Impact of Mindfulness Training on In-the-Moment Attentional Control and Emotion
Dysregulation in Older Adults: Secondary Analysis of a Pilot, Placebo-Controlled
Randomized Controlled Trial

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Abstract

The current study performed secondary analyses of a pilot randomized controlled trial (RCT) comparing the effects of mindfulness-based attention training (MBAT) and a lifestyle education control group on attentional control and emotion dysregulation in older adults. These analyses are motivated by the lack of training effects observed for global measures of attention and the finding that MBAT yielded less frequent mind-wandering. Differential effects of training were assessed for 1) in-the-moment effects of mind-wandering on accuracy and reaction time during a sustained attention task, and 2) emotion dysregulation, measured via self-report. In addition, baseline working memory (WM) was assessed as a moderator of training effects on these outcomes. There were no significant between-group differences for in-the-moment attentional control or emotion dysregulation. However, WM significantly moderated the effects of MBAT on emotion dysregulation. These findings indicate that brief mindfulness training, when compared with an active control group, may not mitigate the local effects of mind-wandering on attention or reduce emotion dysregulation in older adults. However, in our sample, WM moderated the effects of mindfulness training on emotion dysregulation, which has implications for identifying aging cohorts that may benefit most from this type of training.

Dedication

To my parents, for their selfless and unwavering support.

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Chapter 1. Introduction

Advanced age is characterized by decline in multiple cognitive domains, including memory, processing speed, and attention. Although aspects of attentional control, including task-switching and multitasking follow this trend, evidence for age-related decline in the ability to sustain attention is mixed (for review, see Zanto & Gazzaley, 2014). Sustained attention to a particular task, such as reading or driving, may be disrupted by mind-wandering, which involves redirection of focus towards internal mentation (Smallwood & Schooler, 2006). Despite age-related deterioration in supporting cognitive processes (e.g., working memory), accumulating evidence indicates that older adults tend to mind-wander less frequently than young adults (Giambra, 1989; Jackson & Balota, 2012; Krawietz, Tamplin, & Radvansky, 2012; Maillet & Rajah, 2013; Zavagnin, Borella, & De Beni, 2014; Fountain-Zaragoza, Puccetti, Whitmoyer, & Prakash, 2018); for review, see Maillet & Schacter, 2016). The mechanisms underlying this age paradox are still contested; however, given the functional consequences of mind-wandering for daily activities such as driving (Yanko & Spalek, 2014), ambulation (Nagamatsu, Kam, Liu-Ambrose, Chan, & Handy, 2013), and emotion regulation (Killingsworth & Gilbert, 2010; Ruby, Smallwood, Engen, & Singer, 2013) sustained attention remains an important target for intervention in this group.

Originally rooted in Eastern tradition, the practice of mindfulness, translated into the contemporary sciences, involves nonjudgmental awareness of present moment experiences as they unfold. Mindfulness training includes instruction in attitudinal principles associated with this practice, and guided exercises to focus on a specific anchor (e.g., the in and out-flow of the breath), while minimizing the tendency to mind-wander. Mindfulness has been shown to alleviate depressive symptoms (Segal et al., 2010), reduce perceived levels of stress (Baer, Carmody, & Hunsinger, 2012), and improve attentional control (Alexander, Langer, Newman, Chandler, & Davies, 1989; Moynihan et al., 2013; Whitmoyer et al., under review). This type of cognitive training is well-suited to older adults, who tend to prioritize socioemotional goals (Carstensen, Fung, & Charles, 2003). A still-developing literature indicates that mindfulness training may yield significant benefits for older adults, including improved memory and emotional well-being (Lenze et al., 2014; Splevins, Smith, & Simpson, 2009) and reduced inflammation (Creswell, 2012; Gallegos et al., 2013). Our laboratory recently completed a 4-week randomized controlled trial, which found reduced mind-wandering and response time variability during a Go/No-Go task following mindfulness-based attention training in older adults. However, training did not differentially impact global attention during this task, indexed by a signal detection sensitivity index (d_L). In light of this null finding, the current study conducted secondary analyses to assess the impact of training on local metrics of attention, which compare response behaviors immediately preceding on-task versus off-task thought. Our methods are adapted from previous studies (McVay, Meier, Touron, & Kane, 2013; Fountain-Zaragoza et al., 2018), which found differences in

reaction time and accuracy during Go/No-Go trials preceding mind-wandering reports. In addition, although cognitive and emotional outcomes following mindfulness training are often reported separately, emerging evidence suggests that these outcomes are closely related (Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010; Sahdra, 2011; Rahl, Lindsay, Pacilio, Brown, & Creswell, 2017). The current study also assessed the effects of mindfulness training on self-reported emotion dysregulation, with reduced mind-wandering frequency and improved in-the-moment attention as candidate mediators of these effects. Finally, we performed exploratory analyses to evaluate the role of baseline working memory (WM) as a moderator of training effects on local attention and emotion dysregulation. These analyses build on primary analysis of this RCT, which found that WM moderated the effects of training on d_L , such that for participants with high WM, MBAT yielded greater increases in d_L .

Sustained Attention in Aging

Sustained attention is a basic attentional process, indexed by the ability to maintain vigilance over an extended period (Drag & Bieliauskas, 2010; Zanto & Gazzaley, 2014). Tasks of sustained attention require that a participant continuously monitor a stream of auditory or visual events, and selectively respond to a subset of these events (Giambra, 1997). The present study employed a variant of the Sustained Attention to Response Task (SART), a Go/No-Go (GNG) task in which participants must respond to frequently occurring symbols and withhold response to rare, target symbols (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). In this paradigm, failure to

inhibit responses to infrequent “No-Go” trials (i.e., “errors of commission” or “SART errors”) reflects impaired attentional control (Staub, Doignon-Camus, Després, & Bonnefond, 2013). The response pattern typically observed in older adults during similar tasks is characterized by a “speed-accuracy tradeoff,” wherein a larger proportion of correct responses is achieved at the expense of increased response latency (Brache, Scialfa, & Hudson, 2010; Carriere, Cheyne, Solman, & Smilek, 2010; Jackson & Balota, 2012). However, one previous study has demonstrated that using a z-score transform to account for general age-related slowing may attenuate the effects of age on response speed (Jackson & Balota, 2012).

Additional markers of deficits in sustained attention, including reaction time (RT) variability, anticipations (RT < 100 milliseconds), and omissions (i.e., failing to respond to “Go” trials) during SART, may be less biased by this speed-accuracy tradeoff (Carriere et al., 2010). A cross-sectional study of participants aged 14 to 77 years found that these indices tended to steeply decrease in early adulthood, with little change thereafter; however, consistent with previous reports, age was negatively correlated with error rate and positively associated with reaction time (Carriere et al., 2010). Similarly, McVay et al., 2013 and Fountain-Zaragoza et al. (2018) observed no age-related differences in RT variability during SART and a Continuous Performance Task (CPT), respectively. However, increased response variability in older adults has also been found during SART (Fountain-Zaragoza et al., 2018; McAvinue et al., 2012) and a gradual-onset CPT (Fortenbaugh et al., 2015), confounding characterization of age-related change. Reports of omission frequency across age groups are also discrepant. For example, rate of

omission has been positively associated with age during SART (McAvinue et al., 2012), a simulated air traffic control task (Thackray & Touchstone, 1981), and AX-CPT with visually degraded stimuli (Mani, Bedwell, & Miller, 2005). However, in an AX-CPT with fully intact stimuli, Mani et al. (2005) found no significant correlation between omission errors and age. Across vigilance tasks, assessment of age-related differences in signal detection sensitivity (d' or d_L) and vigilance decrement (i.e., decline in d' with time on task) has also yielded inconsistent results. For example, age equivalence in d' for young and older adults has been observed during digit discrimination (Berardi, 2001) and a selective visual attention task (Quigley, Andersen, & Müller, 2012). By contrast, one previous study found that older adults exhibited higher d_L during SART (McVay et al., 2013), and still others indicate age-related decreases in d' during similar attentional tasks (Fortenbaugh et al., 2015; Parasuraman, Nestor, & Greenwood, 1989). Age-related differences in vigilant decrement also remain unclear. Staub et al. (2014) found that commission errors during a GNG task significantly increased with time on task for young adults only, whereas Parasuraman et al. (1989) found that d' declined more steeply in older adults during digit discrimination, and Berardi et al. (2001) observed no significant relation between age and vigilance decrement.

In summary, although age-related change in general response strategy (i.e., speed-accuracy tradeoff) is consistently reported during sustained attention tasks, other performance metrics produce less conclusive results. However, given its duration and highly repetitive response pattern, SART is well-suited to the assessment of mind-wandering (Jackson & Balota, 2012). Accumulating evidence suggests that mind-

wandering detrimentally impacts attentional control (McVay & Kane, 2012; McVay et al., 2013; Smallwood, McSpadden, & Schooler, 2007; Thomson, Besner, & Smilek, 2013; Seli, Cheyne, & Smilek, 2013; Fountain-Zaragoza et al., 2018); however, few studies have examined this link in older adults.

Age-Related Effects on Propensity to Mind-Wander

Mind-wandering, or a shift in attentional resources away from a primary task towards the processing of internal goals (Smallwood & Schooler, 2006) has been estimated to occupy 30- 50% of our waking life (Killingsworth & Gilbert, 2010; Kane et al., 2007). Although theoretical models of age-related decline in goal maintenance or inhibitory control (i.e., Braver & West, 2011; Hasher & Zacks, 1988) might predict that advanced age is associated with an increased propensity to mind-wander, empirical evidence does not support this view. Within the context of multiple laboratory tasks, including the Sustained Attention to Response Task (SART), reading comprehension, and continuous performance tasks (CPT), older adults endorse fewer episodes of mind-wandering compared to younger adults (Giambra, 1989; Jackson & Balota, 2012; Krawietz et al., 2012; Maillet & Rajah, 2013; Zavagnin et al., 2014; Fountain-Zaragoza et al., 2018; for review see Maillet & Schacter, 2016).

Three primary models have been proposed to account for this paradox. According to the cognitive resource hypothesis advanced by Smallwood & Schooler (2006), task-unrelated thoughts (TUTs) require attentional resources that might otherwise be allocated towards a primary task. Thus, cognitively demanding tasks will tend to deplete

resources that would support mind-wandering, particularly in older adults, who exhibit age-related decrements in working memory capacity (Craik & Salthouse, 2008). In addition, this hypothesis predicts that mind-wandering episodes will yield performance deficits due to the limited availability of resources to complete the primary task. Results from a recent study comparing SART performance in healthy middle-aged adults, healthy older adults, and older adults with early stage Alzheimer's disease (AD) are consistent with this model (Gyurkovics, Balota, & Jackson, 2017). Individuals with AD, followed by healthy older adults, endorsed on-task thoughts with the highest frequency, compared to middle-aged participants. By contrast, frequency of self-reported "tune-outs" (i.e., "while doing the task, I was aware that thoughts about other things popped into my head") decreased with age, and to a larger extent in the AD group. In addition, across groups, a positive relationship between tune-out frequency and working memory capacity, indexed by reading span score (Daneman & Carpenter, 1980) was observed; however, given that group differences in rates of mind-wandering were still significant after controlling for reading span score, the authors acknowledge that working memory capacity may only partially account for these differences. AD pathology is typically characterized by reduced attentional resources; thus, these results lend support to the cognitive resource hypothesis of mind-wandering. However, several studies that report negative or non-significant associations between working memory capacity and mind-wandering rate (McVay & Kane, 2009; McVay & Kane, 2012; Kane et al., 2007) diminish the strength of this view.

A separate hypothesis, proposed by McVay and Kane (2010) invokes age-related shifts in task motivation as a contributor to reduced mind-wandering in older adults. According to the control failure x current concerns account, TUTs result from deficits in executive control to suppress off-task thoughts during cognitively demanding tasks. However, dispositional factors such as level of interest in the primary task, attribution of saliency to the primary task (relative to internal thoughts), and worries related to task performance, may buffer against frequent TUTs. Unlike the cognitive resource hypothesis, this model conceptualizes TUTs as automatically-generated components of the thought stream that do not rely on attentional resources to surface (McVay & Kane, 2009). In addition, although both models predict reduced frequency of TUTs during challenging tasks, the control failure x current concerns hypothesis attributes this association to the recruitment of control processes that prevent TUTs from coming online. Critically, this hypothesis also suggests that a separate mind-wandering type, “task-related interference” (TRI) may better characterize off-task thought in older adults. According to this view, increased frequency of TRIs, which reflect evaluative thoughts about task performance (e.g., “I’m doing well!” or “I’m failing.”), may account for reduced TUT rate in aging samples. In line with this hypothesis, several studies that have found that, relative to younger adults, older adults tend to report more TRIs and fewer TUTs during tasks of sustained attention (McVay et al., 2013; Frank, Nara, Zavagnin, Touron, & Kane, 2015). Although the mechanism underlying these age-related differences is unclear, self-reports indicating increased motivation (Frank et al., 2015) and task interest (Jackson & Balota, 2012; Krawietz et al., 2012) in older adults evince

support for the control failure x current concerns hypothesis. Relatedly, environmental cues available in an experimental setting, including student personnel, campus buildings, and computer monitors, will likely prompt fewer TUTs in older adults, who prioritize achievement-related goals less highly than undergraduate participants (Carstensen et al., 2003). Of note, a recent study in our lab found similar rates of TRI in young and older adults during a Go/No-Go task, which may be attributed to the older sample's near-ceiling performance (Fountain-Zaragoza et al., 2018).

An inherent limitation of self-reports of mind-wandering is that they are susceptible to report bias. A third hypothesis to account for reduced TUT frequency in older adults suggests that age-related changes in meta-consciousness (Einstein & McDaniel, 1997; Schooler, 2002) may contribute to this observed difference. According to this view, impaired ability to monitor, evaluate, or recall subjective experiences may compromise thought-report validity in aging samples; however, behavioral indices of mind-wandering (e.g., increased error rate, reaction time, and eye movement regression) are similarly predictive of TUT in young and older adults (McVay et al., 2013; Frank et al., 2015), which suggests that older adults can accurately perceive and report off-task thought. In addition, cross-sectional studies comparing meta-awareness during memory encoding in young and older adults indicate that this type of cognition is spared with aging (Hertzog & Dunlosky, 2011; Emanuel Robinson, Hertzog, & Dunlosky, 2006), supporting the use of thought reports in this cohort. Thus, although advanced age is broadly characterized by cognitive decline, mind-wandering frequency tends to decrease with age. In light of this paradox, investigation of the extent to which mind-wandering

impacts attentional control in older adults is warranted. Existing research in this domain has produced conflicting results. For example, Krawietz et al. (2012) found that recognition accuracy during a text comprehension task was significantly higher following on-task versus off-task thought reports; however, no main effect of age and no interaction between age and thought type was observed. Using a word encoding paradigm, Maillet and Rajah (2013) found that frequency of mind-wandering was negatively correlated with subsequent retrieval success in young adults only. More recently, Zavagnin et al. (2014) found that response time variability during SART was higher in blocks with self-reported mind-wandering in “old-old” adults only, whereas young and “young-old” adults did not exhibit this effect. By contrast, McVay et al. (2013) found that in both young and older adults, rate of TUT was negatively associated with RT variability and dL during SART and an N-back task. However, using a similar Go/No-Go task, our laboratory found that mind-wandering frequency, averaged across TUT and TRI reports, was not significantly correlated with dL or RT variability in either young or older adults (Fountain-Zaragoza et al., 2018).

Given these discrepancies, continued exploration of relation between mind-wandering and attentional control in older adults is critical. In contrast with previous methodologies (e.g., Krawietz et al., 2012; Maillet & Rajah, 2013; Zavagnin et al., 2014), which characterized this relation using broad measures of attention, the current study employed local attentional metrics, which approximate online effects of mind-wandering.

Local Metrics of Attentional Control

Attentional control, and its relation to mind-wandering frequency, has been characterized using broad, global metrics, which average response behaviors across a full task or task block, and local metrics, averaged over several consecutive trials. Local measures of attention are typically tied to a specific event, such as an error or mind-wandering report, and assess performance during multiple trials immediately preceding or following this event. The current study examined reaction time and accuracy across four trials directly preceding off-task thought during a modified Go/No-Go task. Using a similar paradigm, several studies have found that prior to mind-wandering reports, participants tend to respond more quickly, which may reflect automatic or mindless behavior (McVay et al., 2013; McVay & Kane, 2009; Smallwood et al., 2007). Despite largely discrepant findings related to age-related differences in global sustained attention, only two studies have assessed the effects of mind-wandering on local attention in older adults. In a recent cross-sectional study, McVay et al. (2013) found that both young and older adults were faster to respond to trials preceding task-unrelated thought (TUT) and task-related interference (TRI), in comparison to on-task reports. No main effect of age or mind-wandering type was observed. Contrary to this result, our lab has found slower response latencies prior to off-task thinking across age groups (Fountain-Zaragoza et al., 2018). In addition, mind-wandering events were associated with reduced accuracy in both groups, particularly during No-Go trials.

Although the present study examined local metrics of attention using TUT and TRI as points of reference, previous studies of similar design have probed for other mind-

wandering types. For example, Smallwood et al. (2007) found that during a Go/No-Go task, mind-wandering without awareness of thought content (i.e., “zone outs”) was associated with shorter average reaction time on the 4 preceding trials, relative to mind-wandering with awareness (i.e., “tune outs”) and on-task thought. In addition, reaction time during self-reported “zone outs” predicted failure to correctly inhibit a response (i.e., pressing a key during a “No-Go” trial) during subsequent trials. Using a text recognition task, Schooler et al., (2004) similarly observed behavioral decrements related to zoning out. In this paradigm, participants were randomly probed while reading passages from *War and Peace*; following reports of zoning out, they were asked to respond to a comprehension question related to the passage they had just completed. Zone outs were associated with reduced comprehension accuracy, when compared with performance in a separate group, who received intermittent comprehension questions without mind-wandering probes. More recently, Seli et al. (2013) assessed reaction time variability, a behavioral correlate of attentional lapses (Cheyne, Solman, Carriere, & Smilek, 2009; McVay & Kane, 2009), prior to on task, zoned out, and tuned out reports during a metronome response task. Participants were instructed to respond synchronously to metronome tones presented at regular intervals. Variance in the time between onset of the tone and the corresponding key press, calculated across five trials preceding each thought probe, indexed response variability. Consistent with its behavioral conception, response variability was significantly greater prior to both tune outs and zone outs, relative to on-task reports. Finally, using an item-by-item read aloud task and a Stroop task, Thomson et al., (2013) compared error rate and reaction time to correct trials during five trials

preceding “on-task” and off-task” reports. No main effect of probe on reaction time was observed for either task. In addition, off-task thought was associated with increased error rate during the Stroop task only.

The current study extended these cross-sectional findings to a longitudinal, training context in a sample of older adults. Importantly, no study to date has assessed whether these local metrics of attention, preceding mind-wandering episodes, are modifiable with cognitive training.

Mindfulness-Based Interventions in Aging & Attention

Mindfulness is characterized by purposeful, non-judgmental awareness of the contents of the present moment, including external stimuli, bodily sensations, and mentation. In experimental contexts, mindfulness is typically measured via self-report. For example, the Mindful Attention Awareness Scale (Brown & Ryan, 2003) is a 15-item questionnaire, which asks respondents to rate the frequency of day-to-day experiences that reflect mindlessness (e.g., “I rush through activities without being really attentive to them”). Mindfulness training, which involves didactic instruction in attitudinal principles of mindfulness and engagement in focused meditation, has been adopted as an intervention for physical and cognitive health in aging adults. For example, mindfulness-based stress reduction has been shown to reduce disability in older adults with chronic back pain (Morone et al., 2016), reduce pro-inflammatory gene expression in lonely older adults (Creswell, 2012), and lower blood pressure in low-income African-American older adults (Palta et al., 2012). In addition, several studies have found improved emotional

outcomes in older adults following mindfulness training, including increased positive affect (Gallegos et al., 2013) and reduced worry severity (Lenze et al., 2014). A significant literature related to mindfulness and cognitive preservation in older adults has also developed; this is unsurprising, in light of evidence that mindfulness practices improve sustained attention (MacLean et al., 2010; Semple, 2010), processing speed (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), and executive function (Allen et al., 2012; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013) in non-elderly populations. In particular, increased attentional control has been highlighted as a potential benefit of mindfulness training (Chiesa & Serretti, 2010; Keng, Smoski, & Robins, 2011; Chiesa, Calati, & Serretti, 2011), given its emphasis on sustained awareness.

To date, five randomized controlled trials and three feasibility studies have assessed the effects of mindfulness training on attentional outcomes in older adults. Four of these studies involved healthy older adults without significant cognitive impairment. Moynihan et al. (2013) randomized older adults to a standard 8-week Mindfulness-Based Stress Reduction (MBSR) program or a wait-list control group. Immediately after training, the MBSR group exhibited a significantly lower Trails B/A ratio, an index of executive control; however, these differences were not maintained at 3-week and 21-week follow-up assessments. Using a similar design, Oken et al., (2017) randomly assigned older adults with, at minimum, mild levels of self-reported stress, to 6 weeks of one-on-one meditation training or a wait-list control. Intervention did not significantly affect performance on a Stroop test, flanker attention task, verbal fluency (letter or category), or Letter Number Sequencing. To control for the effects of non-

specific factors, a separate study included a brain training comparison group that was matched in frequency and duration to an 8-week breath awareness meditation program (Malinowski, Moore, Mead, & Gruber, 2017). Following training, older adults randomized to the meditation group displayed significantly faster reaction times on an emotional-counting Stroop test. Primary analysis of the current RCT, in which older adults were randomized to four weeks of mindfulness-based attention training (MBAT) or a lifestyle education control, found that MBAT yielded reduced response time variability (RT_CV) during a Go/No-Go task, but not during a CPT (Whitmoyer et al., under review). However, in each group, significant within-group differences in RT_CV and dL during both tasks were observed. In addition, working memory capacity was found to moderate the effects of MBAT, such that participants with higher working memory at baseline exhibited greater changes in dL during the Go/No-Go task. Finally, in a proof of concept clinical trial, Wells et al. (2013) randomly assigned older adults with mild cognitive impairment to 8 weeks of MBSR or usual care. At post-assessment, the control group performed better on Trail Making Test Parts A and B, which the authors attribute to the effects of fatigue and order of testing. No significant group differences were found on the Rey Auditory Verbal Learning Test, animal naming, Boston Naming Test, Controlled Oral Word Association Test, or Alzheimer's Disease Assessment Scale-Cog.

Three feasibility studies in aging samples indicate mixed effects for attentional outcomes following mindfulness training. Lenze et al. (2014) found that 8 weeks of MBSR produced increased verbal fluency, reduced color-word interference, and

improved recall during a paragraph learning task in older adults with self-reported cognitive dysfunction and worry. In a sample of bereaved older adults, O'Connor, Piet, & Hougaard (2014) found that 8 weeks of mindfulness-based cognitive therapy yielded improved performance on a letter-number sequencing task, relative to a wait-list control. Finally, Mallya and Fiocco (2016) found that MBSR did not significantly improve performance in older adults during Trail Making Tests Part A and B or verbal fluency.

Inverse Association Between Mindfulness and Mind-Wandering

A clear association between mindfulness and reduced rates of mind-wandering has been multiply established, both within the context of training and in cross-sectional studies of trait mindfulness. Mind-wandering during tasks of attention has been assessed using retrospective self-report, probe- and self-caught measures, and behaviorally, via error rate and reaction time variability. Mrazek, Smallwood, and Schooler (2012) randomly assigned undergraduate students to engage in 8 minutes of mindful breathing, reading, or passive relaxation prior to completing a Sustained Attention to Response Task (SART). Students in the mindful breathing group exhibited significantly fewer errors and reduced reaction time variability (RT_CV) during SART in comparison to either control group. In a more recent study, Mrazek and colleagues assessed mind-wandering during reading comprehension and an operation span task in university students randomized to 2 weeks of mindfulness training or nutrition education (Mrazek et al., 2013). Post-training, the mindfulness group displayed less probe- caught and self-caught mind-wandering during both tasks. In addition, relative to the control condition, mindfulness training

yielded significantly improved accuracy during reading comprehension and increased recall during the operation span task; these effects were mediated by training-related reduction in mind-wandering, but only in participants who reported rates of mind-wandering at least one standard deviation above the mean at baseline. Following more intensive training, 7 hours delivered over 7 weeks, undergraduate students assigned quasi-randomly to a mindfulness group exhibited improved accuracy and less self-reported “off-task” behavior during SART, relative to a no-intervention control group (Morrison, Goolsarran, Rogers, & Jha, 2014). Positive effects of mindfulness training on the propensity to mind-wander have also been demonstrated in non-student samples. High-stress pre-deployment military personnel randomized to an 8-week Mindfulness-based Fitness Training program who logged more time spent on homework exercises displayed an increased proportion of “on task” reports during SART, when compared with a wait-list control (Jha, Morrison, Parker, & Stanley, 2017). In addition, primary analyses for the current RCT found that older adults who completed a 4-week MBAT program exhibited marginally reduced frequency of TUT, but not TRI, in comparison to a lifestyle education control group (Whitmoyer et al., under review).

Similar findings in studies of self-reported trait mindfulness corroborate the results of these longitudinal experiments. Mrazek et al. (2012) used the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) to assess trait mindfulness in a sample of undergraduate students. The MAAS is a 15-item scale that asks respondents to rate the frequency with which they tend to focus on experiences unrelated to the present moment (e.g., “I rush through activities without being really attentive to them”). This study

demonstrated that high dispositional mindfulness was negatively associated with error rate and RT_CV during a SART task. In addition, probe-caught TUT during a 10-minute mindful breathing task was also inversely related to trait mindfulness. More recently, Fountain-Zaragoza et al. (2016) found that trait mindfulness in older adults, indexed by MAAS score, was negatively correlated with TUT and TRI during a modified Go/No-Go task, and with TUT during a Continuous Performance Task (CPT). A mediation model revealed a significant, indirect effect of trait mindfulness on proactive control during the CPT through TUT.

Mindfulness, Emotion Regulation, and the Mediating Effect of Attentional Control

A non-dissociable component of mindfulness as a cognitive training tool is instruction in emotion regulation and awareness. Emotion regulation involves conscious or unconscious management of the duration and onset of particular emotions (Gross, 2002). Mindfulness, which emphasizes sensitivity to the cognitive and physiological aspects of emotional events, may facilitate emotion regulation by increasing awareness of these cues (Teper, Segal, & Inzlicht, 2013). A positive association between dispositional mindfulness and self-reported emotion regulation ability has been consistently reported. For example, using experiential sampling in undergraduate students, Hill and Updegraff (2012) found that three components of trait mindfulness (nonreactivity, describing/labeling, and nonjudging), indexed by higher scores on the Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006) predicted less emotion regulation difficulty. A similar association has been observed in

patients with multiple sclerosis (Schirda, Nicholas, & Prakash, 2015) and adults with mood and anxiety disorders (Desrosiers, Vine, Klemanski, & Nolen-Hoeksema, 2013). Our own laboratory has found that in both young and older adults, emotion dysregulation, measured using the Difficulties with Emotion Regulation Scale (DERS; Gratz & Roemer, 2004) is negatively correlated with trait mindfulness (Prakash, Hussain, & Schirda, 2015; Prakash, Whitmoyer, Aldao, & Schirda, 2017). Parallel to these cross-sectional findings, mindfulness training has shown to reduce emotion dysregulation. In a student sample, Menezes and Bizarro (2015) found that 6 weeks of focused meditation training, compared with progressive relaxation and a wait-list control, yielded improved scores on two domains of DERS: limited access to emotion regulation strategies and nonacceptance of emotional responses. In addition, within the meditation group, frequency of weekly practice was positively associated with impulse control, emotional clarity, and reduced difficulty accessing emotion regulation strategies. Similarly, Robins et al. (2012) found that healthy adults randomized to 8 weeks of MBSR, in comparison to a wait-list control, reported less difficulty with strategy access following intervention.

Although both cognitive and emotional benefits are consistently linked with mindfulness training, the relationship between these observed benefits, and the course of their development, are not well understood. More specifically, it is unclear whether training-related improvements in cognitive control precede enhanced emotion regulation ability or if improved emotion regulation following training facilitates cognitive gains. The results of three existing studies support the first model, in which socioemotional outcomes are mediated by training-induced change in top-down control. In a study of a

pre-deployment military cohort undergoing 8 weeks of mindfulness training, Jha et al. (2010) found that self-reported negative affect, assessed using the Positive and Negative Affective Schedule (Watson, Clark, & Tellegen, 1988) was negatively correlated with practice minutes. This association was mediated by training-related increases in working memory capacity, which was measured using an operational span task. More recently, Sahdra et al. (2011) examined the effects of a 3-month intensive meditation retreat on behavioral inhibition and “adaptive functioning,” a single latent variable constructed based on self-report measures of mindfulness, empathy, and emotion regulation, in experienced practitioners. Improved performance during a sustained response inhibition task, in which participants were required to respond quickly to frequently occurring stimuli and withhold response to infrequently occurring stimuli, was found to statistically predict increases in adaptive functioning over the course of training. Results from an active-controlled neuroimaging study of short-term mindfulness training also appear to support this mediation model. Allen et al. (2012) reported that adults who completed 6 weeks of meditation training exhibited reduced affective Stroop conflict, in comparison to participants randomized to a “shared reading and listening” intervention. In addition, meditation training yielded significantly increased activity in dorsolateral prefrontal cortex, a component of the canonical executive control network, during Stroop task performance, which suggests greater top-down modulation of affective processing.

Fewer studies have directly examined improved socioemotional function as a precursor to increased cognitive control. In a cross-sectional study of experienced meditators and meditation-naïve controls, Teper and Inzlicht (2013) found that greater

meditation experience (i.e., more years of practice) was associated with fewer errors on a Stroop task, and that self-reported emotional acceptance, measured using the Philadelphia Mindfulness Scale, mediated this association. A recent dismantling study of mindfulness training also evinces support for increased acceptance as a pathway to improved attentional performance (Rahl et al., 2017). Young adults were randomized to a 3-day training program incorporating attention monitoring and acceptance, attention monitoring only, relaxation training, or an active reading-control condition. Participants in the attention monitoring and acceptance group displayed increased discrimination ability during a Sustained Attention Response Task post-training, relative to participants in the other groups, including attention monitoring only. This result suggests that enhanced emotional acceptance induced by training may support positive attentional outcomes, particularly during tasks of sustained attention that tend to elicit feelings of boredom or frustration.

Given the variability in study design, sample characteristics, and selected measures of interest, substantive claims about mechanism based on the reviewed evidence are difficult to provide. In addition, neither mediation type has been assessed in an aging sample, which may respond differently to training in mindfulness, particularly due to their prioritization of socioemotional goals (Carstensen, Fung, & Charles, 2003). However, an expansive literature within cognitive aging suggests that successful emotion regulation in older adults is supported by top-down control, which accords with a model in which affective outcomes are mediated by training-related improvements in cognitive control. One line of evidence indicates that individual differences in executive

control, as well as task conditions involving high cognitive load, may modulate the positivity effect typically observed in older adults – an age-related bias towards recall of positive information (Carstensen & Mikels, 2005). Mather and Knight (2005) reported that older adults who performed well on tasks of executive control were more likely to exhibit the positivity effect during recall of affective images. In addition, if older adults were required to divide their attention between picture encoding and a goal-irrelevant task, the positivity effect was reversed, such that a greater proportion of negatively-valenced pictures were recalled (Mather & Knight, 2005; Knight, 2007). In a separate study of tracked eye movements during processing of emotional face pairs, older adults with lower conflict scores on the Attention Network Task (ANT: Fan, McCandliss, Sommer, Raz, & Posner, 2002) who displayed a preference towards viewing happy faces tended to resist mood decline over the course of the task (Isaacowitz, Toner, & Neupert, 2009). Thus, positively-biased affective processing associated with advanced age may rely on the availability of cognitive resources, which suggests that training- related increases in this domain may support improved emotion regulation.

Similarly, deployment of particular emotion regulation strategies appears contingent on cognitive control. For example, Opitz et al. (2014) reported that successful use of cognitive reappraisal, a resource-demanding strategy that involves reinterpretation of emotion-eliciting events, was associated with higher fluid cognitive ability in older adults. In addition, previous neuroimaging research indicates that brain areas involved in working memory come online during cognitive reappraisal, suggesting that higher-order executive function supports use of this strategy (Ochsner et al., 2004; McRae et al.,

2010). Finally, electrical activation and structural integrity within prefrontal cortex, a region of the brain that is consistently implicated in cognitive control (Koechlin, Ody, & Kouneiher, 2003; Miller, 2000) predict emotion regulation ability (D. C. Jackson et al., 2003) and vulnerability to late onset depression (Firbank, Lloyd, Ferrier, & O'Brien, 2004), which underscores the role of cognitive control in emotional health.

Specific Aims

The goal of the current study was to perform secondary analyses of a 4-week randomized controlled trial (RCT) comparing the effects of mindfulness-based attention training (MBAT) and a lifestyle education control group on attentional control and emotion dysregulation in older adults (ClinicalTrials.gov Identifier: NCT03432754). Primary analysis of this RCT found that older adults randomized to MBAT, when compared with the active control group, displayed less frequent mind-wandering and reduced response time variability during a Go/No-Go (GNG) task (Whitmoyer et al., under review). In addition, intervention type did not differentially impact signal detection sensitivity (d_L) during this task, a “global” or summary metric of attentional control. However, baseline working memory (WM) significantly moderated the effects of intervention on d_L such that for participants with high WM, MBAT yielded larger increases in d_L . Given this background, the objectives of the current study were as follows:

1. To examine the impact of a 4-week mindfulness training program (MBAT), in comparison with a lifestyle education intervention, on reaction time and

response accuracy immediately preceding self-reported mind-wandering during a Go/No-Go task. We hypothesized that older adults randomized to MBAT, compared with those in the control group, will exhibit faster reaction time and increased accuracy on trials preceding off-task thought.

2. To investigate whether training-related improvement in local attention is mediated by reduced mind-wandering frequency. We hypothesized that reduced frequency of TUT in the MBAT group, relative to an active control group, will yield shorter response latencies and increased accuracy prior to off-task thought reports, mediating the relation between group and local attention.
3. To assess the differential impact of MBAT versus an active control group on self-reported emotion dysregulation, and the possible mediating effect of training-related increases in local attentional control. We hypothesized that the MBAT group, relative to an active control group, will display reduced emotion dysregulation post-training, and that this effect will be mediated by improved local attentional control or reduced TUT frequency.
4. To evaluate baseline working memory (WM) as a moderator of training effects on local attention. We hypothesized that for participants with high WM, MBAT will yield shorter response latencies and increased response accuracy prior to off-task thought, when compared with an active control group.
5. To evaluate WM as a moderator of training effects on emotion dysregulation. We hypothesized that for participants with high WM, MBAT will produce greater decreases in self-reported emotion dysregulation.

Chapter 2. Methods

Participants

Older adults (M age = 66.16) were recruited from the greater Columbus area to participate in a four-week lifestyle intervention. Baseline data for these participants is presented in Fountain-Zaragoza, Londerée, Whitmoyer, & Prakash (2016), and primary analyses for the randomized controlled trial are reported in Whitmoyer et al. (under review). To reduce expectation bias in favor of or against a particular intervention group, recruitment materials advertised characteristics shared by both groups only, and excluded identifying phrases such as “mindfulness,” “meditation,” or “physical activity.” The intervention was described as a series of 4 weekly workshops intended to promote health behaviors in older adults. Prior to enrollment, participants were provided only with information relevant to both intervention groups; details pertaining to their assigned group were given following randomization, on the first day of the intervention. Following the study’s completion, all participants were debriefed on the intended aims and hypothesized outcomes.

The following criteria were used to screen for participant eligibility: 1) aged 60-74 years; 2) no regular engagement in mindfulness training, yoga, or meditation; 3) availability to attend all training sessions; 4) corrected near and far visual acuity of 20/40 or better; 5) normal color vision; 6) no self-reported history of psychiatric, neurological, or chronic inflammatory illness; 7) no regular use of psychiatric medication; 8) native English speaker; 9) score > 23 points on the Mini-Mental Status Examination (MMSE;

Folstein, Folstein, & McHugh, 1975); and 10) score ≤ 10 points on the Geriatric Depression Scale (Yesavage et al., 1982). All participants were paid \$8 per hour for pre- and post-intervention assessments. Intervention participation was not compensated, but training was provided at no cost. In accordance with The Ohio State University Institutional Review Board policy, all participants provided written, informed consent.

In total, 147 older adults completed eligibility screening over the phone and during the first assessment session. Seventy-four volunteers, who met the eligibility criteria in full, were randomly assigned to an intervention group, following the pre-training assessment (see Table 1 for demographic information). Of these participants, 25 in the MBAT group (M age = 66.52; 56% female) and 32 in the active control group (M age = 66.47; 53.13% female) completed the entire study. Three participants in the MBAT group and three participants in the lifestyle education group completed a post-assessment after withdrawing from the intervention.

An *a priori* power analysis was conducted for the current study to estimate the sample size required to detect an effect of intervention. No existing studies have assessed the impact of cognitive training on metrics of local attention. Thus, a power calculation was performed based on the results of a similar randomized controlled trial in older adults, which found that mindful breath awareness training, relative to a brain training group, produced faster response times during an emotional-counting Stroop task (Malinowski et al., 2017; $F(1,42) = 6.263$, $d = .77$). Using an alpha level of .01, it was estimated that a total sample of 68 participants, or 34 participants in each training group, would be required to achieve a power of .95 in the current study. However, given that this

was an archival dataset, we did not recruit additional participants to power these analyses. In addition, our primary outcome of interest is a three-way interaction between group, time, and probe, whereas Malinowski et al. (2017) sought a two-way interaction between group and time. Thus, it is likely that a sample larger than 68 participants would be required to detect these effects, and this should be noted as a limitation of the current study.

Study Design

Within two weeks of the start and end of training, participants completed a 2.5-hour behavioral assessment, which included computerized tasks, subtests of the Wechsler Adult Intelligence Scale (WAIS-IV), and self-report questionnaires. The order of these tasks was counterbalanced across participants and pre- and post-training assessments. Trained research staff and graduate students in the Clinical Neuroscience Lab at the Ohio State University collected these data. Between November 2014 and March 2015, five MBAT and five lifestyle education cohorts participated in the study. Facilitators for both intervention groups were community-based instructors with extensive didactic experience. Training sessions for both groups were scheduled at the same time of day in separate rooms in the Psychological Services Center at the Ohio State University. Training programs were 4 weeks in duration, with one 1.5-hour weekly group meeting. Although standard-form MBSR typically includes 8 weeks of training, the brief length of the present trial was tenable, based on recent results from Mrazek, Franklin, Phillips, Baird, and Schooler (2013), which found training-related benefits after only six hours of

intervention. An active control group was included to control for non-specific effects of group-based intervention, such as social support or group contact (Baumeister, Twenge, & Nuss, 2002; Seeman, Lusignolo, Albert, & Berkman, 2001). In addition, both training programs were matched for assigned homework (~30-45 minutes per day) and time divided between didactics and activities during group meetings to control for participant engagement.

Interventions

Mindfulness-based attention training (MBAT). MBAT in the present study was an abbreviated version of the Mindfulness-based Stress Reduction (MBSR) program (Kabat-Zinn, 1982), which includes sitting meditation, breath awareness exercises, body scan meditation, and instruction in attitudinal qualities of mindfulness. A central aim of mindfulness training is to cultivate present-focused attention by reducing susceptibility to reactive thinking (Bishop et al., 2004). This training emphasized cognitive (vs. socioemotional) aspects of MBSR, particularly the deployment of selective attention towards thoughts, emotions, and body sensations. An instructor with 17 years of experience leading MBSR facilitated the MBAT groups, which included five to 9 participants each. Group meetings included a brief didactic portion, guided mindfulness practice, and a review of the previous week's homework. Participants were provided with readings, audio recordings, assigned exercises, and homework logs to practice with training content between group meetings.

Lifestyle education group. The active control intervention involved discussion of science-based health and lifestyle information. An exercise physiologist facilitated weekly group meetings, which included six to 9 participants each. Didactic lectures were based primarily on content from *The Culprit and The Cure: Why lifestyle is the culprit behind America's poor health and how transforming that lifestyle can be the cure*, authored by professor of lifestyle medicine, Steven Aldana (2005). This text, written for a lay audience, highlights scientific research related to health information promoted by popular media. Group meetings also included stretching/toning exercises, discussion of healthy food options, and a review of the previous week's homework. For homework, participants were asked to complete readings from *The Culprit and The Cure*, monitor their diet, survey food products at a local retailer, and perform stretching/toning exercises. Homework logs were also provided.

Primary Measures

Modified Go/No-Go (GNG) task. Participants were instructed to make a key press as quickly as possible in response to visually presented stimuli (i.e., "Go" response), unless the stimulus was paired with an auditory tone, which cued the participant to withhold their response (i.e., "No-Go" response). During each block of this task, thought probes (described below) were presented at quasi-random intervals (i.e., following 15-20 trials). Dependent variables for the current study were two metrics of local attention: 1) percent accuracy during the four trials immediately preceding thought reports, and 2)

reaction time (RT) averaged across four correct “Go” responses preceding thought reports.

Thought probes. In response to these probes, participants were instructed to label their immediately preceding thoughts as: (1) on-task, (2) directed towards their task performance (task-related interference; TRI), or (3) off-task (task-unrelated thought; TUT). Local accuracy and RT were compared between the four trials preceding on-task thought (i.e., response category 1) and the four trials preceding off-task thought (i.e., response category 2 or 3).

Difficulties in Emotion Regulation Scale (DERS). This scale is a 36-item self-report assessment of six components of emotion dysregulation: non-acceptance of emotional responses, difficulty engaging in goal-directed behavior, deficits in impulse control, lack of emotional awareness, limited access to emotion regulation strategies, and lack of emotional clarity (Gratz & Roemer, 2004). Participants indicated how frequently each statement item (e.g., “I am attentive to my feelings”) characterizes their behavior, using a 5-point scale. The dependent variable for the current study was the total sum score.

Secondary Measures

Working Memory Index from the Wechsler Adult Intelligence Scale (WAIS-IV; Wechsler, 2008). Two subtests of the WAIS-IV Working Memory Index were administered: Digit Span and Arithmetic. Both tests require encoding, maintenance, and manipulation of auditory information. An age-normed standardized composite score was

computed based on these subtests, and the baseline composite score was assessed as a moderator of training effects.

Analytic Approach

All analyses were completed in SPSS Version 25.

Data inclusion and outlier correction. Consistent with the intent-to-treat principle, all participants who were randomized and provided valid data at T1 were included in analysis. All variables were screened for statistical outliers, defined as data points greater than or less than 2.5 standard deviations (SD) from the mean. Outliers were replaced with values equivalent to 2.5 SD in the appropriate direction. Sixteen outliers were replaced in total, with no identifiable clustering of outliers.

Identification of covariates. Baseline group differences in demographic variables, cognitive status, and neuropsychological performance were assessed to identify covariates for our mixed effects models (below). All variables were first submitted to a Shapiro-Wilk normality test. Following this, independent samples *t*-tests were performed for normally distributed data and Mann-Whitney *U*-tests were performed for non-normal data.

Mixed effects models. All mixed effects models were estimated by the Restricted Maximum Likelihood (REML) method. For all analyses, the full factorial model was tested, and random intercepts were modeled to estimate subject-level variance. Post-hoc analyses were performed to probe significant main effects and interactions.

Pre-Registered Secondary Analyses

Our first aim was to evaluate the impact of mindfulness training, relative to a lifestyle education control group, on response accuracy and RT immediately preceding off-task versus on-task thought reports during a GNG task. A mixed effects model including the fixed effects of group (MBAT, lifestyle education), time (pre-training, post-training), and probe type (on-task thought, off-task thought) was tested, with response accuracy and RT as the dependent variables in two separate models.

The second aim of this study was to assess the relative effects of MBAT and the lifestyle education group on self-reported emotion dysregulation. DERS total score, our index of emotion dysregulation, was tested as the dependent variable in a mixed effects model including group (MBAT, lifestyle education) and time (pre-training, post-training) as fixed effects.

Pre-Registered Exploratory Analysis

We pre-registered an exploratory analysis to assess baseline working memory (WM), measured using the WAIS-IV Working Memory Index, as a moderator of training effects on local attention. This was pre-registered as “exploratory” because moderation by WM was assessed in an exploratory analysis in the primary analyses of this RCT. Mixed effects models including group (MBAT, lifestyle education), time (pre-training, post-training), probe type (on-task thought, off-task thought) and WM as fixed effects was constructed to explore this moderation. Response accuracy and RT were included as dependent variables in two separate models, and WM was modeled as a continuous

variable. To probe significant interactions in these models, and to visually depict these interactions, we categorized participants into an average WM group ($WMI < 115$) and high WM group ($WMI \geq 115$). In the normative sample, the mean score on the WMI is 100, with a standard deviation (SD) of 15. Thus, WMI scores 1-2 SD above this mean (i.e., $WM > 115$) represent “above average” performance, and scores below 115 points represent “average” or “below average” performance. Following this initial categorization, we calculated the median WMI score for each group, which resulted in the selection of 102 points and 119 points for the average and high WM groups, respectively.

Exploratory Analysis

We conducted an exploratory analysis to assess moderation by WM of training effects on emotion dysregulation. These analyses were not pre-registered, and thus, were entirely exploratory. A mixed linear model including group (MBAT, lifestyle education), time (pre-training, post-training), and WM as fixed effects was tested, and consistent with the pre-registered analyses above, WM was modeled as a continuous variable. Dichotomization of WM for post-hoc contrast analyses and depiction of interaction results was performed using the same methods described in the previous section.

Chapter 3. Results

Sample Characteristics

Demographic characteristics and baseline neuropsychological performance for each training group are reported in Table 1. The average age of participants was 65.75 years ($SD = 3.76$) in the MBAT group and 66.41 years ($SD = 4.13$) in the lifestyle education group. In both groups, the proportion of female participants was slightly higher: 58.3% participants of the MBAT group and 56.8% of participants in the lifestyle education group were women. On average, participants in both groups received over 16 years of education, and attained MMSE scores above 28 points (where 30 represents the maximum score), suggesting that our sample of participants was a highly educated group without marked cognitive impairment.

In addition, we found that Go/No-Go response accuracy at baseline was near-ceiling, with 98% on-task accuracy and above 95% off-task accuracy in both groups. Baseline WMI scores were normally distributed in our sample, with a range of 74 to 134 points. Based on the categorization scheme noted above, 53 participants scored within the below average to average range, and 20 participants scored within the above average range. Finally, DERS score at baseline in this sample was non-normally distributed with skewness of .656 ($SE = 2.81$), kurtosis of -.308 ($SE = .555$), and a range of 41 to 93 points. Although there are no standardized clinical cutoffs for DERS score, previous studies have shown that clinical samples, including adults with generalized anxiety disorder and eating disorders, score within the range of 80 to 127 points (Harrison,

Sullivan, Tchanturia, & Treasure, 2010; Staples & Mohlman, 2012). Thus, our sample did not report clinically significant levels of emotion dysregulation, which is unsurprising, as participants with any known psychiatric conditions were excluded from this study.

Identification of Covariates

No significant group differences in age, proportion of female participants, years of education, WM score, local accuracy or local RT during the Go/No-Go task, or DERS score at baseline were observed (all p -values $>.05$). Only scores on the Mini-Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975) significantly differed between groups, with higher baseline scores in the MBAT group ($M = 29.44$, $SD = .65$), compared with the lifestyle education group ($M = 28.97$, $SD = 1.17$; $t(56.822) = 2.139$, $p = .037$). However, the mean score in both groups was within the range of “normal cognition.” In addition, consistent with CONSORT guidelines, because MMSE score was not hypothesized to predict training outcomes, we report the results of the unadjusted mixed effects models (i.e., without inclusion of this covariate). Of note, the adjusted models did not shift the significance level of any of the reported values.

Pre-Registered Secondary Analyses: Training Effects on Local Attention

For local accuracy, a significant main effect of probe type was observed ($F(1, 181.280) = 15.233$, $p < .001$). Post-hoc analysis of this main effect indicated that response accuracy preceding off-task thought was significantly lower ($M = .967$) when compared

with response accuracy preceding on-task thought ($M = .984$). In addition, the main effect of group was trending towards significance ($F(1, 70.999) = 3.670, p = .059$), and a post-hoc test of this effect showed that the MBAT group ($M = .981$) achieved marginally higher accuracy when compared with the lifestyle education group ($M = .970$) across time points. By contrast, the main effect of time ($F(1, 191.773) = 2.806, p = .096$) and the interactions of group x time ($F(1, 191.773) = .003, p = .954$) and group x time x probe type ($F(1, 177.335) = .009, p = .925$) were not significant (Table 4, Figure 2).

For local RT, the main effect of probe type was also significant ($F(1, 174.316) = 18.129, p < .001$). A post-hoc test of this main effect showed that RT preceding off-task thought was significantly slower ($M = 582.900$), when compared with RT preceding on-task thought ($M = 559.571, p < .001$). The main effect of time ($F(1, 178.637) = 3.467, p = .064$) approached significance, and post-hoc analysis of this effect indicated that across groups, RT at post-training ($M = 566.015$) was marginally faster than RT at pre-training ($M = 576.456$). However, the main effect of group ($F(1, 73.224) = .992, p = .322$), and the interactions of group x time ($F(1, 178.637) = .593, p = .442$), and group x time x probe type ($F(1, 172.645) = .096, p = .757$) were not significant predictors of local RT (Table 5, Figure 3). Given that the interaction of group x time x probe type was not a significant predictor of local accuracy or local RT, mediation analyses were not pursued.

Taken together, these results indicate that performance decrements (i.e., reduced accuracy and slower RT) immediately preceding self-reported off-task thought were not differentially impacted by training type.

Pre-Registered Secondary Analyses: Training Effects on Emotion Dysregulation

For DERS score, the main effect of time was significant ($F(1, 197.019) = 9.251, p = .003$), and a post-hoc test of this effect indicated that across groups, DERS score following training ($M = 60.637$) was significantly lower than DERS score at baseline ($M = 62.199$). Thus, both groups reported reduced emotion dysregulation between pre- and post-training. By contrast, the main effect of group ($F(1, 71.347) = .826, p = .366$) and the interaction of group x time ($F(1, 197.019) = .139, p = .710$) were not significant predictors of DERS score (Table 6, Figure 4). Given that the interaction of group x time was not a significant predictor of DERS score, mediation analyses were not pursued.

Pre-Registered Exploratory Analyses: Baseline Working Memory as a Moderator of Training Effects on Local Attention

For both analyses testing WM as a moderator, this variable was modeled continuously. For local accuracy, we found a significant interaction of group x time x probe type x WM ($F(1, 171.363) = 5.155, p = .024$) (Table 7, Figure 5).

Post-hoc contrast analyses indicated that the group x time x probe type interaction was significantly different for the average and high WM groups (estimate = .053, $SE = .023, p = .024$), such that baseline WM moderated the effects of MBAT more so than lifestyle education training. However, contrast analyses within the average and high WM groups, collapsed across training groups, suggest that two lower-order interactions may be driving this four-way interaction. First, within the average WM group, we found a larger reduction in the effects of mind-wandering on response accuracy in the MBAT group,

relative to the lifestyle education group, although this difference was not statistically significant (estimate = .009, $SE = .018$, $p = .614$). Second, in the high WM group, the effects of mind-wandering on local accuracy in the lifestyle education group were marginally reduced, when compared with the MBAT group (estimate = -.043, $SE = .024$, $p = .074$); however, given the disparity in baseline performance between high and average WM participants in the lifestyle education group, this effect likely reflects regression to the mean. Thus, although statistical comparison of these two lower-order interactions yielded a significant four-way interaction, it is likely not indicative of moderation. Note that in our assessment of training effects on local accuracy (i.e., prediction by group x time by probe), we observed a non-significant group x time interaction (Table 5, Figure 2); however, in the moderation model described here, the group x time interaction is significant ($p < .05$), which reflects the fact that lower-order terms in this model (e.g., group x time) are fixed at a value of 0 for WM. Thus, in this model, the interaction of group x time significantly predicts local accuracy when WM is equivalent to 0. However, given that the lowest possible score of this index is 50 points, and the minimum value in our sample is 74 points, 0 does not represent a meaningful score at which to interpret this group x time interaction. For local RT, the interaction of group x time x probe type x WM was not significant ($F(1, 167.161) = .602$, $p = .439$) (Table 5).

Exploratory Analysis: Baseline Working Memory as a Moderator of Training Effects on Emotion Dysregulation

We found that the interaction of group x time x WM significantly predicted DERS score ($F(1, 193.879) = 7.856, p = .006$) (Table 8, Figure 6). Again, although in our pre-registered analysis we found that group x time did not significantly predict DERS score (Table 6, Figure 4), this interaction became significant in the moderation model ($p < .004$); however, this interaction term is not interpretable because it is fixed at a value of 0 for WM. Post-hoc contrast analyses indicated that the interaction of group x time was significantly different for participants with average and high WM (estimate = -3.78, SE = 1.35, $p = .006$), such that in the MBAT group, training effects on DERS score were moderated by baseline WM more so than in the lifestyle education group. Specifically, participants with high WM in the MBAT group displayed larger reductions in emotion dysregulation than participants with average WM in this group (estimate = -3.04, SE = .90, $p = .001$); however, in the lifestyle education group, the difference in training effects between average and high WM participants was comparatively smaller (estimate = -1.03, SE = 1.12, $p = .355$.)

Chapter 4. Discussion

The present study performed secondary analyses of a 4-week randomized controlled trial, comparing the effects of MBAT and a lifestyle education control group on local metrics of attentional control and emotion dysregulation in older adults. Primary analyses of this dataset found that global attention during a GNG task was not differentially impacted by training program. However, following training, mind-wandering frequency during this task was reduced in the MBAT group, when compared with the control group. Thus, metrics of attention that more directly capture the impact of mind-wandering during sustained attention may be more attuned to the effects of mindfulness training. In this study, these in-the-moment effects of mind-wandering were operationalized by comparing response accuracy and reaction time during the four trials preceding thought reports of on-task and off-task thinking.

The primary aim of the current study was to examine the relative effects of mindfulness training and an active control group on local metrics of attentional control, assessed prior to quasi-randomly distributed mind-wandering probes, during a GNG task. We hypothesized that MBAT, which emphasized sustained attention and awareness towards off-task thoughts, emotions, and sensations, would mitigate the effects of mind-wandering on local metrics of attentional control. However, contrary to our initial hypothesis, four-week training in mindfulness did not differentially improve metrics of local accuracy and local RT, compared with an active control group, in our sample of older adults.

Mindfulness training, which is typically delivered in a group-based format, has been increasingly employed as a cognitive rehabilitation tool, with a particular emphasis on enhancing attentional control (Chiesa et al., 2011; Fountain-Zaragoza & Prakash, 2017, Prakash et al., under review). Within older adults, the extant literature assessing the effects of mindfulness training on attentional outcomes has yielded mixed results (Prakash et al., under review; for review, see Fountain-Zaragoza & Prakash, 2017). For example, relative to a wait-list control group, Moynihan et al. (2013) found that 8 weeks of mindfulness training yielded lower Trails B/A ratio, an index of executive attention, whereas Oken et al. (2017) found that 6 weeks of one-on-one meditation training, again, relative to a wait-list group, did not improve attentional outcomes (e.g., Stroop test, flanker attention task, verbal fluency, letter-number sequencing) in older adults with mild levels of self-reported stress. These discrepant results for wait-list comparison studies may be explained by differences in the training duration and format (i.e., group-based vs. individual), and in the components of attention assessed by these outcome measures. Specifically, whereas Trails B/A is a putative measure of task-switching efficiency, the Stroop and flanker attention tasks require inhibition of a prepotent response. In addition, one of these studies included participants with a specific psychological profile (i.e., self-reported stress of at least mild intensity), which may have implications for the observed results.

Placebo-controlled studies of mindfulness training in older adults have also produced conflicting findings. The parent study of these secondary analyses found that 4 weeks of mindfulness training, relative to a lifestyle education group, was associated with

reduced response time variability during a GNG task; however, signal detection sensitivity was not significantly improved with training (Whitmoyer et al., under review). By contrast, Malinowski et al. (2017) found that 6 hours of breath awareness training, when compared with a brain training group, resulted in faster response time during an emotional-counting Stroop test. Here, although the training programs were equivalent in dose, the primary outcomes were distinct, with the first study assessing vigilance and the second assessing inhibitory control and processing of emotional stimuli. In the current study, we additionally focused on examining the effects of mindfulness training on behavioral performance preceding off-task thoughts. Thus, it is likely that key differences between tasks employed across the various studies may contribute to the observed discrepant findings.

Additionally, another factor that may account for the lack of between-group differences observed in our study is the low baseline rate of mind-wandering in our older-adult sample. In accordance with previous findings (Giambra, 1989; Jackson & Balota, 2012; for review, see Maillet & Schacter, 2016), a cross-sectional comparison of mind-wandering frequency in this sample of older adults and an education-matched sample of young adults found that older adults reported less mind-wandering during the GNG task (Fountain-Zaragoza et al., 2018). Thus, due to the relatively low frequency of mind-wandering in this sample, it is possible that the impact of mind-wandering on GNG performance was minimal at baseline, and therefore, the margin for improvement with training was small. In contrast, a similar duration of mindfulness training provided to young adults led to reduced mind-wandering and improved scores for a reading

comprehension task and an operation span task (Mrazek et al., 2013). In addition, improvement on these tasks was mediated by reduced mind-wandering frequency, but only in participants who mind-wandered with a rate of at least one standard deviation above the mean at baseline. In the current study, only 9 participants in the MBAT group and 9 participants in the lifestyle education group mind-wandered with a frequency of one standard deviation above the mean. Thus, it is likely that the low rates of mind-wandering at baseline coupled with high accuracy preceding off-task thoughts, may have additionally contributed to the lack of differential gains in the mindfulness group.

The second goal of the present study was to evaluate the differential impact of mindfulness training and an active control group on emotion dysregulation in an aging sample, which was assessed via self-report using the DERS questionnaire. Our laboratory has previously found that trait mindfulness in older adults is inversely associated with emotion dysregulation (Prakash, Hussain, & Schirda, 2015; Prakash, Whitmoyer, Aldao, & Schirda, 2017). In addition, longitudinal training studies in young adults have evinced support for reduced emotion dysregulation following mindfulness training (Menezes & Bizarro, 2015; Robins et al., 2012). We hypothesized that MBAT, relative to a lifestyle education control group, would produce larger reductions in emotion dysregulation. Similar to our findings for local RT, we found that although emotion dysregulation decreased between T1 and T2 for both groups, there were no significant between-group differences. Thus, reduced emotion dysregulation in both groups may be attributed to non-specific effects of intervention, such as social support, interaction with an expert facilitator, or demand characteristics. Consistent with this idea, previous studies that have

observed positive effects of mindfulness training on emotion dysregulation have used wait-list comparison groups (Mitchell et al., 2017; Robins et al., 2012), whereas studies with interactive group-based control groups tend to report null results (Glasner-Edwards et al., 2017). To date, no previous studies assessing the effects of mindfulness training on emotional outcomes in older adults have used the DERS questionnaire. However, one previous study found that MBSR, compared with a wait-list group, produced greater changes in positive affect in older adults (Gallegos et al., 2015), particularly in participants over age 70 with lower baseline depressive symptoms. In addition, a feasibility study in older adults reporting significant worry found that 8 weeks of MBSR reduced worry severity (Lenze et al., 2014). However, here again, a placebo control was not employed. Thus, inclusion of an active control group in the current study may partially account for the lack of group effects.

Additional methodological differences may account for discrepant findings between the current study and previous studies finding benefits of mindfulness training for emotion dysregulation. Specifically, as the aim of the primary analyses was to examine the effects of mindfulness training on attentional control, older adults with known psychiatric conditions (i.e., indicated by diagnosis by a healthcare professional) were excluded from this study. As such, our sample of participants did not exhibit elevated levels of emotion dysregulation at baseline, reporting a mean DERS score of 61.99, which is below the range of mean scores typically observed in clinical samples (80-127; Haynos, Roberto, & Attia, 2015). One previous study assessing the psychometric properties of DERS in an aging sample found that the mean DERS score

for older adults with generalized anxiety disorder was 79.51 ($SD = 19.76$), whereas in an age-matched sample of healthy controls, the mean score was 53.78 ($SD = 9.08$) (Staples & Mohlman, 2012), which more closely reflects the composition of our sample. In contrast with the null findings reported here, mindfulness-based therapies in older adults with clinical levels of depression and anxiety have been shown to increase emotional well-being (Splevins et al., 2009; Foulk, Ingersoll-Dayton, Kavanagh, Robinson, & Kales, 2014), albeit in the absence of an active control group. Thus, few self-reported difficulties with affective regulation at baseline in a non-clinical sample of older adults may have restricted the range of training effects. Furthermore, although DERS represents a summary measure of emotion dysregulation, additional indices of this construct, such as use of maladaptive emotion regulation strategies, may also be remediated with mindfulness training. In line with this notion, a cross-sectional study in our laboratory showed that use of thought avoidance mediated the relationship between trait mindfulness and emotion dysregulation in older adults (Prakash et al., 2017). Thus, modification of strategy use in emotion-eliciting situations may be a useful target for future training studies in aging samples.

In addition to these secondary analyses, we pre-registered an exploratory analysis assessing baseline WM as a moderator of training effects on local attention. Primary analysis of this dataset found that WM moderated the effects of mindfulness training on global attention, such that in the MBAT group, higher WM was associated with increased improvement in global attention during the GNG task. Although WM performance is frequently assessed as an outcome of mindfulness training, (Lenze et al., 2014; Zeidan,

Johnson, Diamond, David, & Goolkasian, 2010; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Jha et al., 2010; Oken et al., 2017), few studies have examined moderation by WM or other baseline cognitive abilities for the effects of mindfulness training. However, in view of equivocal findings for the efficacy of mindfulness training for attention-related metrics (Fountain-Zaragoza & Prakash, 2017; Prakash et al., under review), it is critical to identify variables that systematically impact the strength of such training. Within the broader cognitive training literature, this line of study has produced mixed results. For example, previous studies using cognitive-physical training, game-based training, and speed-of-processing training in older adults have found that higher baseline cognitive ability is associated with less training-related improvement (Rahe et al., 2015; Whitlock, McLaughlin, & Allaire, 2012; Olazaran et al., 2004; Ball, Edwards, & Ross, 2007). By contrast, other studies, including primary analyses of this RCT, have found that higher baseline ability is predictive of increased training benefits (Whitmoyer et al., under review; Fairchild, Friedman, Rosen, & Yesavage, 2013; McKittrick et al., 1999). Thus, based on these mixed results, we assessed whether training effects on local attention were moderated by WM.

For local accuracy only, we found a significant four-way interaction between group, time, probe, and WM. This interaction was likely driven by two lower-order effects. First, among participants with average WM, we observed a larger, although non-significant reduction in the effects of mind-wandering on response accuracy in the MBAT group. By contrast, in participants with high WM, we found a larger, marginally significant reduction in the effects of mind-wandering in the control group, although this

may reflect regression to the mean in this group. Thus, this four-way interaction does not appear to indicate moderation by WM, but instead, a regression artifact. Assessment of this relationship in a larger sample with increased variance in baseline WM is needed to clarify interpretation of these results.

Finally, we performed exploratory analyses to examine moderation of training effects on emotion dysregulation by baseline WM. We chose to pursue this analysis based on the observation that WM significantly moderated the effects of training on global attention in the primary analysis of this dataset (Whitmoyer et al., 2014). In addition, justification for assessing this moderation is based in an expansive literature showing that emotion regulation ability in older adults relies on cognitive control, such that higher levels of cognitive control, measured via tasks of working memory, inhibitory control, and task-switching, are associated with improved emotion regulation and context-appropriate recruitment of emotion-regulation strategies (Opitz et al., 2014; Mather & Knight, 2005; Knight, 2007). Based on this literature and the results of our primary analyses, we hypothesized that mindfulness training would result in reduced emotion dysregulation in individuals with high baseline WM.

Interestingly, we found a significant three-way interaction, indicating that in the MBAT group, older adults with high baseline WM exhibited larger reductions in emotion dysregulation, when compared with older adults with average WM. Thus, similar to the finding in our primary analyses that MBAT participants with high WM improved more in global attention, this result suggests that training-related reduction in emotion dysregulation may be contingent on higher cognitive ability at baseline. This accords

with the broader cognitive aging literature, which has found that successful emotion regulation in older adults, including maintenance of the positivity effect (Mather & Knight, 2005; Knight, 2007) and the deployment of particular emotion regulation strategies (Opitz et al., 2014), relies on intact cognition. Furthermore, previous studies have found that improved emotion regulation following mindfulness training was related to or predicted by changes in cognition and activity within the executive regions of the brain (Jha et al., 2010; Sahdra et al., 2011; Allen et al., 2012). Thus, the findings of this study are consistent both with cross-sectional data supporting a relationship between cognition and emotion regulation ability in older adults, but also with longitudinal studies showing this relationship in the outcomes of mindfulness training. However, in light of the fact that these were exploratory analyses in a small sample, replication of these results in a larger sample is warranted.

Limitations

Design limitations of the original RCT, including the absence of a wait-list control group, attrition rate in the MBAT group, and small sample size are reported in Whitmoyer et al. (under review). As noted in the Methods section, an a priori power analysis indicated that the current study was likely underpowered to detect the effects of training on local attention. Additional limitations of these secondary analyses also merit discussion. First, due to our strict inclusion criteria, our sample of participants was quite healthy in terms of cognitive and psychiatric health. The majority of our participants were highly educated (average years of education = 16), and no participants exhibited any

marked cognitive impairment. In addition, although baseline working memory scores were normally distributed, only 4 of our participants (5%) scored within the “below average” range, whereas 49 (67%) scored within the “average” range, thus resulting in our combined group of below average to average WM, and 21 (29%) scored with the “above average” range. Thus, the significant moderation of training effects on emotion dysregulation by baseline working memory should be considered within this context. In other words, this result suggests that individuals with high baseline working memory, relative to individuals with average working memory (i.e., with an underrepresentation of individuals with below average working memory in this group) may benefit from mindfulness training to a greater extent. A related limitation is that performance on the Go/No-Go task was near ceiling at baseline, with 98% and 96% accuracy rates for responses preceding on-task and off-task thought, respectively. In addition, in terms of psychiatric health, to be eligible to participate, participants had to report no known psychiatric conditions. As a result, our sample did not report elevated levels of emotion dysregulation, scoring on average below the mean that has been observed in clinical samples. Consequently, our sample may not be wholly representative of the aging population, and thus, additional studies that recruit older adult samples with more variability in baseline cognitive ability and emotion dysregulation would be useful. Second, using this task design, we were underpowered to examine differential training effects on local attention preceding two types of off-task thought: task-unrelated thought and task-related interference (TRI). Previous studies have found that relative to young adults, older adults tend to report similar or elevated rates of TRI, (Fountain-Zaragoza et

al., 2018; McVay et al., 2013), which reflect evaluative thoughts about performance. Thus, it is possible that local attention preceding TRI may be impacted by training in this group, and tasks that elicit higher rates of TRI (e.g., by priming evaluative thoughts) may yield different results. Finally, limitations related to training duration should also be considered. The shorter duration of this study was selected based on a previous finding that brief mindfulness training in young adults produced significant improvements in attentional outcomes (Mrazek et al., 2013). However, it is possible that the brief duration of this study may account for the observed null effects, particularly given that this was a sample of older adults. In addition, based on the finding in the primary analysis that WM was a moderator of training effects, it is plausible that with additional training time, individuals with average or below average WM may have improved to a greater extent. However, further research investigating the possibility of a dose-response relationship for mindfulness training in older adults is warranted to support this interpretation.

Conclusions

This represents the first study to assess the impact of mindfulness training on in-the-moment effects of mind-wandering during sustained attention in an aging sample. Contrary to our hypothesis, we did not observe differential effects of training on these local attentional metrics, and we did not find evidence for moderation of training effects by baseline WM. However, in view of the detrimental effects of mind-wandering for activities that support healthy aging, including driving (Yanko & Spalek, 2014) and ambulation (Nagamatsu, Kam, Liu-Ambrose, Chan, & Handy, 2013), further exploration

of these effects in a sample of older adults with larger variance in baseline cognitive ability is warranted. This study is also one of the few placebo-controlled assessments of mindfulness-based training for emotion dysregulation in older adults. We found that compared with an active control group, MBAT did not produce significant reductions in emotion dysregulation. However, we found that baseline WM moderated the effects of training, such that within the MBAT group, participants with higher WM displayed larger reductions in emotion dysregulation. This finding contributes to a developing literature documenting the relationship between cognitive and emotional outcomes following mindfulness training. In addition, this study represents one of the only efforts to identify moderators of mindfulness training, which, in light of equivocal findings for the efficacy of this training, is a critical next step.

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Appendix A. Tables and Figures.

Table 1. Demographic characteristics and baseline performance for participants randomized to mindfulness-based attention training (MBAT) and lifestyle education.

Characteristic	MBAT (n = 36)	Lifestyle Education (n = 37)
Age	65.75 (3.76)	66.41 (4.13)
Education	16.99 (2.86)	16.32 (2.48)
% Female	58.3	56.8
WMI	109.14 (14.74)	103.95 (10.80)
MMSE	29.44 (.65)	28.97 (1.17)
DERS	60.86 (10.83)	63.54 (13.96)
On-task accuracy	0.98 (.03)	0.98 (.03)
On-task RT	560.22 (60.33)	571.67 (63.72)
Off-task accuracy	0.97 (.04)	0.95 (.05)
Off-task RT	577.26 (74.63)	598.87 (78.47)

Note. Reported values are means (SD), unless otherwise indicated; WMI = working memory index; MMSE = mini-mental status examination; DERS = difficulties with emotion regulation scale; mean values for response accuracy and reaction time (RT) are reported for trials preceding “on-task” and “off-task” thought during a Go/No-go task.

Table 2. Mean scores for local accuracy preceding on-task thought and off-task thought during a Go/No-Go task in participants randomized to mindfulness-based attention training (MBAT) and lifestyle education.

Group	Pre-Training					Post-Training				
	<i>M</i>	<i>SE</i>	<i>df</i>	95% CI		<i>M</i>	<i>SE</i>	<i>df</i>	95% CI	
				<i>LL</i>	<i>UL</i>				<i>LL</i>	<i>UL</i>
MBAT										
On-task	.984	.006	227.8	.972	.996	.988	.007	234.1	.974	1.00
Off-task	.970	.006	231.0	.957	.982	.981	.008	238.6	.966	.996
Lifestyle Education										
On-task	.981	.006	226.5	.969	.992	.983	.006	230.6	.970	.995
Off-task	.953	.006	229.9	.941	.965	.965	.007	233.6	.952	.977

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit

Table 3. Mean scores for local reaction time preceding on-task thought and off-task thought during a Go/No-Go task in participants randomized to mindfulness-based attention training (MBAT) and lifestyle education.

Group	Pre-Training					Post-Training				
	<i>M</i>	<i>SE</i>	<i>df</i>	95% CI		<i>M</i>	<i>SE</i>	<i>df</i>	95% CI	
				<i>LL</i>	<i>UL</i>				<i>LL</i>	<i>UL</i>
MBAT										
On-task	558.7	11.3	128.9	536.5	581.0	550.1	12.2	155.6	526.1	574.1
Off-task	576.4	11.7	141.0	553.3	599.5	572.8	13.1	182.5	546.9	598.6
Lifestyle Education										
On-task	571.7	11.0	126.3	549.9	593.5	557.8	11.4	137.5	535.3	580.3
Off-task	599.0	11.3	134.4	576.7	621.3	583.4	11.7	147.2	560.4	606.5

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit

Table 4. Type III tests of fixed effects from mixed effects models predicting local accuracy during a Go/No-Go task.

	<i>df</i>	<i>F</i>	<i>p</i>
Group	71.0	3.67	.059
Time	191.8	2.81	.096
Probe	181.3	15.23	.000***
Group x time	191.8	.003	.954
Group x probe	181.3	2.12	.147
Time x probe	177.3	1.06	.304
Group x time x probe	177.3	.009	.925
Residual variance	.0011		
Random effect variance	.0002		

*** $p < .001$ level

Table 5. Type III tests of fixed effects from mixed effects models predicting local reaction time during a Go/No-Go task.

	<i>df</i>	<i>F</i>	<i>p</i>
Group	73.2	.992	.322
Time	178.6	3.47	.064
Probe	174.3	18.13	.000***
Group x time	178.6	.593	.44
Group x probe	174.3	.335	.56
Time x probe	172.6	.023	.88
Group x time x probe	172.6	.096	.76
Residual variance	1741.60		
Random effect variance	2756.43		

*** $p < .001$ level

Table 6. Type III tests of fixed effects from mixed effects models predicting self-reported emotion dysregulation.

	<i>df</i>	<i>F</i>	<i>p</i>
Group	71.3	.83	.366
Time	197.0	9.25	.003**
Group x time	197.0	.14	.71
Residual variance	16.2		
Random effect variance	131.5		

**p < .01 level

Table 7. Type III tests of fixed effects from mixed effects models predicting local accuracy and reaction time during a Go/No-Go task with moderation by baseline working memory (WM) score.

	Accuracy			Reaction Time		
	df	<i>F</i>	<i>p</i>	df	<i>F</i>	<i>p</i>
Group	66.6	.35	.56	70.5	4.81	.032*
Time	179.3	.075	.78	170.7	1.82	.179
Probe	175.8	2.56	.11	169.1	4.44	.037*
WM	65.9	.67	.42	70.1	1.22	.27
Group x time	179.3	5.00	.027*	170.7	3.23	.074
Group x probe	175.8	.005	.95	169.1	.15	.70
Group x WM	65.9	.62	.43	70.1	4.46	.038*
Time x probe	171.4	1.22	.27	167.2	.071	.79
Time x WM	178.6	.001	.98	170.3	1.39	.24
Probe x WM	175.1	1.33	.25	168.8	2.67	.104
Group x time x probe	171.4	4.94	.028*	167.2	.65	.42
Group x time x WM	178.6	5.00	.027*	170.3	3.03	.084
Group x probe x WM	175.1	.04	.84	168.8	.13	.715
Time x probe x WM	171.4	1.66	.20	167.2	.093	.761
Group x time x probe x WM	171.4	5.16	.024*	167.2	.602	.439
Residual variance	.001			1737.3		

Table 7 (continued).

Random effect variance	.0002	2610.1
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*p < .05

Table 8. Type III tests of fixed effects from mixed effects models predicting self-reported emotion dysregulation with moderation by baseline working memory (WM) score.

	<i>df</i>	<i>F</i>	<i>p</i>
Group	68.9	.05	.833
Time	194.0	1.67	.197
WM	68.9	.28	.600
Group x time	194.0	8.29	.004**
Group x WM	68.9	.016	.901
Time x WM	193.9	2.54	.112
Group x time x WM	193.9	7.86	.006**
Residual variance	15.3		
Random effect variance	135.9		

** $p < .01$

Figure 1. CONSORT flow diagram depicting the movement of subjects through each phase of the randomized controlled trial.

Figure 2. Three-way interaction of group, time, and probe type in predicting local accuracy during the Go/No-Go task. Mindfulness training (blue), relative to a lifestyle education group (red) did not differentially impact the effects of mind-wandering (dotted line) on local accuracy.

Figure 3. Three-way interaction of group, time, and probe type in predicting local reaction time during the Go/No-Go task. Mindfulness training (blue), relative to a lifestyle education group (red) did not differentially impact the effects of mind-wandering (dotted line) on local reaction time.

Figure 4. Group by time interaction for prediction of DERS total score. There was no significant difference in the effects of MBAT (blue) relative to lifestyle education (red) on self-reported emotion dysregulation.

Figure 5. Four-way interaction of group, time, probe, and baseline working memory in predicting local accuracy during a Go/No-Go task. A significant four-way interaction was observed; however, this interaction was likely driven by regression artifact, and does not reflect true moderation of training effects on local accuracy by working memory.

Figure 6. Three-way interaction of group, time, and baseline working memory (WM) in predicting DERS total score. Training effects on self-reported emotion dysregulation were significantly moderated by WM, such that for participants with high WM, MBAT resulted in larger reductions DERS score.