table 1. Descriptive statistics for questionnaires and tasks completed in experiments 1 and 2.

Experiment	Measure type	Measure/Task	*M*	*SD*
Experiment 1	Mindfulness	FFMQ	2.98	.48
		MAAS	3.28	.72
		Est. Frequency	.98	2.17
	AC	OSPAN	35.70	10.75
		Stroop Errors	.06	.07
	EM	Dual-List Recall	.58	.17
Experiment 2	Mindfulness	FFMQ	3.20	.54
		MAAS	3.55	.86
		Est. Frequency	.99	1.57
		Engagement	6.63	1.65
	AC	OSPAN	32.93	10.30
		Stroop Errors	.07	.12
		Antisaccade	.80	.13
		CVOE Errors	.04	.04
	EM	Dual-List Recall	.55	.12

Notes: AC refers to attentional control, EM refers to episodic memory, FFMQ refers to mean Likert scores averaged across the five facets, MAAS refers to average Likert scores, Est. frequency refers to the estimated hours individuals practice mindfulness weekly, Engagement refers to individuals perceived engagement levels to the interventions on a 1–10 Likert scale, OSPAN refers to average partial score across blocks, Stroop errors refer to incongruent errors, CVOE errors refers to switch-task error rates, and dual-list recall accuracy rates (as a proportion) and are collapsed across proactive and retroactive interference conditions.

(congruent, neutral, and incongruent). The proportion of errors on incongruent trials were the primary dependent measure, as incongruent trials are more attentionally demanding and produce the highest error rates of the three trial types.

Dual-list task

Dual-list task analysis computed correct recall rates, interference rates (retroactive and proactive), and total intrusions rates from the two intrusion types (interference or non-presented items). For the analyses, the proportion of correct recall was the primary dependent measure to remain consistent with previous analyses using this paradigm (Huff et al., 2015). No differences were found between proactive and retroactive lists (.58 vs. .57, for proactive and retroactive lists, respectively), $t < 1$, $p = .52$, $BF_{01} = 8.92$. However, a significant difference in intrusion rates were found between proactive and retroactive lists, (1.65 vs. 1.48), $t(148) = 2.14$, $p = .03$, $BF_{01} = 1.21$. Given our use interest in interference effect in general and not interference type, we collapsed across interference types in subsequent analyses.

Principal component analyses

The three mindfulness measures (FFMQ-15, MAAS, and frequency estimates) were initially submitted to a principal components analysis (PCA) to examine factor loadings across variables. A single component was identified (with an Eigenvalue greater than 1) which accounted for 49.17% of variance across measures which was attributed to dispositional mindfulness. Frequency estimates had a poor factor loading of .083. Given this poor loading, a second PCA was conducted that only included the FFMQ-15 and MAAS. Again, a single component was identified which accounted for 73.65% of variance across both measures which was again attributed to dispositional mindfulness. From this analysis, a standardised component score was derived which was used in subsequent analyses to examine attention and memory relationships with mindfulness.

A component score was similarly extracted for attentional control using a principal components analysis. Both attentional control tasks were analysed by including the mean error rate for incongruent trials in the Stroop task and the partial score from the OSPAN for each participant. A single component was extracted which accounted for 52.57% of variance across both task types which was attributed to attentional control (see Table 2 for factor loadings). Like the mindfulness questionnaires, a standardised component score was derived and used in subsequent analyses.

Table 2. Loadings of attentional tasks on the attentional control composite in experiment 2.

Task	Attentional control loading
OSPAN Score (Partial)	.703
Stroop Incongruent Errors	−.419
Antisaccade Accuracy	.704
CVOE Errors	−.549

Correlations

Bivariate correlations were computed to examine the relationships between variables (see Table 3). Only one significant relationship was found. A relationship between the attentional control composite and episodic memory ($r = .191$, $p = .019$, $BF_{10} = 1.53$). However, no significant relationships were found between the mindfulness composite and attentional control composite ($r = -.136$, $p = .098$, $BF_{01} = 2.52$) or the mindfulness composite and dual-list recall performance ($r = -.142$, $p = .083$, $BF_{01} = 2.21$), in contrast to predictions.

Bivariate correlations were computed to examine the relationship between the five dispositional aspects of mindfulness (i.e. FFMQ-15) and attentional control and episodic memory. A few significant relationships were found between dispositional aspects of mindfulness and some attention/episodic memory measures. Specifically, small negative relationships between describing and OSPAN ($r = -.170$, $p = .04$, $BF_{10} = .87$) and describing and dual-list recall ($r = -.167$, $p = .04$, $BF_{10} = .79$) were found. However, no significant relationships were found between the other mindfulness facets and measures of attention/episodic memory.

Discussion

The purpose of Experiment 1 was to evaluate potential relationships between trait mindfulness, the estimated frequency of mindfulness practice, and attentional control and episodic memory. To ensure reliable measures of mindfulness and attentional control, PCAs were used to derive component scores for mindfulness and attentional control. Following these analyses, bivariate correlations revealed that trait mindfulness measures were not related to either attentional control or episodic memory, contrary to predictions. However, there were weak negative relationships between the ability to describe one's thoughts and/or feelings (i.e. the "describing" facet in the FFMQ-15) and working memory and episodic memory. Because of the negative

Table 3. Descriptives and bivariate correlations between observed variables in experiment 1.

	OSPAN	Stroop	Dual-List	AC Comp.	FFMQ	MAAS	Frequency Est.	Mindfulness Comp.	Obs.	Desc.	Aware ness	Non-judging	Non-reactivity
OSPAN	–	.051	.369**	.725**	−.126	−.121	.035	−.144	−.029	−.170*	−.063	−.024	−.037
Stroop		–	−.092	.725**	−.014	−.077	−.058	−.053	.085	.088	−.132	−.044	−.013
Dual-List			–	.191*	−.203	−.042	.054	−.142	−.046	−.167*	.210	−.117	−.068
AC Comp.				–	−.097	−.137	.016	−.136	.039	−.057	−.134	−.047	−.034
FFMQ					–	.473**	−.029	.858**	.296**	.708**	.534**	.531**	.412**
MAAS						–	.074	.858**	.142	.431**	.215*	.176*	.226*
Frequency Est.							–	.026	−.024	−.056	.038	.036	−.078
Mindfulness Comp.								–	.255**	.664**	.437**	.412**	.255**
Obs.									–	.181*	−.303**	−.356**	.356**
Desc.										–	.137	.163*	.335**
Awareness											–	.642**	−.265**
Non-judging												–	−.291**
Non-reactivity													–
M	35.7	.06	.58	–				–	3.34	2.82	2.81	3.03	2.89
SD	10.75	.07	.17	–				–	.89	.91	.91	1.10	.94

Notes: * = $p < .05$; ** = $p < .01$. *M* and *SD* were 0.00 and 1.00 for the Attentional Control and Mindfulness composites as these scores were standardised.

relationship found between the non-judgmental facet of mindfulness and false alarms in Rosenstreich and Ruderman (2016), we had initially predicted a positive relationship between the describing facet and attention/ episodic memory; however, the relationships were not in evidence. However, a positive relationship was found between attentional control and episodic memory as assessed by dual-list recall, which replicates prior work (Wahlheim et al., 2019). Overall, these findings suggest that an individual's reported mindfulness state was not associated with attentional control and episodic memory.

Although the unreliable relationships between reported mindfulness and attentional control and mindfulness and episodic memory were inconsistent with predictions based on past findings, it is possible that these null patterns may be due to participants not achieving a mindful state while completing the cognitive tasks. As reviewed in the Introduction, mindfulness engagement has been shown to improve performance on cognitively challenging tasks (Moore & Malinowski, 2009; Mrazek et al., 2013; Quach et al., 2016), and therefore, one may need to achieve a mindful state or regularly achieve a mindful state to procure cognitive benefits. In Experiment 1, no relationship was found between self-reported frequency of mindfulness practice and attentional control ($r = -.02$, $p = .85$, $BF_{01} = 9.58$) and frequency of practice and dual-list recall ($r = .05$, $p = .51$, $BF_{01} = 7.88$), however, reported frequency of practice was quite low ($M = 0.98$ hours/week, *Range* = 0-14), which suggests that participants may not have sufficiently achieved a mindful state that may have affected task performance. This possibility is tested in Experiment 2 by implementing a brief mindfulness intervention in which individuals engaged in two bouts of mindfulness practice while completing attentional control and episodic memory tasks. If a mindful state is a requisite for cognitive benefits, training individuals on mindfulness and having them engage in mindfulness practice should improve performance relative to a control group that does not engage in mindfulness. Additionally, attentional control encompasses a broader cognitive spectrum exclusively beyond working memory and selective attention. Trait mindfulness could potentially exhibit stronger associations with other facets of attentional control that were not assessed in Experiment 1. Given the multifaceted nature of attentional control, expanding our battery of measures to encompass a more diverse set of components may yield more differing results. This broader approach would allow for a more comprehensive understanding of how trait mindfulness relates to attentional control more broadly.

Experiment 2: mindfulness intervention on attention and memory

The goal of Experiment 2 was to determine whether engagement in mindfulness via brief 5-minute mindfulness sessions would provide benefits on attention control and episodic memory relative to a control group that did not achieve a mindful state. The inclusion of two brief mindfulness sessions rather than one aimed to prevent any potential decline in mindfulness benefits during the experiment because of the considerable time consumption and cognitive challenge of completing all attentional control and memory tasks taken together. Additionally, we chose to employ a body scan meditation as our brief mindfulness intervention because it integrates elements from both FA and OM mindfulness practices. Although, some may argue that the body scan may lean towards a FA technique due to the sequential nature of directing attention to individual body parts, it still fosters present moment awareness and acceptance, facets which are characteristic of OM practices. Thus, we believed it was an appropriate technique to induce a state of mindfulness. Participants who engaged in the mindfulness practice were instructed to be present in the moment and to concentrate on their breathing and bodily sensations as they occurred throughout the session by following an audio mindfulness session directed by Jon Kabat-Zinn. Unlike Mrazek et al. (2013), who used a nutrition control task, the control task in Experiment 2 was carefully chosen to allow for restful activity that did not encourage internal reflection but rather had participants focus on an external process. Specifically, control participants were presented with an audio clip depicting Bob Ross describing painting a secluded bridge (Janson, 2016) and participants were tasked with mentally visualising the painting that was described. This control was chosen to match the participation level and audio modality of the guided mindfulness practice group.

Like Experiment 1, participants completed a battery of attentional control/working memory assessments consisting of the OSPAN and the Stroop colour-naming task. However, some additional modifications to Experiment 2 were made. All procedures were completed exclusively in-person and two additional attentional control tasks were included. As attentional control is a multifaceted cognitive process encompassing various components, we opted to broaden the array of tasks employed to assess it. This expansion aims to provide a more comprehensive perspective on how mindfulness might impact attentional control beyond its exclusive examination in working memory (OSPAN; Foster et al., 2015) and selective attention (Stroop; Spieler et al., 1996). These additional attentional control tasks consisted of the antisaccade visual inhibition task (Kane et al., 2001), and the CVOE task-switching paradigm (Huff et al., 2015). Participants also completed the same dual-list interference task as an episodic memory measure (Wahlheim & Huff, 2015). We predicted that the mindfulness intervention would improve performance in all measures of attentional control relative to the control group.

This prediction was based on Mrazek et al. (2013) who found an increase in working memory and reduced mind-wandering following a 2-week mindfulness training programme. Similarly, we anticipated that the mindfulness intervention would improve episodic memory as assessed in the dual-list recall task relative to the control intervention. Thus, we expected to find that episodic memory can be improved through a brief mindfulness intervention. This prediction is based on Lueke and Lueke (2019) who found an increases in verbal learning and memory through enhancements of the encoding process, rather than storage and/or retrieval processes after individuals listened to a 10-minute audiotape of mindfulness practice versus a control.

Method

Participants

University of Southern Mississippi undergraduates participated in Experiment 2 and were compensated with partial course credit. Participants were randomly assigned to either the mindfulness intervention group ($n = 46$) or the control group ($n = 45$). Due to a technical error, mindfulness questionnaires (FFMQ-15, MAAS, and frequency estimates) were unavailable from three participants and thus were not included in correlational analyses with the mindfulness measures. The sample size chosen for Experiment 2 was based on a sensitivity analysis conducted using G*Power (Faul et al., 2007) which indicated that a sample of 90 would yield adequate power (.80) to detect medium effect sizes of Cohen's $d = 0.53$ or greater. We chose to examine for medium effect sizes because if benefits to cognition are found, a medium-or-larger effect size would be more likely to produce practical significance than a small effect. Participants that completed Experiment 1 were ineligible to complete Experiment 2 to avoid any confounds such as practice effects emerging due to previous task exposure.

Materials

Participants similarly completed an attentional control battery. This battery consisted of the OSPAN (Foster et al., 2015) and Stroop tasks (Spieler et al., 1996) from

Experiment 1, and computerised versions of the antisaccade task (Kane et al., 2001; Hutchison, 2007) and CVOE switch task (Huff et al., 2015). These measures were conducted using a computer running E-Prime software. The dual-list recall task (Huff et al., 2015) used in Experiment 1 was again used in Experiment 2. All demographics and mindfulness measures remained the same.

Antisaccade task

The antisaccade task was based on a version used by Kane et al. (2001) and Hutchison (2007). Participants were instructed with looking at a fixation point on the centre of the computer screen where they were informed that a large asterisk would be presented on the far left or far right side of the screen randomly and at the same horizontal level as the fixation point. Participants were instructed that once the asterisk was detected in their peripheral vision, to quickly look away from the asterisk to the opposite side of the screen to detect a capital "O" or "Q" target letter that was presented. Participants were informed that the target would be presented briefly and covered up by a mask (##) and that their task was to report the correctly presented target letter by pressing the "O/Q" labelled keys on the keyboard, guessing if necessary. Trials were given with the presentation of a fixation point (+) which was centred on the screen for either 1000 or 2000ms prior to the presentation of the asterisk. This timing difference varied randomly and was implemented to make the asterisk presentation unpredictable. After the 1000 or 2000ms delay, a large asterisk presented in 20 pt. font appeared on the left or the right side of the screen for 300 ms. The target immediately followed the asterisk and was displayed for 100 ms followed by the mask which remained on the screen for 5000 ms or until the participant entered in their "O" or "Q" response. If no response was entered during this time, participants were presented with a feedback screen that stated "No Response Detected" to encourage correct responding on future trials. Participants were given a total of 64 trials which included 16 practice trials and 48 experimental trials. The experimental trials were divided into 3 blocks of 16 trials with a self-paced rest break presented between each block. Fixation durations and target letters were equally distributed across practice and experimental trials.

CVOE task

The CVOE task was taken from Huff et al. (2015). In this task, participants were exposed to a bivalent letter/number stimulus pair (e.g. O 27) on each trial. Two instructions sets were given, either to classify the letter of the stimulus as a consonant or vowel (C/V) or classify the number of the stimulus as odd or even (O/E). The letters used in the bivalent stimuli consisted of 5 vowels and 5 consonants (e.g. A, D, E, H, I, J, O, P, S, U). Whereas the numbers were randomly shuffled between 1-99, distributed evenly between odd and even numbers. Either the words "consonant/vowel" or "odd/even" were presented at the top left and right corners of the computer screen, which instructed participants to response to either the letter or the number dimension of the stimulus. Participants were instructed to press the "q" key on the keyboard when responding either consonant or odd, and the "p" key when responding either vowel or even. Each block consisted of correct responses that were distributed equally between the two keys. 24-point Courier New font was used for the bivalent stimuli. Trials were presented without an intertrial delay. Stimuli pairs were allowed to repeat throughout a block, but they could not repeat consecutively.

Participants were initially exposed to 10 practice trials with feedback and then completed 3 blocks. The order of the blocks was always 2 pure blocks and then 1 switch block. A participant was instructed to focus on classifying a single stimuli type (letter or number) throughout a block (pure block). Alternatively, participants may have been instructed to shift focus and classification from letter to number or number to letter, in the same block (switch block). The first pure block always consisted of C/V trials, followed by a block of O/E trials, and each consisted of 48 trials. Whereas the switch block contained 60 trials with a cue in every trial given above the stimuli pair indicating whether a number or letter was to be classified. Trials were presented in an alternating-runs sequence in which cues for one trial were presented successively and then switched to the other trial type that was run successively (e.g. CV, CV, OE, OE, CV, CV, OE, OE …). This occurred continuously until completion of the block. Participants were asked to respond to each trial quickly, but without compromising accuracy.

Procedure

Experiment 2 was administered using E-Prime 3 software (Psychology Software Tools, 2016). All testing was conducted in-lab with an experimenter present. Participants were tested individually. Following informed consent, participants completed the same mindfulness measures from Experiment 1 (MAAS, FFMQ-15, and mindfulness frequency estimation), which were followed by the mindfulness/control intervention and attentional control and episodic memory tasks. Participants completed the same order of the following tasks: Intervention 1, OSPAN, Stroop, dual-list recall, intervention 2, antisaccade, and CVOE. A diagram depicting the tasks and their ordering is presented in Figure 1. During intervention 1, participants completed either the mindfulness-mediation practice or the control task depending upon their randomly assigned group. This intervention was completed in 5 minutes.

Intervention 2 was completed at approximately the midpoint of the experiment and was designed as a "booster" session for either the mindfulness intervention or the control task. Intervention 2 was nearly identical to intervention 1. The mindfulness intervention was an audio excerpt of a guided body-scan mindfulness practice led by Jon Kabat-Zinn, which closely followed mindfulness practice in MBSR programmes (Sounds True, 2019). Prerecorded guided mindfulness practices were chosen to ensure the same quality of each mindfulness intervention session and eliminated confounds that may appear in experimenter led interventions. The 10-minute audio excerpt was taken from an audiobook filled with a variety of guided mindfulness practice (Kabat-Zinn, 2002). The control intervention consisted of an audio clip of Bob Ross painting a secluded bridge with descriptions about the process (Janson, 2016). Participants were instructed to visualise the act of painting the bridge during the presentation. The control task was designed to provide a non-active task (like mindfulness), but without the promotion of self-reflection and present focus that is characteristic of mindfulness practice. Following each intervention, participants were asked to rate how engaged they were during the intervention and told that regardless of their answer given their compensation received would not be affected. Following completion of the tasks, participants were provided with a debriefing screen consisting of study information as well as the purpose of the study and then received compensation for their participation.

Results

Mindfulness measures

Both FFMQ-15 and MAAS scores were computed as in Experiment 1. The overall FFMQ-15 mean was 3.20 (*Range* = 2.87–3.64) and the MAAS mean was 3.55 (*Range* = 2.90-4.28); both had acceptable reliabilities (α = .74 and α = .87 for the FFMQ-15 and MAAS, respectively). Table 1 displays mean scores for each of the measures and tasks in Experiment 2.

Attentional control and dual-List tasks

The OSPAN, Stroop, and dual-list tasks were analysed as in Experiment 1. Although, analyses of the dual-list tasks indicated differences in recall accuracy between proactive and retroactive lists (.57 vs. .53, for proactive and retroactive lists, respectively), $t(90) = 2.68$, $p = .01$, $BF_{10} = 3.27$. However, no differences in intrusion rates were found between proactive and retroactive lists (1.33 vs. 1.22), $t(90) = 1.51$, $p = .13$, $BF_{01} = 2.88$. Like Experiment 1, we collapsed across interference types for subsequent analyses. For the antisaccade task, the primary measure was accuracy which was computed by taking the total number of correct target classifications, divided by the total number of non-practice trials (48). Accuracy ranged from 38-98% across participants and chance performance was 50%. For the CVOE, the primary measure was the proportion of errors on switch trials in the switch block which were the most demanding due to participants switching tasks sets (i.e. task-set reconfiguration; Rogers & Monsell, 1995). CVOE analyses were consistent with the Stroop task in that only the error rates for the most challenging trials were used in the analyses.

Principal components analysis

As in Experiment 1, the three mindfulness measures (FFMQ-15, MAAS, and frequency estimates) were submitted to a PCA to examine factor loadings across variables. A single component was again identified which accounted for 53.89% of variance across measures, but frequency again had a poor factor loading of −.072. A second PCA was conducted that only included the FFMQ-15 and MAAS. A single component was identified

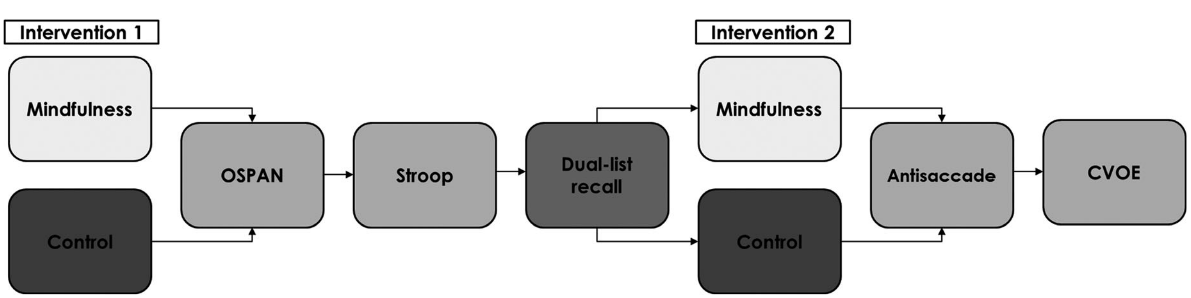

Figure 1. Procedural phases for Experiment 2.

Table 4. Summary Statistics for Attentional Control and Episodic Memory Tasks/Composites as a Function of Intervention Group in Experiment 2.

Intervention Type	Measure/Task	*M*	*SD*
Mindfulness	AC Comp	.08	.98
	OSPAN	33.30	10.60
	Stroop Errors	.05	.08
	Antisaccade	.80	.12
	CVOE Errors	.04	.05
	Dual-List Recall	.55	.13
Control	AC Comp	−.08	1.02
	OSPAN	32.56	10.10
	Stroop Errors	.08	.14
	Antisaccade	.80	.14
	CVOE Errors	.05	.04
	Dual-List Recall	.55	.09

Notes: AC comp refers to attentional control composite *z*-score, OSPAN refers to average partial score across blocks, Stroop errors refer to incongruent errors, CVOE errors refer to switch-task error rates, antisaccade refers to accuracy proportion, and dual-list recall rates reflect accuracy rates (as a proportion) and are collapsed across proactive and retroactive interference conditions.

which accounted for 80.72% of variance across both measures which was attributed to daily states of mindfulness. From this analysis, a standardised component score was derived which was used in subsequent analyses to examine attention and memory relationships with mindfulness.

As in Experiment 1, a component score was similarly extracted for attentional control using a PCA. A single component was extracted which accounted for 36.70% of variance across task types which was attributed to attentional control. Both the OSPAN and Antisaccade tasks loaded positively with higher scores indicating greater levels of AC (i.e. greater span scores and greater accuracy). Whereas Stroop incongruent trial errors and CVOE switch trial errors loaded negatively as greater error rates were indicative of lower attentional control. Like the mindfulness questionnaires, a standardised component score was derived and used in subsequent analyses (see Table 2 for factor loadings).

Mindfulness vs. control group comparisons on attention and memory

Mean composite scores for individual attentional control tasks and dual-list task performance for the mindfulness group and control group are presented in Table 4. Regarding attentional control composite scores, there were no differences in the mindfulness group relative to the control group (.08 vs −.08), $t < 1$, $p = .43$, $BF_{01} = 3.44$. Similar patterns were found when comparing between individual tasks of attentional control: No differences between the mindfulness and control groups were found on the OSPAN task (33.30 vs. 32.56), $t < 1$, $p = .73$, $BF_{01} = 4.31$, on Stroop incongruent error rates (.05 vs .08), $t(89) = 1.26$, $p = .21$, $BF_{01} = 2.27$. No difference was found in the mindfulness group relative to the control group in CVOE performance (.05 vs .04), $t < 1$, $p = .50$, $BF_{01} = 3.73$, indicating moderate evidence in favour of an absence of effect of brief mindfulness on task switching in the CVOE task. No difference was found in the mindfulness group relative to the control group in antisaccade performance (.08 vs .08), $t < 1$, $p = .96$, $BF_{01} = 4.55$. Similarly, there was no difference between the mindfulness group relative to the control on dual-list recall accuracy (.55 vs .55), $t < 1$, $p = .99$, $BF_{01} = 4.55$. Taken together, brief mindfulness interventions produced no attentional control or episodic memory benefits relative to the control interventions.

Correlations

Although not a primary goal of Experiment 2, bivariate correlations were again computed between the attentional control and episodic memory tasks, and the mindfulness scales (Table 5). Consistent with Experiment 1 a relationship between the attentional control composite and episodic memory was found ($r = .519$, $p < .001$, $BF_{10} = 115{,}881$); however, no significant relationships were found between the mindfulness composite and attentional control composite ($r = .133$, $p = .21$, $BF_{01} = 3.51$) or the mindfulness composite and performance on the dual-list recall task ($r = .054$, $p = .61$, $BF_{01} = 6.74$).

Like Experiment 1, bivariate correlations were computed to examine the relationship between the five dispositional aspects of mindfulness (i.e. FFMQ-15) and attentional control and episodic memory. A few significant relationships were found between dispositional aspects of mindfulness and attentional control. Specifically, a positive relationship between describing and OSPAN performance ($r = .221$, $p = .04$, $BF_{10} = 1.06$) was found but was in the opposite direction as in Experiment 1. Additionally, a positive relationship was found between awareness and OSPAN performance ($r = .293$, $p < .01$, $BF_{10} = 5.58$), which was not found in Experiment 1. To note, the inverse relationship between describing and dual-list recall performance did not replicate from Experiment 1. No significant relationships were found between the other facets and measures of attention (*ps* > .05). Additionally, a significant positive relationship was found between observing and dual-list recall ($r = .273$, $p = .01$, $BF_{10} = 3.33$) which was not found in Experiment 1. To note, these correlations were conducted for individuals after completing interventions which may have affected the results.

Table 5. Descriptives and Bivariate Correlations Between Observed Variables in Experiment 2.

	OSPAN	Stroop	Anti saccade	CVOE	Dual-List	AC Comp.	FFMQ	MAAS	Frequency Est.	Mindfulness Comp.	Obs.	Desc.	Aware ness	Non-judging	Non-reactivity
OSPAN	–	−.111	.281**	−.152	.403	.703**	.251*	.27*	−.185	.288**	.002	.221*	.293**	.123	.103
Stroop		–	−.101	.085	−.203	−.419**	−.074	−.004	−.001	−.043	−.029	−.112	.077	.022	−.166
Antisaccade			–	−.161	.326**	.704**	.023	−.094	−.175	−.037	.090	−.063	−.040	.046	.055
CVOE				–	−.298**	−.549**	−.038	.036	−.065	−.001	−.080	−.081	−.001	.032	.019
Dual-List					–	.519**	.137	−.040	−.007	.054	.273*	.081	−.007	−.049	.132
AC Comp.						–	.171	.077	−.147	.133	.082	.144	.103	.063	.117
FFMQ							–	.615**	−.011	.899**	.455**	.726**	.572**	.568**	.615**
MAAS								–	−.039	.899**	−.057	.493**	.687**	.490**	.177
Frequency Est.									–	−.028	.087	−.055	−.051	.037	−.012
Mindfulness Comp.										–	.221*	.678**	.700**	.589**	.441**
Obs.											–	.244*	−.126	−.102	.400**
Desc.												–	.283**	.236*	.334**
Awareness													–	.451**	.101
Non-judging														–	.006
Non-reactivity															–
M	32.93	.07	.80	.04	.55	–				–	3.24	3.14	3.06	3.48	3.1
SD	10.3	.12	.13	.04	.12	–				–	.82	.98	.81	1.01	.93

Notes: * = $p < .05$; ** = $p < .01$. *M* and *SD* were 0.00 and 1.00 for the Attentional Control (AC) and Mindfulness composites as these scores were standardised. The AC composite consists of the OSPAN, Stroop, Antisaccade, and CVOE tasks. The mindfulness composite consists of five facets from the FFMQ: Observing, Describing, Awareness, Non-judging, and Non-reactivity.

Additionally, correlations were conducted measuring participant's perceived engagement to the mindfulness or control intervention and performance on attention/episodic measures, and there were no significant relationships found (all *p*s > .30, BF_{01}s > 3.00), including the relationship between perceived engagement and the attentional control composite ($r = .01$ $p = .89$, $BF_{01} = 7.57$). Thus, this suggests that an individual's subjective report of engagement was not related to performance on attention/episodic memory measures.

Discussion

Experiment 2 examined whether two brief 5-minute mindfulness practice sessions would produce benefits to attentional control and/or episodic memory relative to a restful control task but did not involve mindful processes. Between-group comparisons revealed that individuals who completed mindfulness practice before attention and episodic memory tasks did not show performance improvements. Similar null results were found regardless of participants reported engagement in mindfulness, suggesting effort given towards achieving a mindful state may not have been a contributing factor. Although the between-group comparisons are inconsistent with our initial hypotheses, Experiment 2's findings align with the patterns in Experiment 1 and Lueke and Lueke (2019), who similarly reported no differences in attentional control in selective attention and task-switching following brief mindfulness practice.

Bivariate correlations between the attention/memory measures and the mindfulness questionnaires were again conducted, and similar null relationships were found between trait mindfulness and attentional control/episodic memory, providing additional evidence that trait mindfulness, as assessed by the MAAS and FFMQ-15, is not related to attentional control and episodic memory, as in Experiment 1. Additionally, another positive relationship was found between attentional control and episodic memory, consistent with prior work showing a positive relationship between attentional control processes and episodic memory (Wahlheim et al., 2019).

Although attention composite scores were not correlated with mindfulness measures, some task-specific relationships emerged. A positive relationship was found between the facet of describing and OSPAN performance; however, the relationship was reversed in Experiment 1. Similarly, a positive relationship was found between the facet of awareness and OSPAN performance, but the relationship was not significant in Experiment 1. Thus, Experiment 2 further suggests that trait mindfulness and the frequency of mindfulness practice are not associated with attentional control and episodic memory. Overall, Experiment 2's findings suggest that attempting to induce a mindful state via brief mindfulness practice does not benefit attention or episodic memory performance relative to a non-mindful control.

General discussion

The primary goal of our study was to evaluate the effects of trait mindfulness and brief mindfulness practice on cognitive processes, specifically attentional control, and episodic memory. In Experiment 1, we examined the relationship between trait mindfulness and the estimated frequency of mindfulness practice on attentional control and episodic memory functions. Trait mindfulness was found to have no relationship with either attentional control or episodic memory when based on self-reported mindfulness practice. Additionally, the dispositional aspects of mindfulness (i.e. sub-facets of the FFMQ-15) were generally unrelated to either attentional control or episodic memory, except for the relationship with the facet of describing. Specifically, describing was negatively related to attentional control via the OSPAN task and episodic memory recall in the dual-list task.

To evaluate the effects of a mindfulness intervention, Experiment 2 compared whether completing two 5-minute mindfulness-based breathing exercises would benefit attentional control and episodic memory relative to a control task of two 5-minute clips describing Bob Ross painting a picture. The decision to incorporate two brief mindfulness sessions was a strategic measure to mitigate any potential decline in the benefits of mindfulness practice over the course of the experiment. Given the demanding nature and time taken to complete the attentional control tasks, there was a concern that benefits derived from the brief mindfulness practice might be short-lived. As far as existing empirical evidence goes, there is a notable gap concerning the comparative efficacy of different implementations of brief mindfulness practice, rather through a single brief session or multiple brief sessions, or whether a booster session could effectively counteract any potential decay of mindfulness benefits over time. Thus, the inclusion of the booster session was intended to address this concern and ensure a more comprehensive evaluation of the lasting impact of mindfulness on attentional control. We expected that those who engaged in the brief mindfulness practices would show facilitation on tasks of attentional control, working memory, and episodic memory. Results however, indicated that individuals who briefly practiced mindfulness did not show benefits relative to a control task. Although not a primary goal of Experiment 2, bivariate correlations were examined between the attentional control and episodic memory tasks, and the mindfulness scales, as in Experiment 1. Again, trait mindfulness was found to have no relationship with either attentional control or episodic memory.

When comparing the two experiments, the relationships between the sub-facets of mindfulness and performance on attention and memory tasks were weak and contradictory. A negative relationship emerged between describing and attentional control (i.e. OSPAN) in Experiment 1, yet this relationship was positive in Experiment 2. Other inconsistencies were found. A relationship between describing and episodic memory was only found in Experiment 1 and relationships between awareness and observing and episodic memory were only reliable in Experiment 2. Thus, the patterns found cannot be used to make any strong conclusions about the relationships between the dispositional aspects of mindfulness and attention control or episodic memory, as the relationships were too unstable to interpret.

Contrary to our initial predictions, yet suggested through previous findings, trait mindfulness had no relationship to attentional control or episodic memory when these cognitive processes were measured using a comprehensive battery of assessments in two experiments. Additionally, no cognitive performances changes were found when an attempt to induce a mindful state was performed. Thus, our study provides no evidence that engaging in brief mindfulness practice, even with two separate 5 minute sessions, was sufficient to improve cognitive performance relative to a control task.

An important limitation of the study lies in the potential discrepancy between the intended induction of mindfulness and its actual attainment. Despite the aim of the brief mindfulness practice to foster mindfulness, it remains unclear whether participants truly reached a mindful state. Although we assessed trait mindfulness, the absence of measures for state mindfulness following the intervention leaves ambiguity regarding the efficacy of the interventions in inducing mindfulness. Our closest measure to state mindfulness would be perceived engagement to the mindfulness practice, wherein participants self-reported their level of engagement with the breathing exercises. Upon analysing engagement as a moderating variable, no disparities in performance emerged. Overall, the absence of significant findings could stem from various factors, such as the duration or frequency of mindfulness sessions. Notably, our study diverges from comparative studies like Moore and Malinowski (2009) in lacking a group of experienced mindfulness practitioners, who typically exhibit swifter and more efficient attainment of mindfulness states compared to non-practitioners. It is possible that individuals with prior mindfulness experience may derive greater benefits, highlighting a potential avenue for further investigation.

Although our results are inconsistent with previous literature that reported episodic memory benefits following brief mindfulness interventions (Rosenstreich, 2016), we note that that one possibility for these divergent patterns might be due to differences in test types. Specifically, previous memory improvements following brief mindfulness interventions were found using recognition testing rather than tests of free recall. Recognition tests are more reliant upon familiarity-based processes than free recall which are more demanding of recollection processes (Yonelinas, 2002). Indeed, the dual-list recall task requires that participants not only correctly retrieve the studied items, but they must recollect the correct list context which is challenging given both lists were taken from the same semantic category. While the dual-list task produced high rates of interference, which highlights the recollective processes needed to correctly recall target words, we note that the literature does not consistently report mindfulness benefits on other episodic memory tasks that might be recollection-heavy (Rosenstreich & Ruderman, 2017). Thus, it is possible that engagement in mindfulness practice might enhance familiarity-based processes, but these benefits do not extend to recollective processes which were heavily taxed in the dual-list paradigm.

Naturally, one reason for why mindfulness practice was ineffective at influencing attention and memory in our experiments may be due to the length of the intervention. Indeed, in some studies when mindfulness benefits have been reported from participants who engaged in mindfulness practice, the practice was generally repetitive and consistent over multiple weeks (10–20 minutes per session, 4 times per week over 2 weeks; Mrazek et al., 2013, and longer). In our study, our research question was whether brief engagement in mindfulness regardless of an individual's prior mindfulness experience could improve cognitive functions. This is an important question because if mindfulness could improve cognition even following short practice, it would be relatively easy for individuals to implement and could potentially be effective on a variety of tasks. Our results indicate that short bouts of mindfulness do not appear to be effective and are consistent with Lueke and Lueke's (2019) findings, who reported no attention benefits following a brief mindfulness exposure on tasks of selective attention and task-switching. Of course, our study examined attentional control using a comprehensive battery of tasks in addition to episodic memory, yet we similarly found no evidence that a brief intervention can facilitate these cognitive functions relative to a control group. Collectively then, it seems likely that mindfulness practice can facilitate attention and memory processes, but these cognitive benefits appear to be relatively small (Sumantry & Stewart, 2021) and occur on limited tasks (e.g. Stroop task and d2-concentration and endurance test; Moore & Malinowski, 2009, OSPAN task; Jha et al., 2010 and Mrazek et al., 2013, and auto-OSPAN task; Quach et al., 2016) following long-term mindfulness practice. In contrast, the benefits to cognition following brief mindfulness are less clear. Some studies have found cognitive benefits following brief mindfulness practice (Tang et al., 2007; Schofield et al., 2015; Taraban et al., 2017) with these brief mindfulness inductions ranging from as short as 3 mins (Calvillo et al., 2018) to as long as 30 mins (Gorman & Green, 2016) per session. However, other studies show no significant improvements to cognitive processes following brief mindfulness practice (Lai et al., 2015; Johnson et al., 2015; Lueke & Lueke's, 2019), consistent with the results of Experiment 2 in the current study. Overall, as discussed previously in the Introduction of Gill et al.'s (2020) meta-analysis, many studies incorporating brief mindfulness practices are plagued with poor methodological quality that obscure the interpretation of the collective findings.

An additional possibility for why mindfulness may have been ineffective in facilitating cognition may have been due to the demanding nature of our comprehensive battery of attention and memory tasks. Mindfulness may only provide slight benefits for attention and memory which may be expended when the task is too difficult or decays after several tasks. Our data can partially test this possibility. For tasks that were completed immediately after the mindfulness sessions (OSPAN after Session 1 and antisaccade after Session 2), neither of these individual tasks yielded a performance benefit in the mindfulness group, suggesting that any mindfulness improvement likely did not decay over time. We cannot however test whether mindfulness benefits only emerge for less demanding tasks as task difficulty was neither assessed nor manipulated. From an external validity standpoint however, we argue that any immediate cognitive benefits from brief mindfulness would be of little practical value if they do not emerge for challenging tasks. Indeed, any cognitive enhancement would likely be unnecessary for simple tasks and therefore evaluating mindfulness effects on tasks that "test the limits" is critical to establishing the efficacy of a mindfulness intervention. Although this study didn't assess mindfulness benefits on less demanding tasks, it's worth noting that if mindfulness practice shows benefits in simpler tasks, these benefits might gradually extend to more challenging tasks over time through repeated practice. In essence, while this study didn't directly explore the link between mindfulness and task difficulty, future research should consider this factor to understand how mindfulness interventions impact cognitive performance across various task complexities.

Finally, another possibility for null mindfulness benefits in our study may be attributed to the specific choice of the control comparison task. We deliberately opted for a control task designed to emulate certain aspects of guided mindfulness practice (i.e. induced relaxation, audio modality, performing an active process, etc.) while intentionally excluding elements associated with mindfulness, such as inward reflection and non-judgmental acceptance of thoughts and feelings. Our rationale for selecting this control task was to create a scenario that promoted relaxation-based processes, distinct from the unique characteristics of mindfulness practice, to determine whether any observed outcomes could be directly attributed to processes exclusively associated with mindfulness practice. While there may exist debates regarding what constitutes an appropriate control task in mindfulness studies, we posit that the relative comparison used is a crucial factor in determining the presence or absence of mindfulness benefits. In Experiment 2, we implemented a control task featuring exposure to audio recordings of Bob Ross, the esteemed painter, instructing participants to actively visualise him as he painted a serene natural environment. Ross's methodical painting instructions delivered in a soothing voice, along with his positive affirmations and encouragement (e.g. "we don't make mistakes just happy little accidents"), aimed to create a similar state of relaxation as guided mindfulness practice. Overall, the experience provided a relaxing atmosphere to the listeners throughout the task. This may suggest that inner reflection processes characteristic of mindfulness may not be the causal mechanism behind cognitive improvements and could instead reflect relaxation-based processes inherent to mindfulness engagement. We note that several other intervention studies did not use a relaxation-based control tasks (e.g. a nutritional education control, Mrazek et al., 2013; providing a description of an English countryside, Lueke & Lueke, 2019). Thus, it is possible that some of the discrepancies may be chalked up to differences in the control group used, and these comparisons are likely crucial for determining the effectiveness or ineffectiveness of a mindfulness intervention regardless of the length of practice.

Despite the null mindfulness effects found on cognition, a strength of our study is that we included a range of attentional control measures that focus on cognitive processes such as working memory (OSPAN; Foster et al., 2015), inhibition (antisaccade; Kane et al., 2001; Hutchison, 2007, and Stroop; Spieler et al., 1996) and task-switching (CVOE; Minear & Shah, 2008). The use of such a battery allowed us to examine multiple effects of mindfulness on attention more generally and examine task-specific effects. Additionally, our use of the dual-list paradigm (Wahlheim & Huff, 2015) provided an assessment of memory processes under challenging retrieval conditions. We specifically chose a range of task types given many different types of cognitive processes are used in as part of daily functioning such as maintaining information for active use, inhibiting irrelevant information, and correctly retrieving contextual information when presented with interference. If mindfulness benefits cognition, it would be most impactful under cognitively demanding conditions which require additional cognitive resources to complete effectively.

Finally, although mindfulness effects on cognitive processes did not emerge, it is important to emphasise that our findings do not contradict the benefits that have been reported in areas such as reductions in stress, anxiety, depression, and other mental health challenges. While the magnitude of some of these mental health benefits might be in question (see Schumer et al., 2018 for a meta-analysis and review), a general pattern still emerges in which mindfulness practice is largely beneficial. Because our analyses consistently revealed that engaging in mindfulness practice did not produce a cost to attention and memory, we provide no recommendation against the use of mindfulness practice.

Conclusion

In two experiments we found no evidence that engaging in brief mindfulness practice was related to improvements in attentional control and episodic memory both when correlating self-reported mindfulness practice with attention and memory performance (Experiment 1), and when following brief mindfulness interventions relative to a control group (Experiment 2). Our experiments also did not find that brief mindfulness practice results in an attention or memory cost, indicating that mindfulness appears to have no effect on cognitive processes. Although the short mindfulness practices used in Experiment 2 would have been an economical approach to improve attention and memory, the data do not support this pattern. However, our study provided valuable insight into possible limitations of only using brief mindfulness interventions in their relation to cognitive processes that have been reported in a few studies in the literature. Future experiments are needed to determine whether long-term mindfulness practice may benefit cognitive processes and whether these benefits are task-specific or affect more general cognitive processes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethical approval

This study followed the principles of the Declaration of Helsinki and was approved by the IRB of the University of Southern Mississippi (Protocol Number: **IRB-20-380**). Participants of the study were provided informed consent at the beginning of each experiment, were informed that participation was voluntary, and informed all answers provided would be stored anonymously.

Data availability statement

Subject level means across experiments can be accessed on Open Science Framework (https://osf.io/9nft2/?view_only=7ac659756ae4495e981963c6bcefe2a9). Additional data collected for this study are available from the corresponding author (Jacob.Namias@usm.edu) upon request.

Author contributions

This study was completed to satisfy the Master's thesis requirements for Jacob Namias. Both authors conceived the research idea. Both authors constructed the procedural framework. Jacob Namias computed the statistical findings. Mark Huff verified the analytical methods. Mark Huff supervised the findings of this work. Both authors discussed the data patterns and contributed to the final manuscript.

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