Examining the Effects of Mindfulness Training on Executive Functioning in Older Adults

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Abstract

Research in cognitive aging provides extensive evidence of age-related cognitive decline. To better understand the extent of cognitive plasticity in the adult years, researchers have developed interventions designed to improve and maintain cognitive functioning. Research in mindfulness training as a cognitive intervention has demonstrated improvements in attention and working memory performance in young adults, but it remains to be determined whether these effects are observed in older adult populations. In this study, we conducted a randomized control trial to investigate whether mindfulness training improves executive functioning and working memory in community-dwelling older adults. Twenty-seven older adults (ages 60-75) participated in either a low-dose version of the Mindfulness Based Stress Reduction course or a lifestyle education course. Performance between groups was compared on several standardized neuropsychological tasks of visuospatial attention, set-shifting, and working memory. Mindfulness training resulted in a marginally significant improvement in attentional orienting, but no significant improvements in working memory or set-shifting abilities relative to the active control group. Results suggest that mindfulness training may enhance attentional functioning, but further research is needed to determine the cognitive effects of mindfulness training for older adults.

Examining the Effects of Mindfulness Training on Executive Functioning in Older Adults

Research in cognitive aging provides extensive evidence of age-related changes in cognition and neural structures (Head et al., 2004; Park, 2000; Raz et al., 2005; Salthouse, 2010). In general, adults show a decline in cognitive functioning through adulthood, while maintaining the opportunity for both gains and losses (Lindenberger et al., 2008). The popular belief regarding aging is that cognitive ability depends on how we use our brains, as often expressed in the phrase, "use it or lose it". To better understand the processes related to aging, researchers have investigated cognitive changes and the potential for cognitive enhancement in older adult populations. By understanding the mechanisms underlying neuroplasticity in adulthood, we can maximize cognitive functioning through the adult years.

Despite the plastic nature of the brain, it is well known that aging processes result in noticeable changes in cognition across the lifespan. These cognitive changes are most identifiable when comparing older adults to young adults. The dominant perspective in cognitive psychology is that aging accompanies a decline in several domains of cognitive functioning including processing speed, working memory, and executive functioning (Braver & West, 2008; Salthouse, 2010; Verhaeghen & Cerella, 2008). Older adults also experience difficulties in attention, particularly tasks that require attending and responding to multiple sources of information. These differences have been observed in cross-sectional and longitudinal research, indicating that changes in cognition start around 30 years of age and decline linearly across the lifespan (Park & Reuter-Lorenz, 2009).

There are two well-supported hypotheses used to explain the general decline in cognitive performance. One line of research identifies a decline in processing speed as a fundamental mechanism that accounts for age-related variance in many cognitive tasks (Salthouse, 1996).

Because of decreased processing speed, overall cognitive functioning is impaired because of the time sensitivity of incoming information, which if not processed in time, impairs an individual's ability to use that information for other cognitive processes. This decreased processing has been shown to influence working memory, free recall, and verbal fluency (Salthouse, 1996).

Another perspective on cognitive aging is that decreased inhibitory control, or the ability to suppress irrelevant thoughts or actions is responsible for broad deficits in general cognition (Dempster, 1992). A loss of inhibitory functioning decreases a person's ability to attend and respond to incoming information, and reduces working memory capacity and attention. Inhibitory functioning also affects memory processes, as age-related decreases in inhibitory mechanisms fail to suppress irrelevant information and override pre-potent responses (Gerard, Zacks, Hasher, & Radvansky, 1991).

In an effort to better understand these cognitive deficits, research in neuroscience has documented reliable changes in the volume of many brain structures related to aging (Raz et al., 2005, Park and Reuter-Lorenz, 2009). Cross-sectional and longitudinal structural data indicates reductions in prefrontal, hippocampal, caudate, and cerebellar regions, with little change in the visual regions (Raz et al., 2004; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003). Cortical thickness analyses of older adults compared to young adults demonstrate significantly thinner prefrontal cortical regions, but preserved thickness in the parahippocampal and temporal areas (Salat et al., 2004). Structural decline in white-matter fibers that connect gray-matter regions suggest deficiencies in neural communication between brain regions (Head et al., 2004). These structural changes are related to decrements in cognitive performance. White-matter hyperintensities found in older adults have been negatively related to speed of processing (Bartzokis et al. 2009; Sullivan, Rohlfing, & Pfefferbaum, 2010). Hippocampal shrinkage predicts episodic memory, and prefrontal volumetric reduction influences working memory and inhibitory control (Head, Rodrigue, Kennedy, & Raz, 2009). Nevertheless, the study of structural correlates with cognition is still in its early stages. Researchers have not fully elucidated the connection between structural integrity and cognitive functioning.

Even with the cellular loss contributing to changes in brain structure and cognition, cognitive researchers provide evidence the brain develops compensatory mechanisms to maintain optimal cognitive performance in adulthood. Older adults show greater activation across frontal regions in the brain used for comprehension and information management when compared to young adults (Cabeza, 2002; Colcombe, Kramer, Erickson, & Scalf, 2005; Park & Reuter-Lorenz, 2009; Reuter–Lorenz & Cappel, 2008). For example, young adults show left lateralized frontal activity in verbal working memory encoding and right lateralized activity for spatial working memory. In contrast, older adults have bilateral recruitment for both these cognitive processes (Reuter-Lorenz et al., 2000). These hemispheric asymmetry reductions may facilitate task performance evidenced by high performing older adults engaging more bilateral activity than low-performing adults (Cabeza, 2002; Reuter-Lorenz & Cappel, 2009). Conversely, some research suggests these changes indicate neural inefficiency, as high-performing older adults in attentional tasks show lateralized activation patterns similar to those of young adults (Colcombe et al., 2005, Logan et al., 2002). Future research may offer insight into the relationship between activation differences and their relationship to cognitive functioning in older adults.

Given the behavioral, structural, and activation changes that occur with age, understanding brain plasticity is a major factor in designing interventions to maximize cognition. In the past two decades, researchers have focused on cognitive and behavioral interventions that improve cognition in older adults (e.g. Baltes & Kliegl, 1992; Erickson & Kramer, 2009;

Kramer, Larish, & Strayer, 1995). The earliest intervention studies were designed to isolate and train a particular cognitive mechanism (e.g. Kramer & Willis, 2003). This approach enabled the experimentally controlled study of plasticity in adult cognition. In these interventions, training gains were substantial and maintained for a long period, but they were limited to the targeted ability (Wilis & Nesselroade, 1990). Thus, adults showed the ability to obtain knowledge and improve their cognitive performance, but little transfer occurred outside the designated cognitive skill-set (Ball et al., 2002).

Additional intervention studies have looked at the effects of metacognitive training strategies, such as adapting training to shift processing priorities between tasks (Kramer, Larish, & Strayer, 1995; Kramer, Larish, Weber, & Bardell, 1999). With these forms of training, older adults developed better attentional control skills. Jennings et al., (2005) showed that older adults who underwent recollection training had good transfer to task contexts beyond the focus of training. The training of target mechanisms such as executive functioning and working memory (Basak, et al., 2008, Bherer et al., 2005, 2006; Karbach & Kray, 2009; Li et al., 2008) has generalized to multiple task environments. Future research of cognitive interventions will include behavioral measures of cognition along with neuroimaging analyses to illustrate the interaction of biology and cognition across time (e.g. Engvig et al., 2010).

Given that benefits of cognitive training may extend to multiple tasks environments, this study investigates whether mindfulness training can significantly impact cognitive functioning in older adults. The term mindfulness is described as a “self-regulation of attention so that it is maintained on immediate experience, thereby allowing for increased recognition of mental events in the present moment” (Bishop et al., 2004). As a form of attentional control, mindfulness directs cognitive resources toward the present task, rather than being scattered extraneously and less efficiently. To contrast mindfulness, an individual would be preoccupied in several thoughts streams, typically involving past experiences or future anticipations. In particular, rumination, the process of dwelling on one's situation and searching for meaning in regards to negative events, is inversely correlated with mindfulness (Deyo, Wilson, Ong, & Coopman, 2009).

Interest in mindfulness and related practices has resulted in a number of studies examining the therapeutic benefits of mindfulness and meditation-based interventions (Grossman, Niemann, Schmidt, & Walach, 2004). A number of research studies support the use of mindfulness training for improving psychological and physical maladies. Many clinical studies involve an standardized 8-week intervention known as Mindfulness Based Stress Reduction (MBSR). This course of mindfulness training was originally designed to teach mindfulness meditation to chronically ill medical patients (Kabat-Zinn, 1982), but has been studied with healthy adults and other clinical populations. A recent meta-analysis of studies with MBSR supports its effectiveness for improving improve symptoms of stress, pain, anxiety, and depression (Grossman et al., 2004).

In addition to studying the effects of mindfulness training on mood and affect, mindfulness has also been studied for its beneficial effects on cognition. Considered a form of cognitive training (Cahn & Polich, 2006), a growing body of research suggests that mindfulness training and meditation experience may lead to improvements in cognition and changes in the structure and function of the brain (e.g. Davidson et al., 2003; Jha, Krompinger, & Baime, 2007; Lazar et al., 2005; Xiong & Doraiswamy, 2009).

Several studies have investigated the relationship between mindfulness and attentional control. Jha, Krombinger, and Baime (2007) examined the effects of mindfulness training on alerting, orienting, and conflict monitoring using the Attention Network Test (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Participants in an 8-week MBSR course showed improved orienting compared to those in a wait-list control condition. In a 5-day intervention, meditation training with college undergraduates improved selective attention (Tang et al., 2007) . A cross-sectional comparison of attentional processing in mindfulness meditators and controls showed that mediators had better attentional orienting compared to controls (Van den Hurk, Giommi, Gielen, Speckens, & Barendregt, 2010). While the methodologies of training differ, results suggest experience in mindfulness techniques results in enhanced attentional abilities with young adults.

In addition to studying the impact of mindfulness on attentional functioning, mindfulness training enhances working memory in young adults. Jha et al. (2010) showed that a military cohort completing 8-weeks of mindfulness training experienced improvements in working memory capacity. Without prior experience, participants in a 10-day meditation training course demonstrated significant improvements in working memory capacity and sustained attention relative to a wait-list control group (Chambers, Lo, & Allen, 2007). These studies confirm that various forms of mindfulness training result in improved cognitive outcomes. While the duration of the training varies, results indicate that mindfulness training has robust effects in a short amount of time.

There is evidence to support the beneficial effects of mindfulness meditation from research in neuroimaging. There are several studies that look at the relationship between mindfulness meditation and volumetric or cortical thickness measures. Lazar et al. (2005) found that meditation is associated with increased cortical thickness in the left superior frontal gyrus and the right anterior insula. Volumetric increases in meditators have been observed in the right orbitofrontal cortex, right thalamus, and right and left hippocampi (Holzel et al., 2008; Holzel et al., 2010; Luders et al., 2009). These volumetric differences suggest changes in the functionality of emotional regulatory and interoceptive mechanisms (Holzel et al., 2010). Further research is needed to determine whether structural changes related to meditation are associated with significant alterations in cognitive functioning.

Having summarized previous research examining mindfulness, neuroanatomy, and cognitive functioning, it is important to acknowledge that none of this research has directly examined the effects of mindfulness training or related practices with older adults. Given the research that mindfulness training improves cognition in young adults, it remains to be determined whether this relationship applies to populations much older. While plasticity has been demonstrated in older adult populations, the extent to which mindfulness can improve cognition in older adults warrants exploration.

The present study seeks to investigate the impact of a modified version of MBSR on the older adult population. In order to better understand the effects of mindfulness training on cognition, brain structure, and neural recruitment in older adults, volunteers completed one of two possible interventions. The first was an 8-week course of mindfulness training called Mindfulness Based Stress Reduction – Low Dose (MBSR-ld; Klatt, Buckworth, & Malarkey, 2008). This program is slightly modified from the original MBSR (Kabat-Zinn, 1982), in that participants have shorter classes (1 hour) and shorter practice periods (20 minutes). The program consists of informal and formal meditation, Hatha yoga, and focuses on the practical experience of the tenets of mindfulness as designated by the MBSR course. In order to adapt this to a randomized clinical trial, an additional control group completed a lecture series called "The Culprit and the Cure". This group was designed to control for the non-specific effects of the intervention, such as social enrichment and learning. The lecture series covered why lifestyle is the culprit behind American's poor health and provided options for how to improve health through diet and exercise modifications. Participation in this study also entailed cognitive assessment before and after to determine the effects of each intervention. In order to prevent test re-test effects, all tests were modified from their original transcription after the initial assessment. The tests were then re-administered with alternate versions of the tasks, but the instructions and tasks remained the same.

The neuropsychological assessment included several different measures of cognitive functioning; specifically, we sought to measure changes in visuospatial attention, set-shifting, and working memory. We predicted that older adults in the MBSR-ld condition would show significant improvement in attention and task switching based on previous work with young adults (Jha, Krompinger, and Baime, 2007; Tang et al., 2007). We also predicted that mindfulness training would be related to improvements in working memory compared to the active control group (Chambers, Lo, & Allen, 2007; Jha et al., 2010; Zeidan et al., 2010). In addition, we expected higher self-reported mindfulness in the mindfulness-training group following the intervention (Klatt et al., 2008).

Method

Participants and Procedures

Twenty-seven adults ages 60 – 75 (22 females, 6 males) were recruited to participate in the study. Recruitment consisted of newspaper and radio advertisements, flyers posted in public areas, and presentations given throughout the greater Columbus area. Volunteers interested in participating in a lifestyle intervention study underwent a brief telephone interview to determine eligibility. All participants were right handed and had not been diagnosed with color blindness, untreated hypertension, inflammatory diseases, psychiatric illness, or neurological disorders. Additional exclusionary criteria included previous meditation or yoga experience, an inability to perform movement exercise, a score of less than 23 on the Mini Mental Status Exam (MMSE; Folstein et al., 1975) and a score greater than 11 on the Geriatric Depression Scale (GDS; Yesavage et al., 1983). All participants were also screened for their eligibility to participate in an MR environment. Participants were instructed that the study was designed to examine the effects of lifestyle interventions on health behaviors. In order to minimize expectancy effects, the words "mindfulness" and "meditation" were avoided (Shapiro, 1987).

The research design was a mixed 2x2 design with the between subjects factor of group (mindfulness vs. education) and the within-subjects factor of time (pre- and post-intervention). Individual pre- and post-intervention neuropsychological assessments were conducted with all participants. All participants successfully completing the pre-assessment sessions were randomly assigned to one of two groups: an intervention group completing an 8-week Mindfulness Based Stress Reduction - low dose (MBSR-ld) course or an active control group completing an educational course. All 13 participants in the meditation group (M=65.69, SD=4.09, range 60-75; 2 male), and 13 out of 14 in the control group (M=65.79, SD=3.401, range 60-75; 4 male) completed the study. The one participant who did not complete the study reported a family emergency that conflicted with participation. All participants were compensated for their time and participation. The Ohio State University Institutional Review Board approved this study. Table 1 summarizes baseline demographic and neuropsychological characteristics of the participants in this study. There were no significant differences between the two intervention groups with respect to age (p=.80) or education (p=.22).

Self-Report Mindfulness Measure

Mindful Attention Awareness Scale. The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) was administered to all participants to assess trait levels of mindfulness disposition pre- and post-intervention. MAAS is a 15-item instrument designed to assess the experience of mindfulness in general terms as well as in everyday circumstances, including attention and awareness of actions, thoughts, and emotions. Items are scored using a 6-point Likert scale from 1 (*almost always*) to 6 (*almost never*). Please see Appendix 1. The MAAS shows good internal consistency across a wide range of samples (a=0.80–0.87). Test-retest reliability data across a one-month time period suggests mindfulness disposition is stable (Brown & Ryan, 2003). The MAAS has been used in several demographic groups including adolescents (Brown et al., 2011), cancer patients (Carlson & Brown, 2004), and adults (MacKillop, & Anderson, 2007).

Cognitive Measures

Neuropsychological assessment consisted of three widely used measures for assessing various facets of executive control: the n-back task, task-switching, and the cued discrimination task. These tasks were administered at pre- and post-intervention. All tasks were counterbalanced in addition to within subject counterbalancing for pre- and post-assessment. All assessments were held within one month before or after the intervention.

N-Back. We used a computerized version of the N-Back task (McElree, 2001) to measure working memory performance (see Figure 2). The task consisted of a block design with two conditions (1-back and 2-back) presented twice in a random order. The entire run (approximately 8 minutes total) consisted of two blocks of 1-back trials and two blocks of 2-back trials interleaved with blocks of fixation. Participants were asked to indicate whether or not the letter on the screen matched the one right before it (1-back) or matched the letter presented two letters back (2-back). They responded with their right-index finger if it was a match and with their left-index finger if it was not a match. The order of the four blocks was randomized and instruction screens that lasted for 3000 msecs on the screen were presented at the start of each block to alert the participant of the upcoming condition. Each block consisted of thirty trials, and for each trial, a letter was presented on the screen for 1500 msecs and participants were given 1500 msecs to respond to the letter. The inter-stimulus interval was 1500 msecs. The fixation blocks were presented before the instruction screens and after the task blocks, each lasting for 4500 msecs. Both reaction time and accuracy data were recorded for the 1-back and the 2-back trials.

The principal measure of interest for this task was the 2-back cost measuring the cost associated with performance with increasing working memory load. 2-back RT cost was calculated by subtracting the 1-back RT from the 2-back RT. For accuracy, 2-back accuracy cost was calculated by subtracting 2-back accuracy from 1-back accuracy, which represents the decrease in accuracy with increasing task difficulty.

Task Switching. Participants completed a computerized task-switching protocol (Pashler et al., 2000; Boot et al., 2009) to assess set-shifting abilities (see Figure 3). The task consisted of two blocks of single tasks, requiring them to maintain a single attentional set, and one block of dual task, in which they switched from one task to the other depending on the background of the stimuli. The two tasks that were included in the study required the participant to judge whether a number (1,2,3,4,6,7,8, or 9) was high or low (i.e. greater or less than 5) and judge whether the number was odd or even. Numbers were presented individually for 1500 ms against a pink or blue background at the center of the screen, with the constraint that the same number did not appear twice in succession. If the background was blue, participants responded with their left hand to indicate whether the digit was high (“X” key) or low (“Z” key). If the background was pink, participants used their right hand to respond whether the number was odd (“N” key) or even (“M”). The two single blocks consisted of 24 trials, and we calculated both single RT and single accuracy data from these two blocks. The dual task block consisted of 120 trials and involved trials that either required a switch in the task from the previous trial (switch trials) or did not require a switch from the previous trial (repeat trials). We calculated RT and accuracy data for these trials. The total task length was around 18 minutes.

The primary measure of interest was the switch cost associated with maintaining two attentional sets (global switch cost) and the cost associated with shifting between tasks during the dual task condition (local switch cost). Global cost was calculated by subtracting the RT of the trials in the single blocks from the repeat trials of the dual blocks. Local cost was calculating by taking the difference in RT between the switch trials and the repeat trials in the dual task block. Similarly for accuracy, we calculated the global switch cost accuracy and local switch cost accuracy.

Cued Discrimination Task. The Cued Discrimination Task (see Figure 4) is a computerized protocol (Posner & Cohen, 1984) to assess visuospatial attention. The task consists of three conditions (valid, invalid, and neutral), which are randomly presented to the participants in the course of the experiment. For every condition, participants were asked to indicate whether the letter presented on the screen was a consonant (“X” key) or a vowel (“M” key). Before each letter was presented, a 500 ms arrow cue appeared on the center of the screen. This arrow pointed either toward the location of the subsequent letter (valid condition), away from the location of the letter (invalid condition), or alerted the person to the oncoming stimulus with arrows pointing in both directions (neutral condition). Following each cue, a 100 ms delay period elapsed before the presentation of the letter for 2000 ms on either the right or left side of the screen. Participants completed 240 trials during the task, with 80 trials of each condition. The task lasted approximately 15 minutes.

The primary dependent variables in this task were the reaction time and accuracy of participants during the invalid condition, which measures performance on the most challenging condition of this task.

Intervention

Experimental Group: Low-Dose Mindfulness Based Stress Reduction Course (MBSR-ld) - The MBSR-ld course participants met one hour each week with a trained instructor for a total of eight weeks, with one two-hour retreat including a meal in the sixth week instead of the regular class. MBSR-ld incorporates breathing, relaxation, body scans, and yoga movements, with the goal of developing enhanced attention to the present moment. Handouts and homework reflections were provided to deepen understanding of the course material. Participants were also instructed to complete a 20-minute meditation four times a week. To track adherence to the study protocol, participants completed a log of daily meditation time. To facilitate these meditations, participants received two CDs with six different 20-minute recordings. Each recording included a written description of the subject of the recording. Topics on the CD corresponded to themes in the weekly meetings.

Control Group: Lifestyle Education Course **-** As an active control condition, half of the participants were randomized to a lifestyle education course. Participants in this group met for the same duration as the mindfulness group. Discussions and lectures were conducted by a physical therapist experienced with the course material. Each week, participants were asked to read a chapter from *The Culprit and the Cure: Why lifestyle is the culprit behind America's poor health* by Steven Aldana as preparation for the class. To evaluate compliance, weekly quizzes were given at the beginning of each class period. For the retreat, participants were provided with a healthy meal and watched and discussed the film *Super Size Me*.

Analyses

To analyze changes resulting from the intervention on mindfulness disposition and neuropsychological functioning, repeated measures ANOVAs with time (pre-assessment, post-assessment) as the within-subjects factor and group (MBSR-ld, Control) as the between-subjects factor were conducted.

In the mindfulness group, bivariate correlations (Spearman's for non-parametric samples) were conducted to examine the association between formal meditation practice time and changes in mindfulness disposition.

Results

Mindfulness Disposition

The extent to which mindfulness disposition increased following the intervention was analyzed with repeated-measures ANOVA, with group (mindfulness vs. control group) as the between-Ss factor, and time (pre-intervention vs. post-intervention) as the within-Ss factor. Results revealed no significant group X time interaction based on self-reported mindfulness disposition ($F(1,21)=1.48$, $p=.70$, $\eta 2=.01$; See Figure 5), suggesting the mindfulness-training group, relative to the active control group, did not show significantly greater increases in mindfulness scores. There was no main effect of time (*F*(1,21)=1.31, *p*=.27) or group (*F*(1,21)=.00, *p*=.97)

Working Memory Performance

Performance on the n-back working memory task was analyzed with repeated-measures ANOVA, with group (mindfulness vs. control group) as the between-Ss factor, and time (pre-intervention vs. post-intervention) as the within-Ss factor. There was no time x interaction effect for 2-back RT cost (*F*(1,20)=.44, *p*=.52, η2=.02) or 2-back accuracy cost (*F*(1,20)=.05, *p*=.83, η2=.00). We also found no main effects of time (*F*(1,20)=.38, *p*=.54) or group (*F*(1,20)=.44, *p*=.52) for 2-back RT cost, and no main effects of time (*F*(1,20)=.48 *p*=.50) or group (*F*(1,20)=.35 *p*=.56) for 2-back accuracy cost.

Task Switching Performance

Performance on the task-switching task was analyzed with repeated-measures ANOVA, with group (mindfulness vs. control group) as the between-Ss factor, and time (pre-intervention vs. post-intervention) as the within-Ss factor. There was no time X group interaction for local RT cost (*F*(1,22)=.51, *p*=.49, η2=.02) or local accuracy cost (*F*(1,22)=.01, *p*=.92, η2=.00). Further analyses indicate no main effects of time (*F*(1,22)=.20, *p*=.66) or group (*F*(1,22)=2.07, *p*=.16) for local RT cost, and no main effects of time (*F*(1,22)=.13, *p*=.72) or group (*F*(1,22)=1.93, *p*=.18) for local accuracy cost. For global set-shifting, there was no time X group interaction effect for global RT cost (*F*(1,22)=.675, *p*=.42, η2=.03) or global accuracy cost (*F*(1,22)=2.40, *p*=.14, η2=.10). In addition, no main effects of time (*F*(1,22)=.02 *p*=.89) or group (*F*(1,22)= 03 *p*=.86) were found for global RT cost. There was a main effect of time (*F*(1,22)=5.58, *p*=.03 η2=.20), but not group (*F*(1,22)=.00, *p*=.98) for global accuracy cost.

Cued Discrimination Performance

Performance on the cued discrimination task was analyzed with repeated-measures ANOVA, with group (mindfulness vs. control group) as the between-Ss factor, and time (pre-intervention vs. post-intervention) as the within-Ss factor. There was a marginally significant group X time interaction (*F* (1,22)=3.30, *p*=.08, η2=.13) for the invalid trial accuracy (See Figure 6), indicating improved performance on accuracy of invalid trials in the mindfulness group relative to the control group. There was no main effects for time (*F*(1,22)=.49, *p*=.49) or group (*F*(1,22)=1.11, *p*=.30). There was no significant group X time interaction for reaction time data on the invalid trials (*F* (1,22)=.174, *p*=.68, η2=.01). In addition, there were no main effects of time (*F*(1,22)=1.93, *p*=.18) or group (*F*(1,22)=.57, *p*=.46).

Formal Meditation Practice Time and Changes in Mindfulness Scores

Total hours of meditation time for participants in the MBSR-ld course were calculated from logs collected during the intervention. Three participants did not record their practice time and were excluded from analyses of practice time. To calculate formal meditation time, the sum of each week's practice time was calculated. One participant in the mindfulness group practiced significantly more than other participants (2.6 S.D. above the mean). Thus, this person was excluded from the analyses. On average, participants (*n*=8) completed 13.12 hours of formal meditation practice (S.D.= 1.74 hours, range: 6.33 – 16 hours). Non-parametric bivariate correlations of formal meditation time were correlated with changes in mindfulness disposition.

Age was included as a covariate since total practice time was significantly correlated with age (r=.78, p=02). Total practice time was marginally correlated with changes in MAAS scores (r=.76, p=.08; see Figure 7), with practice explaining 35% of the variances in change in MAAS scores.

Discussion

The purpose of the present study was to investigate differences in executive control following a lifestyle intervention for older adults. In particular, we were interested in comparing two similarly structured interventions to determine specific improvements related to mindfulness training. While it was hypothesized that mindfulness training would improve attention and working memory ability, mindfulness training did not significantly improve working memory or set-shifting abilities relative to the active control group. Our results demonstrated a marginally significant improvement in attentional orienting ability for the mindfulness training group.

In addition to the hypothesized improvements in executive functions, we also expected that self-reported mindfulness would increase as a result of the mindfulness training. We did not find significant improvements in self-reported mindfulness in the mindfulness training group relative to the active control group following the intervention. These findings are inconsistent with the findings of previous research (Klatt et al., 2008) using the MBSR-ld intervention with working adults. The authors found a significant change in MAAS scores following the MBSR-ld intervention. There are several important differences between the current study and the previous study which may explain the divergent results. The previous research was conducted for studying stress reduction, whereas the current study was conducted as a lifestyle intervention for cognitive enrichment. As a result, motivating factors of volunteers may have impacted their expectations for the interventions. On average, participants in the study were twenty years older than participants in the previous study (Klatt et al., 2008), and all volunteers in the previous study were full-time faculty and staff at a university. Thus, expectations in the previous study's population (e.g. stress reduction) may have been different than the current population (e.g. education, health improvement). Klatt et al. also had a significantly larger sample in the intervention group (n=24) compared to the 24 participants (12 in each group) in this intervention study. Thus, the current analyses may be underpowered to detect differences between the groups. While Klatt et al. had a wait-list control group, all participants in this study completed an intervention. As a result, there are less differences between the groups analyzed in this study compared to those in the previous study. Together, these differences may explain the divergent results with the previous research involving MBSR-ld.

Although not significant, mindfulness training did improve orienting of attention, with 13% of the variance explained by the intervention. The proposed effects of this mindfulness intervention are consistent with the improvements in attentional orienting following mindfulness training with young adults (Jha et al., 2007). The authors found that 8-weeks of MBSR resulted in improved orienting relative to a wait-list control group. In addition, Tang et al. (2007) reported that undergraduates completing 5 days of meditation training had better performance on a task of selective attention. Although these studies involved younger age groups, the improvements in attention are consistent with the current study, supporting further investigation of the effects of mindfulness training on attentional processing. Future research should identify whether mindfulness training has an effect on other measures of attention with older adults.

MBSR-ld had no significant benefit on set-shifting and working memory function relative to the active control group. With a few exceptions, participants in both groups showed improvement in reaction time and accuracy in these tasks. Previous studies have shown that mindfulness training improves working memory in young adults (Jha et al., 2010; Zeidan et al., 2010). Zeidan et al. (2010) reported that 4 sessions of mindfulness training resulted in improved working memory. In this study, the mindfulness group had a significantly greater number of correct responses in a row on a 2-back task compared to the active control group. However, the authors did not find a significant difference between the two groups in reaction time on the 2-back task. In the study by Jha et al. (2010), the mindfulness group completed 8-weeks of mindfulness training and results were compared to a wait-list control group. The authors reported that mindfulness practice time was related to increased working memory capacity. In previous research on attention, Anderson et al. (2007) reported no improvement in task switching with healthy young adults completing an 8-week MBSR course compared to a wait-list control group. In the switching task, accuracy did not change for group or time and across both groups, and switch costs based on reaction time were larger at pre-test compared to post-test. Results indicate improvements in set-shifting ability were not unique to the mindfulness group. In our study, performance on measures of local cost did not significantly change across time or between groups. The main affect of global accuracy cost indicates that global cost was greater at pre-test compared to post-test, but no group differences were found.

There are several potential limitations of our study, which should be taken into consideration when interpreting the results. As mentioned before, this was a pilot study designed to assess improvements in cognitive functioning following a mindfulness intervention. We had a relatively small sample size in our study, which could have resulted in an underpowered study. In addition, this study addresses the effects of mindfulness in an older adult population, which may lead to different outcomes than young adults from a mindfulness intervention. For example, a reduction in stress may not be the top priority for the participants; instead, older adults may choose to focus more on educational aspects of the intervention. While we observed a change in mindfulness after the intervention, the change in scores were not as large as the changes observed previously by Klatt et al. (2008). This may reflect differences in reporting styles, such that older adults view their mindfulness as more stable across time compared to young adults. Because of the exclusionary criteria, the older adults in this study had no significant health issues. As a result, the intervention may not have resulted in a pronounced change in well-being or cognitive functioning since participants started in good health. Additionally, the inclusion of an active group may have diminished potential improvements of the intervention if we had compared mindfulness training to a wait-list control group.

It is also possible the duration of the intervention was not long enough to result in significant changes in mindfulness. However, this does not seem likely, as the previous MBSR-ld study (Klatt et al., 2008) was two weeks shorter than the current study. Attendance recordings and logs indicate the mindfulness classes had high attendance and participants completed the daily meditations. We did observe a marginally significant correlation when comparing meditation time to change in mindfulness, supporting the hypothesis that regular mindfulness practice is related to increased trait mindfulness. Future research should determine whether increasing the duration of the study results in additional improvements in self-reported mindfulness, such as comparing the low dose intervention to the tradition form of MBSR.

While previous research with young adults has demonstrated mindfulness training leads to better executive functioning, there were no significant improvements following this intervention with older adults relative to the active control group. This is the first study to include an intervention of mindfulness training with older adults. Further research with older adults will clarify the relationship between mindfulness training and attentional abilities.

Mindfulness training should continue to be studied for its potential as a therapeutic resource with the older population. As the benefits of mindfulness on psychological health are well documented in young adults (Grossman et al., 2004), the impact of mindfulness for older adults is an important empirical question. Mindfulness training is a low-cost, easy to implement intervention, and the skills apply to daily behaviors. The potential of mindfulness training to improve cognition is a significant motivating factor for further research. Given the longer life span of the adult generation and the popularity of lifestyle modifications, it is essential to better understand the effectiveness of this practice for the adult population. Research must continue to explore the potential for mindfulness practice to result in long-term cognitive benefits.

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Table 1

Baseline characteristics of participants in the lifestyle interventions

	Mindfulness Group			Education Group			p-value*
	M	**SD**	**Range**	**M**	**SD**	**Range**	
Age	65.67	4.27	60-75	66.08	3.58	60-74	.80
Gender	11 F/ 2 M			10 F/ 4 M			
Education	15.64	2.11	13-20	14.83	2.79	12-20	.45
MMSE	29.16	1.34	26-30	29.00	.95	27-30	.73
GDS	2.50	1.78	0-7	2.33	3.37	0-11	.88

Note. MMSE, Mini Mental Status Exam. GDS, Geriatric Depression Scale.

* *p*-values are two-tailed and based on independent samples t-tests with mindfulness or education as grouping variable.

Table 2

Summary of Performance on Neuropsychological Tasks

	Mindfulness Group (n=12)		Education Group (n=12)		GXT (*p*-value)
	Pre	**Post**	**Pre**	**Post**	
Cued Discrimination					
Invalid RT	742.62(52.83)	719.86(86.22)	737.00(101.64)	694.72(51.47)	.68
Invalid ACC	0.97(0.02)	0.99(0.02)	0.98(0.03)	0.97(.03)	.08*
NBack					
2-back RT cost	118.09(100.25)	169.36(163.95)	91.2(173.30)	89.48(104.95)	.52
2-back ACC cost	0.26(.24)	0.23(0.14)	0.31(0.21)	0.26(0.09)	.83
Task Switching					
local RT cost	200.46(248.89)	259.00(134.04)	313.11(136.95)	299.97(174.91)	.49
global RT cost	259.62(175.21)	282.41(110.17)	277.88(175.85)	245.74(137.70)	.42
local ACC cost	0.00(0.05)	0.01(0.03)	0.04 (0.08)	.02(.05)	.92
global ACC cost	0.09(0.16)	-.06(.126)	0.04(0.17)	-.01(.14)	.14

Note. All values represent mean scores on the neuropsychological tests. Standard deviations are given in parentheses. RT= reaction time (milliseconds). ACC = accuracy (percentage). G X T represents the probability of a group X time interaction.

* p <.10.

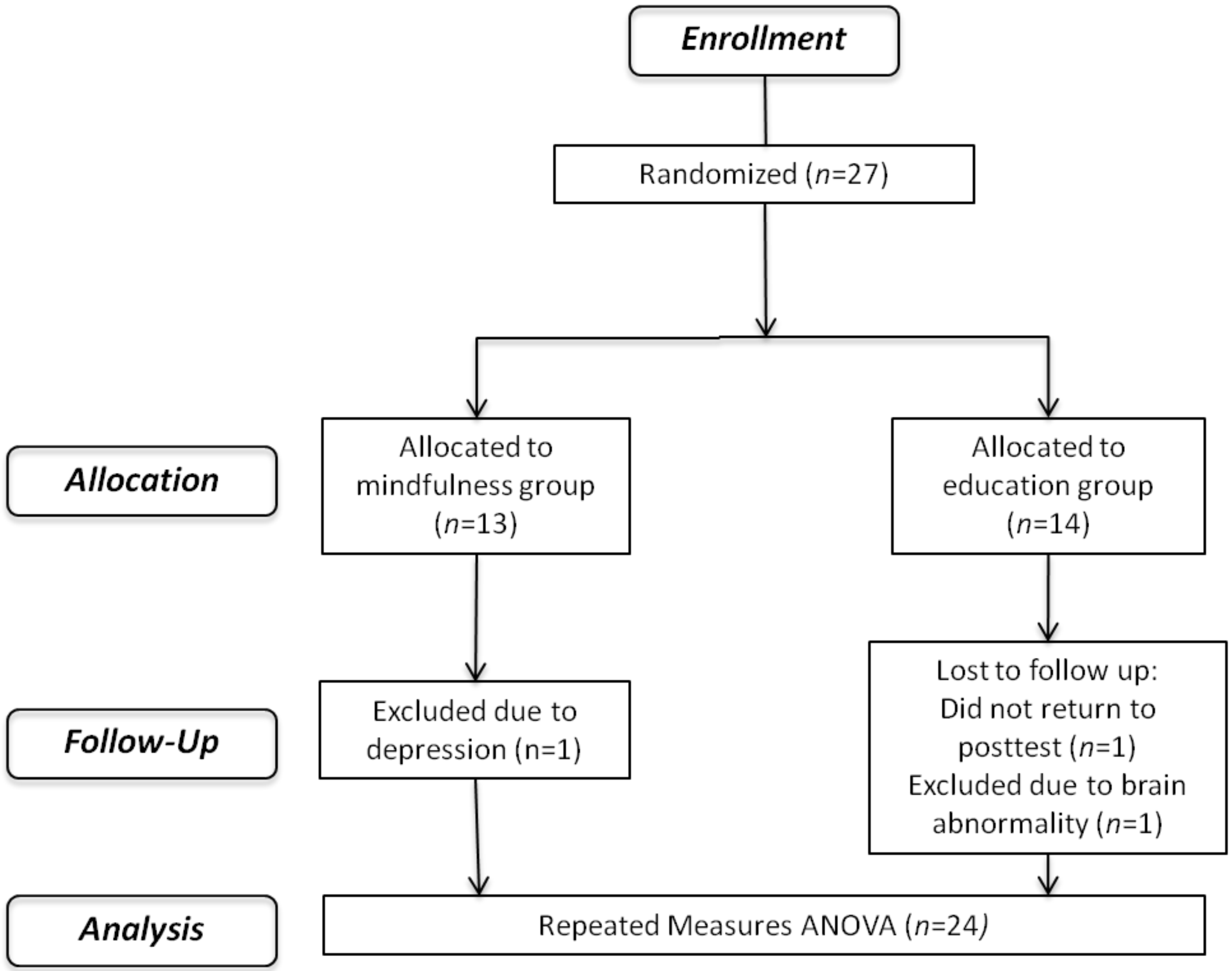

Figure 1. Participant flow chart. ANOVA= analysis of variance.

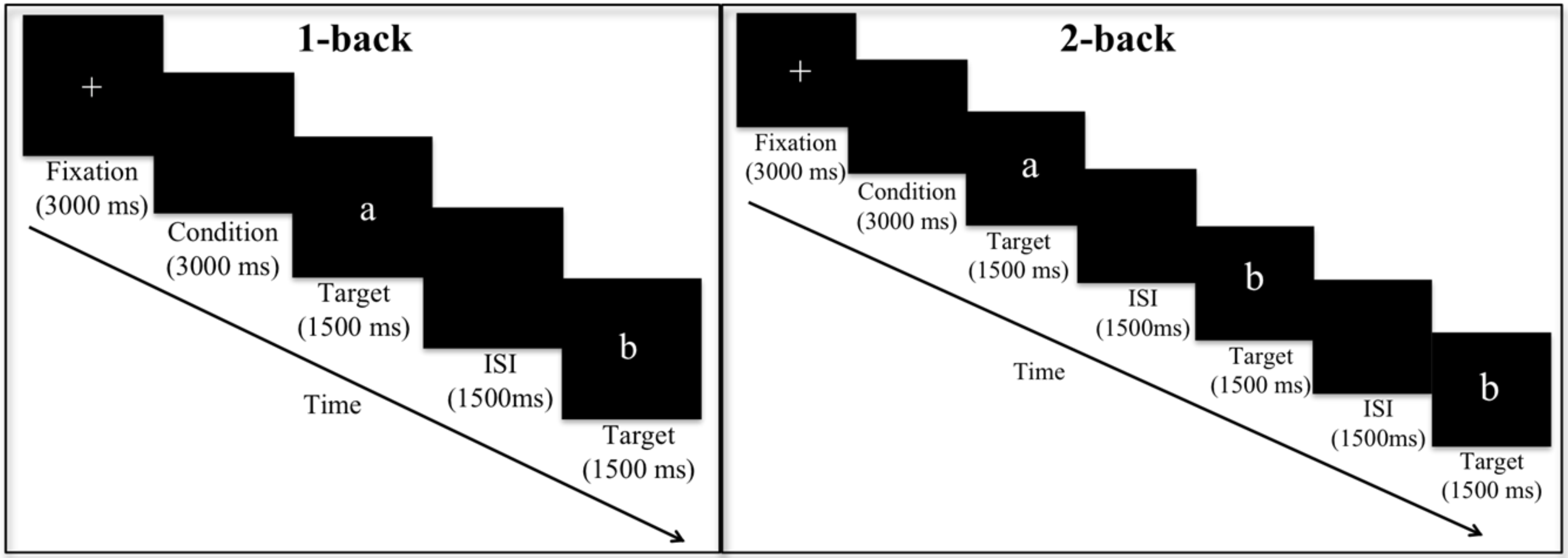

Figure 2. Diagram of the n-back working memory task. Participants were asked to indicate whether or not the letter on the screen matched the one right before it (1-back) or matched the letter presented two letters back (2-back).

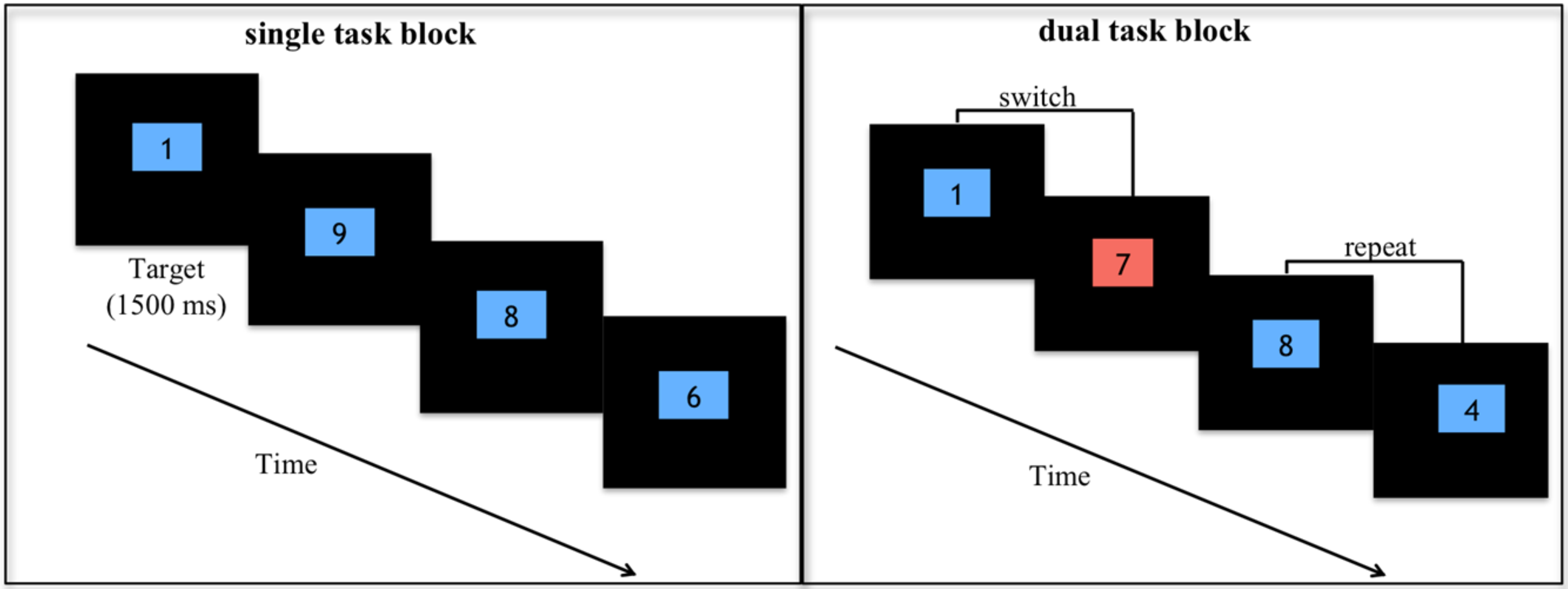

Figure 3. Diagram of the computerized task-switching protocol. The task consisted of two blocks of single tasks, requiring them to maintain a single attentional set, and one block of dual task, in which they switched from one task to the other depending on the background of the stimuli. The dual task block involved trials that either required a switch in the task from the previous trial (switch trials) or did not require a switch from the previous trial (repeat trials).

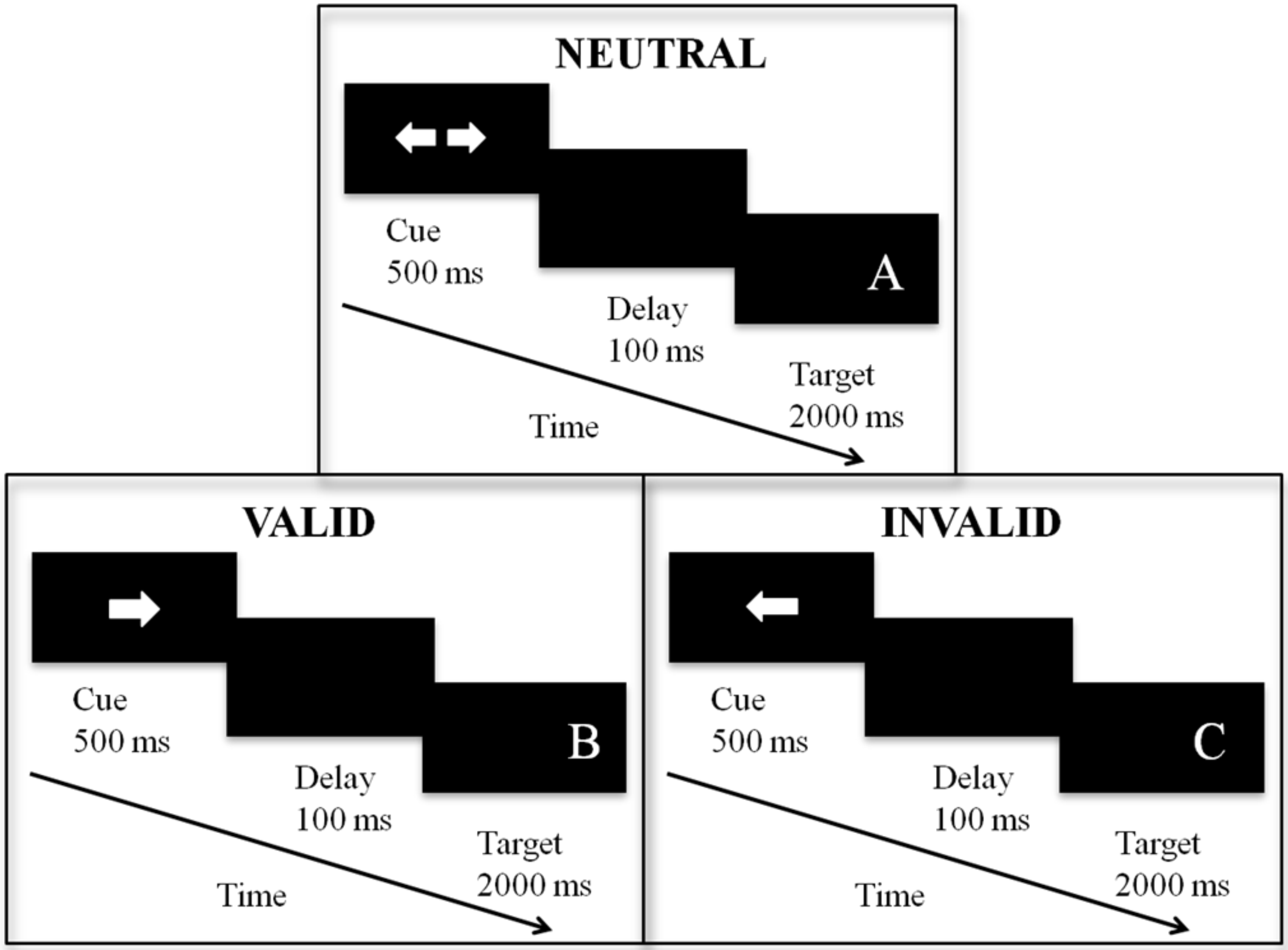

Figure 4. Diagram of the cued discrimination task. Before each letter was presented, a 500 ms arrow cue appeared on the center of the screen. This arrow pointed either toward the location of the subsequent letter (valid condition), away from the location of the letter (invalid condition), or alerted the person to the oncoming stimulus with arrows pointing in both directions (neutral condition).

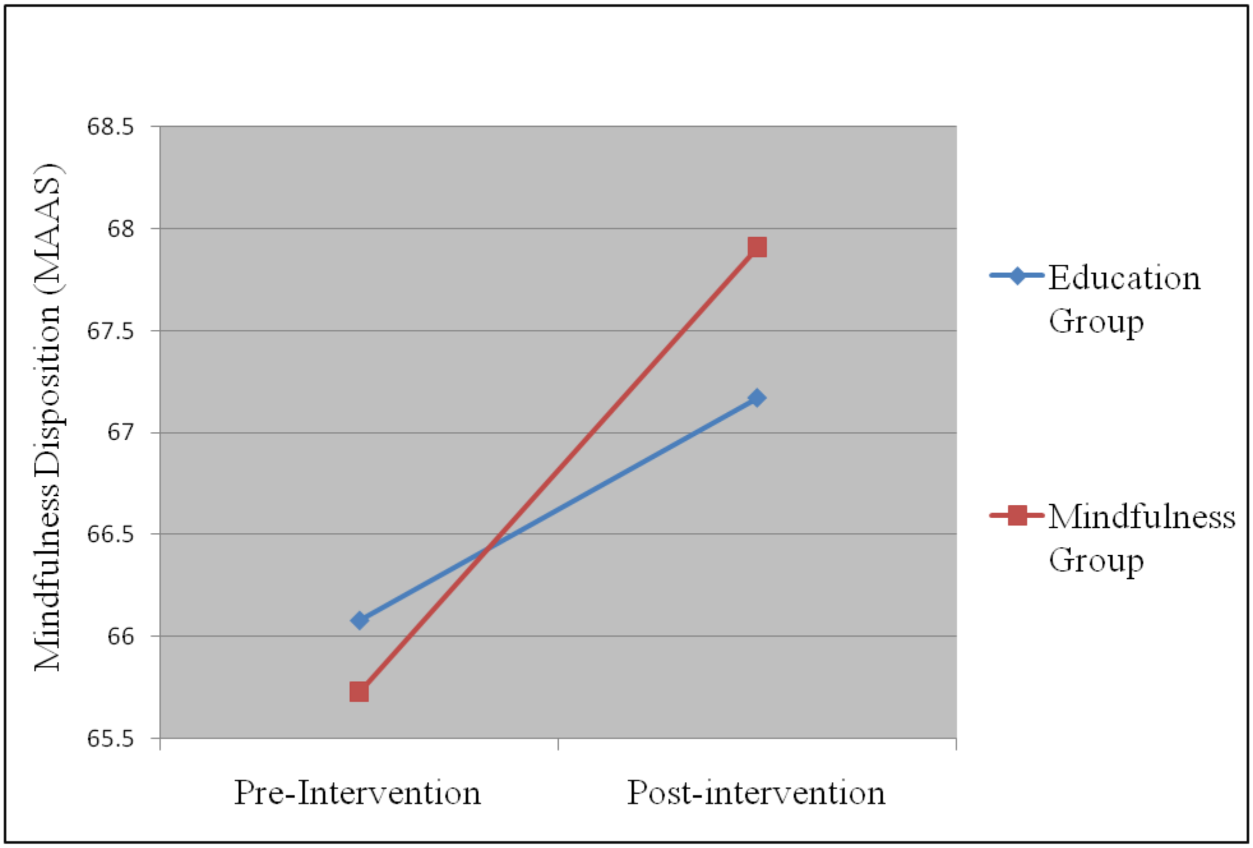

Figure 5. Changes in self-reported mindfulness disposition on the MAAS following the intervention. Group X Time interaction was not found to be significant.

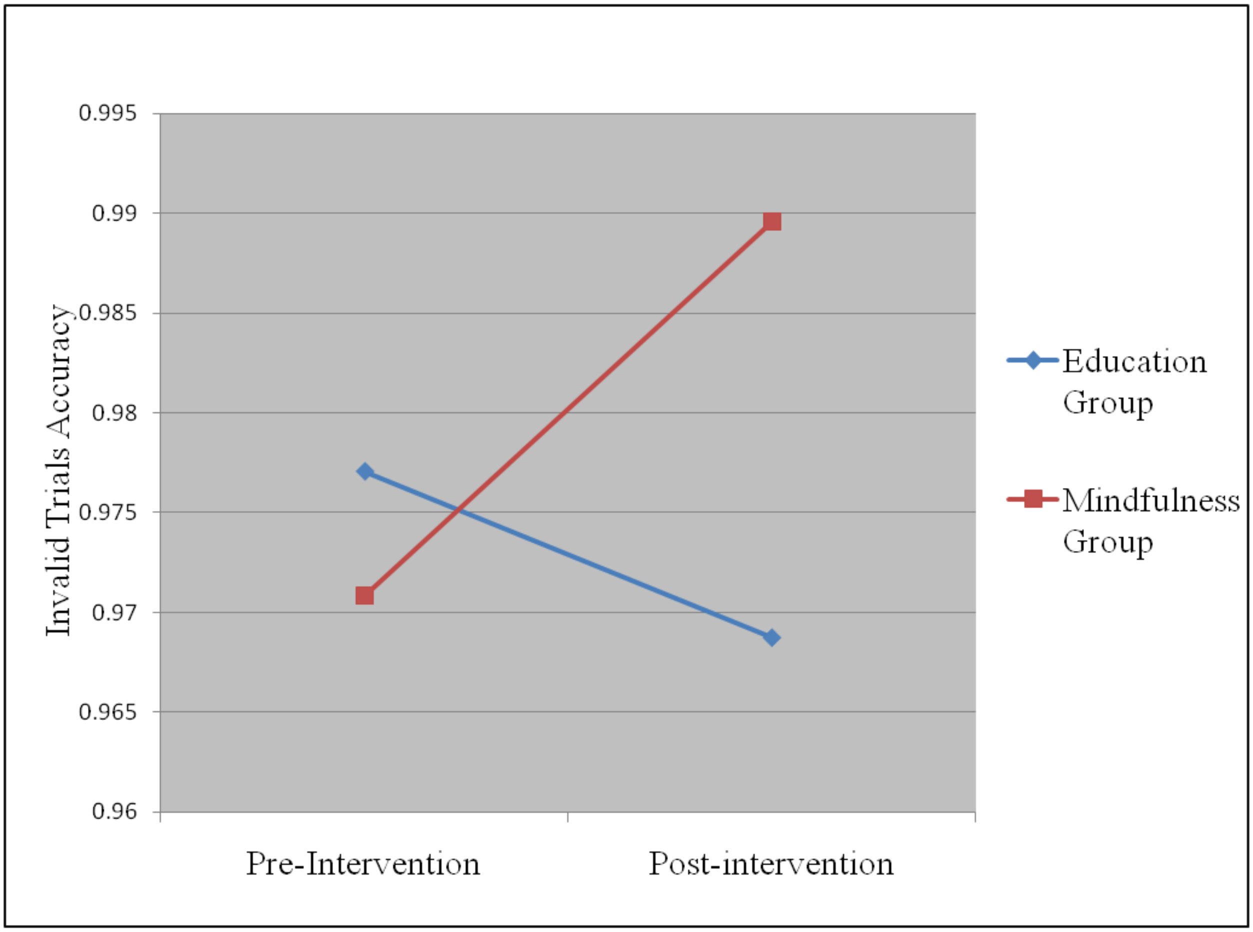

Figure 6. Changes in invalid accuracy following the intervention. Group X Time interaction was found to be marginally significant at p=0.08, η2=.13.

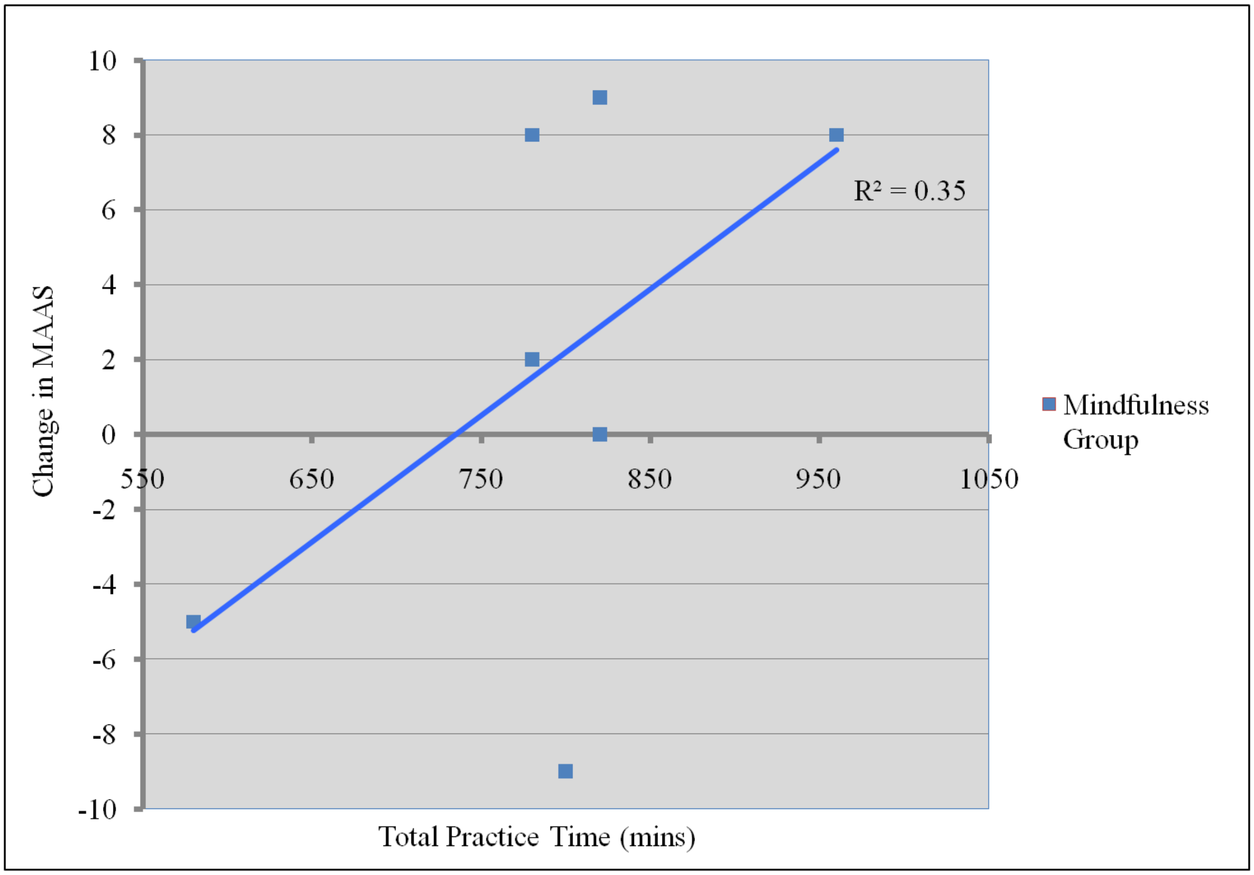

Figure 7. Correlation of mindfulness disposition and total practice time for the mindfulness group.

Appendix 1.

Mindfulness Attention Awareness Scale (MAAS)

Below is a collection of statements about your everyday experiences. Using the 1-6 scale below, please indicate how frequently or infrequently you have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be.

1-------------2-----------3-----------4------------5-------------6

Almost Always Almost Never

_____1. I could be experiencing some emotion, and not be conscious of it until some time later.

_____2. I break or spill things because of carelessness, not paying attention, or thinking of something else.

_____3. I find it difficult to stay focused on what's happening in the present.

_____4. I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.

_____5. I tend not to notice feelings of tension or physical discomfort until they really grab my attention.

_____6. I forget a person's name almost as soon as I've been told it for the first time.

_____7. It seems I am "running on automatic" without much awareness of what I'm doing.

_____8. I rush through activities without being really attentive to them.

_____9. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.

_____10. I do jobs or tasks automatically, without being aware of what I am doing.

_____11. I find myself listening to someone with one ear, doing something else at the same time.

_____12. I drive places on "automatic pilot" and then wonder why I went there.

_____13. I find myself preoccupied with the future or the past.

_____14. I find myself doing things without paying attention.

_____15. I snack without being aware that I am eating.