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Mindfulness Modulated Attention with Neurofeedback in Multiple Object Tracking

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MINDFULNESS MODULATED ATTENTION WITH NEUROFEEDBACK IN MULTIPLE OBJECT TRACKING

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ABSTRACT

MINDFULNESS MODULATED ATTENTION WITH NEUROFEEDBACK IN MULTIPLE OBJECT TRACKING

by Jennifer M. Brennan

Attention determines what we selectively perceive out of all available stimuli. The multiple-object tracking paradigm is a way of examining divided attention for object tracking in a complex visual scene. Mindfulness is a broad term for a set of diverse and specific methods for distinct attentional engagement and is one technique for increasing visual attentional ability and decreasing distractibility. Neurofeedback can be a way of enhancing mindfulness training for novice participants. This study examined the relationship between attention and mindfulness with neurofeedback through performance on a multiple-object tracking task and the Five Facet Mindfulness Questionnaire. We examined the effectiveness of using a brief mindfulness session to bring about state mindfulness and cognitive enhancement. All participants (N=90) performed a session of the multiple-object tracking task before and after either a mindfulness or relaxation intervention. Additionally half of the participants in the mindfulness training condition received neurofeedback. Results demonstrated that a single, brief mindfulness training session with neurofeedback was successful in increasing divided attention ability and was sufficient for bringing about an increased mindfulness state. An effect of mindfulness without neurofeedback on attention was not found. Results have implications for the use of brief mindfulness practices in a laboratory setting that could be applicable to a real world setting and the feasibility of neurofeedback as a mindfulness training tool.

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Introduction

Attention is what is consciously selected out of everything in our awareness. There are evolutionary and survival benefits to being able to choose what to attend to in an environment, known as top-down attention. As hunters, it helps humans to select prey in a complex environment and in modern society, it helps people make good use of their limited cognitive resources. In daily life people are rarely presented with a single object to detect and process at a time; instead people are typically confronted with many stimuli simultaneously. The ability to selectively focus and sustain attention across multiple objects requires the simultaneous ability to filter out distraction from the visual scene. If we are able to facilitate development of abilities that better allow us to enhance the amount of information we are able to maintain in our awareness, this allows for a greater perceptual ability and many other cognitive benefits. Attention is a main component in working memory, learning, and executive function. The degree to which people can selectively attend to information and ways of increasing this attentional capacity can serve to improve a variety of real life skills that allow us to achieve better driving ability, military performance and visual sensitivity.

The practice of mindfulness has been shown to increase attentional capabilities to allow for longer, more focused attention spans as well as improved accuracy for selectively attended stimuli in the environment (Baird, Mrazek, Phillips, & Schooner, 2014; Brown, Forte, & Dysart, 1984). Mindfulness is a technique for quieting the inner dialogue of the mind and allowing the practitioner to focus on a desired thought, object or task. Mindfulness practice also leads to a greater ability to suppress internal detractions from emotional arousal states and mind wandering (Brown et al., 1984; Jha, Morrison, & Dainer-Best, 2015). The practice of mindfulness has been used by practitioners for everything from stress and pain reduction to improving cognition, motivation and attention (Cardeña, Sjöstedt, & Marcusson-Clavertz, 2014; Spowart, 2015). One proven way of increasing mindfulness outcomes in novice practitioners is neurofeedback. Neurofeedback is given by a piece of technology that provides neurological information to the user in real time, based on the user's brain activity during a specific task (Gruzelier, 2013). From a cognitive standpoint this study focused on understanding the effects of practicing mindfulness with and without neurofeedback for cognitive enhancement in consciously perceiving and tracking multiple selected objects out of several simultaneously possible objects. The paper will address the questions of whether and how mindfulness with and without neurofeedback might modulate top-down divided attentional processes.

Multiple Object Tracking and Visual Attention

The multiple object tracking (MOT) paradigm is a cognitive task developed by Pylyshyn and Storm (1988) and it has been used to study attention, perception, and memory in the visual system. In a typical MOT experiment, participants view a computerized display with a varying number of objects on a neutral background; to start, some objects are identified as targets, whereas the rest are designated as distractions. The identifying features then disappear so that the targets and distractors appear identical. The goal of the multiple object tracking task is to track targets as they move and interact with distractors to ultimately to be able to identify the original targets. Most other cognitive attentional paradigms only evaluate attention to one object at a time; the MOT task is unique for its ability to examine divided attention as well as distractor suppression simultaneously. For this reason the current study will use the MOT task to examine divided attention and distractor suppression in the visual system.

Multiple object tracking has been successfully used to demonstrate attentional capabilities and limitations in many scenarios and is considered a good measure of attention. When first introduced by Pylyshyn and Storm (1988) it was used as a way to study detection in perception and object tracking in the visual field. They found that participants performed very well on the task, with an average accuracy rate of 90%. Since then, the underlying mechanism for the MOT has been better elucidated. Pylyshyn determined that attention to tracking multiple objects requires a pre-attentitive first step in which an object is subconsciously assigned an index or internal reference that is bound to the object, referred to as the feature-indexing (FINST) model (Pylyshyn, 2004). According to this model, once an observer indexes an object, the object's feature identity is maintained independently of position (Pylyshyn, 1994). Furthermore, object recognition and sustained control are provided by a cognitive system that constructs a conceptual representation from visual stimuli and connects it with certain elements in the environment (Pylyshyn, 2001). This suggests that tracking multiple objects in a visual scene requires both object feature detection, sustained attentional control of objects and suppression of distractors in order to successful identify tracked objects as targets. Sustained attentional ability required for MOT has been further confirmed. For example, Wolfe et al. (2007) tested the ability of participants to tack multiple objects over extended periods of time. They used a continuous block, rather than separate trials, of multiple targets and distractors in which the participant was probed at periodic intervals to say whether a selected item was a target or not, followed by feedback regarding their success. They found that, given feedback, participants could sustain attention to tracking multiple objects for up to 10 minutes (Wolfe, Place, & Horowitz, 2007). Sustained attention has clear real world implications, in that tracking may need to take place over several minutes, not just a few seconds as with most trials in laboratory MOT conditions.

Multiple object tracking was first adapted for study with functional magnetic resonance imaging (fMRI) by Culham and colleagues (1998) to look at brain activation associated with divided attentional control. They found the most reliable and robust activation in the parietal and frontal cortices (Culhamn et al.,1998) in the active tracking versus passive viewing condition. Within active tracking, the areas with the strongest blood oxygen level–dependent (BOLD) signal were the superior parietal lobules, suggesting this area's essential role in attentional tracking. In 2001, Jovicich and colleagues used fMRI to examine the neural mechanism underlying the effect of attentional load in MOT. Comparing active areas during engaged multiple object tracking versus passive viewing, researchers identified a small number of areas, most attentional in nature, the parietal cortex as well as the cerebellum and frontal cortex (Jovicich et al., 2001). Their results confirm Culhman et al.'s findings and suggest the attentional role of these areas in generating top-down signals for modulating attention to visual information.

The specific mechanism of attention for target enhancement and distractor suppression during MOT has been examined using electrophysiological measures as well. An electroencephalogram (EEG) measures the electrical signals of the brain on the surface of the scalp in the form of event-related potentials (ERPs). Examining ERPs after a stimulus onset is a way to measure brain activity associated with the allocation of attention to that stimulus. Using EEG, Drew et al. (2009) used EEG to look at the P1 and N1 components of the ERP response in participants performing a probe-dot version of the MOT in which probes were presented either above targets, moving and stationary distractors or empty space. P1 and N1 are pre-perceptual components in the form of positive and negative EEG activity that occur 80-130 ms and 120-300 ms post-stimulus onset for P1 and N1 respectively. For both P1 and N1 components, amplitude was highest for target probes. With distractor probes, P1 showed the greatest amplitude for moving distractors versus stationary but showed no difference for empty space (Drew, McCollough, Horowitz & Vogel, 2009), and N1 showed the greatest amplitude increase for targets (Doran, 2010). These findings support the idea that tracking multiple objects amongst distractors is a two-fold process involving focused target enhancement and purposeful distractor suppression on the neural level, as well as nonattention to empty space. MOT is a good measure of sustained and divided visuospatial attention required for multiple-object enhancement and distractor suppression in a visual scene.

EEG can also be used to look at the distinct waves of the brain. The brain emits five different bands of frequencies measured in cycles per second (Hz), each of which is distinctly associated with different mental states. From previous studies looking at attention, the alpha, beta and theta bands have come to be associated with attention for various cognitive tasks (Gruzelier, 2013). For instance, alpha has a frequency of 8 to 12 Hz, and is associated with relaxation and focus (Gruzelier, 2013). In a study using neurofeedback to obtain desired alpha levels, participants who successfully were able to achieve consistent alpha wave activity significantly improved their spatial rotation accuracy on a mental rotation task (Zoefel, Huster, & Herrmann, 2011). Beta has a frequency of 12 to 30 Hz, and low levels are associated with day dreaming and poor cognition whereas at higher levels are associated with conscious focus (Gruzelier, 2013). Theta at low levels (~5-6HZ) can lead to tiredness or inattention, but at optimal levels (~7Hz) is also associated with very deep mediation and visualization and has also been connected to focused attention and sustained concentration (Lagopoulos et al., 2009; Missonier & Deiber, 2006). Missonier and Deiber (2006) used EEG to examine bands associated with an oddball detection task that measures attention. They found an increase in theta power with increased performance on the attention task. Researchers were able to conclude that this increase reflected the activation of neural networks involved in allocation of attention related to target stimuli (Missonier & Deiber, 2006). Taken together, these data suggest that attention demanding tasks modulated brain waves at alpha, beta, and theta frequencies.

Mindfulness and Visual Attention

Mindfulness is the processes of developing an awareness of self as well as nonjudgement, nonreactivity and impassionate observation of presented stimuli (Carmody, Baer, Lykins, & Olendzki, 2009). The process leads to a shift in one's perceptual awareness from phenomenological to ontological, and from inner awareness to greater awareness beyond the self (Lutz, Slagter, Dunne, & Davidson, 2008). Mindfulness can be practiced in several ways including, yoga, tai-chi, raiki, meditation, and self-reflection, among other techniques (Semich, 2014). Of these techniques, meditation has been most widely studied for its cognitive benefits. The practice of mindfulness training has been shown to have numerous cognitive and health benefits. Mindfulness has been shown to decrease undesirable thoughts or behaviors by utilizing executive functioning in the prefrontal cortex. For example, the Mindfulness-Based Stress Reduction program (Kabat-Zinn,1994) has been shown for its health benefits to reduce depression and anxiety symptoms (Gu, Strauss, Bond, & Cavanagh, 2015), its cognitive benefits to improve working memory (Mrazek, Franklin, Philips, Baird, & Schooler, 2013) and spatial ability (Doran, 2010) and even a brief mindfulness training has been shown to impulsivity behaviors such as over-eating and risky sexual behavior (Papies, Pronk, Keesman, & Barsalou, 2014). The practice of mindfulness involves focusing one's attention on internal states with cultivating, enhancing and sustaining attention being some of the main goals. For these reasons this study will focus on the influence of a mindfulness training on the divided attention task of MOT.

Practicing mindfulness has been shown to improve attention and reduce distractibility (Jha et al., 2015). In their 2015 study, Jha et al. looked at the impact of mindfulness training on attentional performance in military cohorts. They found increased attentional sustainability in those who underwent the Mindfulness Based Stress Reduction program (Kabat-Zinn, 1994) as compared to those who did not as measured by reduced attentional performance lapses (mind wandering) in the Sustained Attention to Response Task (SART) (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) in which participants viewed stimuli on a computerized display and pressed a button whenever a non-target was shown. Results demonstrated that mindfulness training can be used to improve sustained attention and decrease distractibility. In another study, the visual attentional differences between experienced meditators and non-meditators using the SART was examined. Meditators had faster response times and reported fewer task-related interferences than non-meditators (Cardena et al., 2014). Meditators also reported higher intrinsic motivation for the attentional task, whereas non-meditators reported higher success motivation (Cardena et al., 2014). Together these results suggest that mindfulness increases visual attention and decreases susceptibility to distractions while increasing intrinsic motivation for sustained attention. While the mechanism for how mindfulness improves cognitive performance for attentional tasks has been understood, the specific relationship between mindfulness and divided attention ability with the MOT paradigm has yet to be examined. This is important as divided attention ability is applicable to a real world setting.

Studies looking at meditation support the mechanism by which multiple object tracking is thought to work. In 2010 MacLean and colleagues found that practitioners of mindfulness mediation tested for visual sensitivity and sustained attention ability before and immediately after a three-month mediation retreat showed an increase perceptual ability in target detection and discrimination ability as well increases in sustained attention. Results indicate that perceptual improvements from meditation can reduce the resource demand involved in target discrimination tasks thus allowing for more capacity for sustained attention. Researchers concluded that mindfulness meditation enables practitioners to become aware of some of the preattentive processes involved in visual detection (MacLean et al., 2010). Pylyshyn's FINST model states that object tracking requires a preattentive first step of object indexing (Pylyshyn, 2006). Mindfulness practitioners could have a greater ability for object indexing. Meditators became more aware than non-meditators of the biasing factors that affect perception such as arousal changes, perceptual sets, detection decisions, attitudes, and thoughts (Brown et al., 1984). In a visual sensitivity study, meditators could detect shorter light flashes and required a shorter interval to differentiate between successive flashes than non-meditators (Brown et al., 1984). It is further accepted that data from visual tracking studies can predict one's relative visual sensitivity (Bonnen, Urge, Yates, Pillow, & Cormack, 2015). Therefore, those that meditate should have greater visual sensitivity and be less affected by some of the factors that bias visual perception, which should allow for better performance on a MOT task. The mechanism by which mindfulness is thought to work corresponds to the mechanisms involved in successful multiple object tracking; however, this relationship has not been tested.

The neural mechanisms underlying the modulatory effects of mindfulness on attention have been examined. In a study comparing experienced meditators versus nonmeditators, meditators showed greater activation in areas implicated in attentional control including areas in the parietal and frontal cortex (Moadab, 2013) in meditators. Additionally, in a study comparing participants having undergone a mindfulness treatment versus a relaxation treatment, ERP signals were used to look at P1 and N1 measures in response to attended stimuli. The P1 component measures positive potentials immediately following stimulus onset and is associated with the suppression of unattended stimuli, whereas the N1 component measures negative deflection following P1 deflections and facilitates enhancement of attended stimuli. Results showed that mediators had larger P1 and N1 amplitudes in the extrastriate cortex compared to the relaxation group (Moadab 2013), suggesting that mindfulness practitioners have a greater ability to enhance attention for selected stimuli while simultaneously having a greater ability to inhibit distracting stimuli. Drew et al. 2009 research has shown that attention to tracking multiple objects simultaneously requires a two-fold process by the participant to enhance targets and suppress distractors. Meditation might be a way to selectively enhance both of these cognitive processes. Greater activation in brain regions implicated with attentional functions in meditators support the notion that mindfulness improves attentional abilities. In the present study, patterns in the frontal cortex were analyzed for evidence of a mindfulness state.

Both meditation and relaxation have been shown to produce cognitive benefits, but meditation practice has been shown to have a significant decrease in distractibility compared to relaxation (Jain et al., 2007). While relaxation has been shown to have a positive correlation with increased mind-wandering, previous research has demonstrated a negative correlation between mindfulness and mind-wandering (Mrazek, Smallwood, & Schooler, 2012). Researchers found that as little as eight minutes of mindfulness breathing reduced behavioral indicators of mind-wandering during a SART task compared to relaxation and reading conditions. These findings lend further support to Jha's findings (2015) that mindfulness practice reduces mind wandering and increases sustained attention. In a 2013 study Cahn, et al. looked at experienced practitioners of Vipassana meditation (known as mindfulness in western cultures) versus controls using EEG. Participants were instructed to either meditate or let their minds wander for 20 minutes. They were then presented with auditory stimuli for four minutes and told not to attend to it. Results from the EEG showed meditators, compared to controls, were less impacted by the presence of distractors as indicated by lower delta waves and greater event-related active suppression indicated by a reduction of alpha frequencies demonstrating meditators ability to actively, not passively, suppress distracting stimuli. Additionally with standard (attended) stimuli, meditators showed increased alpha and gamma power (involved in higher mental activity, observed in highly experienced meditators) suggesting enhanced processing of target stimuli. Researchers concluded that mindfulness evokes a brain state of enhanced perceptual clarity and decreased automated reactivity (distractibility) (Cahn, Delorme, & Polich, 2013). The present study used both a mindfulness and a relaxation intervention in order to see if the ability of mindfulness practice to better enhance attention and reduce distractibility compared to relaxation is replicable.

Mindfulness can be both a state and a trait. A mindfulness state refers to altered sensory, cognitive and self-referential awareness. Some state changes in mindfulness include cessation or slowing of the mind's internal dialogue, experiences of perceptual clarity and conscious awareness (Cahn & Polich, 2013). Trait mindfulness refers to the lasting change in dimensions of sensation, perception and cognition that persist irrespective of being actively engaged in mindfulness practice. Trait mindfulness is developed through repeat practice over prolonged periods of time. Some trait characteristics of mindfulness include a deepened sense of calm and a heightened awareness of the sensory field (Cahn & Polich, 2013). Both state and trait mindfulness are associated with a metacognitive shift in the relationship between emotions and cognitions in which both are thought of as arising, passing phenomena instead of occupying one's full attention, thus freeing up attentional capacity for other goals. However novice practioners cannot keep themselves in a mindfulness state for long periods of time the way that practiced practioners can. This is in line with Brown et al.'s research that states that practicing mindfulness allows the practitioner a greater ability to be free from pre-perceptual biasing factors such as emotional arousal states (Brown et al., 1984), inner dialogue/wandering thoughts (Jha et al., 2015), and allows for a greater sense of perceptual clarity (Lutz et al., 2008). Mindfulness practice induces distinct states and traits of consciousness.

EEG analysis has shown neurophysiological changes that occur as the result of state and trait mindfulness. For instance, alpha band power has been shown to increase during meditation states (Cahn & Polich, 2013). Another study looking at trait mindfulness, however, found that increased alpha power the in frontal cortex was only observed in advanced, not novice, meditators (Zhang, Li, & He, 1988). Alpha band power has also been shown to be stronger by as much as 1 HZ (a big significant difference) at rest in experienced meditators compared to control (Aftanas, &

Golocheikine, 2002). Past research suggests that both state and trait alpha changes emerge as a result of mindfulness practices. Furthermore previous research suggests that trait mindfulness can impact early top-down attention and discrimination of visual stimuli. Research has shown that trait mindfulness predicts larger (more negative) N1 signals to both go and no-go stimuli and enhanced moment-to-moment attention (Quaglia, Goodman, & Brown, 2015). However Quickel, Johnson, and David, (2014) tested whether trait mindfulness effects performance on working memory and focused attention. They tested 164 participants with no meditation experience and found that individuals who scored high on mindfulness scales did not perform better on focused attention (Quikel, Johnson, & David, 2014). However these researchers used participants with no meditation experience, therefore they did not in affect measure trait mindfulness as it is something that results from experienced practioners. Therefore the present study will look at the effect of trait mindfulness on divided attentional ability as well as the effect of state mindfulness to cognitively enhance attentional ability.

Previous research is inconclusive on the effectiveness of a brief mindfulness session to increase state mindfulness and cognitive enhancement. Previous research has demonstrated the benefits of a long-term, mindfulness intervention typically around eight hours of training over the course of two months (Jha et al., 2015; Kabbat-Zinn, 1994; MacLean et al., 2011). Furthermore, much research on specific mindfulness practices, such as meditation, often utilizes a well-practiced sample population who would possess a high level of trait mindfulness (Brown et al., 1988; Cardena et al., 2014). However, there is also an interest in the effectiveness of a brief mindfulness session on novice participants. A short, single-session of mindfulness used by novice practitioners would be more generalizable to an average population and have more practical real-world use. The effectiveness of a brief mindfulness session on state mindfulness and cognitive enhancement is debated in previous research. For instance in 2015 Johnson and colleagues examined the effects of a single, 25-minute meditation session compared to a sham meditation and book-listening control on state mindfulness, attention and working memory. They found that one session of meditation or sham meditation had an effect on state mindfulness while the audio book did not, with meditation showing the strongest effect. However they did not find any effect for attention or working memory enhancement in any condition (Johnson, Gur, David, & Currier, 2015). In another study looking at the influence of a brief (20 minutes or 45 minutes) mindfulness exercise on learning, people in the 20 and 45 minute mindfulness sessions were able to remember significantly more novel words than no treatment controls. There were higher levels of self-reported state mindfulness for the 20-minute mindfulness condition and no change in the 45-minute and no treatment control conditions (Bonamo, Legerski, & Thomas, 2015). Most recently researchers examined the effect of a 10-minute, single-session mindfulness training on state mindfulness, executive attention and memory. It was found that 10 minutes was sufficient to increase self-reported state mindfulness but had no effect on executive attention or memory. Researchers further found that trait mindfulness moderated the efficacy of the mindfulness training at reducing emotional interference on the task of executive attention (Waiter & Dubois, 2016). The mixed results of previous research call into question whether a brief, 20-minute mindfulness training can be sufficient enough to bring about increased state mindfulness and cognitive enhancement. The present study attempted to lend further support to the effectiveness of a single, 20-minute session for enhancing state mindfulness and attention.

Neurofeedback with Mindfulness and Visual Attention

Mindfulness can be difficult to achieve, even for experienced practitioners. Receiving neurofeedback can be a way to improve mindfulness practice in novice practitioners (Brandmeye & Delmore, 2013). Neurofeedback is the process of gaining awareness of one's neural processes through the use of instruments that provide feedback regarding ongoing brain activity with the goal of being able to manipulate brain activity. Using neurofeedback in conjunction with meditation practice has been shown to improve mindfulness as well as attentional abilities (Gruzelier, 2013). A neurofeedback device for mindfulness provides a cue to users when their mind starts to wander so they can refocus their attention and can therefore improve cognitive and mindfulness practice alike (Brandmeye & Delmore, 2013). In a typical neurofeedback task, a participant wears an EEG cap or undergoes an fMRI scan while performing a task. The EEG device measures electrical activity in the brain using electrodes placed on the scalp. These electrical frequencies are converted into feedback that is given to participants in real-time based on the desired outcomes of the experiment. Feedback can be auditory, visual, or perceptual, such as color cues to indicate strong/weak performance or increases in task difficulty when the participants mind is wandering. Neurofeedback is meant to help the participant fine tune their cognition and adjust their actions to improve experimental outcomes.

With mindfulness, feedback is in the form of how calm, focused and frequent the brain signals are. Alpha, beta, and theta brainwaves are most commonly affected during mindfulness practice (Braboszcz, & Delorme, 2011). Alpha is a dynamic signal that is sensitive to stimulus presentation and expectation, and beta activity originates from the frontal cortex and is associated with attention-demanding tasks. While engaged in mindfulness, alpha, beta, and theta power increase during and following meditation practices (Cahn, & Polich, 2013). This is distinct from relaxation which has only been shown to increase alpha power (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Using neurofeedback with a meditation session for as little as 20 minutes has been shown to significantly increase theta power in frontal and temporal regions and increase alpha power in posterior regions (Lagopoulos et al., 2009). EEG neurofeedback has linked the subjective experience of mindfulness with brain activity during a meditation session in both novice and experienced participants (Van Lutterveld et al., 2016). Researchers examined brain activity in the posterior cingulated cortex (PCC) and found that there was less activity in this region when participants reported having a greater subjective experience of mindfulness and that both novice and experienced participants were able to control PCC signals in the direction associated with mindfulness through meditation using neurofeedback. This research support the feasibility of using EEG neurofeedback to link an objective measure of brain activity with the subjective experience of mindfulness as well as the utility of neurofeedback as a tool for meditation training (Van Lutterveld et al., 2016). Meditation experience is difficult to quantify because there is no outward indicator of performance; thus, looking at patterns of the EEG data is one way of confirming the effectiveness of the mindfulness session.

Using neurofeedback while practicing mindfulness has been shown to enhance mindfulness outcomes and cognitive abilities. Both mindfulness and neurofeedback facilitate and improve concentration, for which attentional and cognitive control are necessary. Used together these techniques can be an effective way of training novice participants who may struggle with maintaining a basic mindfulness practice. Braboszcz and Delorme (2011) used a breath counting exercise, typical of mindfulness practice, to look at distractibility. Participants wore an EEG cap and were instructed to press a button every time they realized their attention had drifted away from the task. They found alpha (9-11 HZ) and beta (15-30 HZ) waves decreased during reported mind-wandering, and theta (4-7 HZ) and delta (2-3.5 HZ) waves increased. Delta waves are commonly associated with sleep, and while the theta band can be associated with very deep meditation it can also be associated with light sleep (Braboszcz & Delorme, 2011). These results could indicate that mind-wandering is a period of mental fatigue and reduced cognition. In a meta-analysis, Gruzelier reviewed eight studies that used mediation with neurofeedback in terms of gains in attentional abilities. He found that the alpha and theta frequency bands trained in most cognitive enhancement protocols share many similarities with the frequency bands that show the most significant change during the early stages of meditation practice (Gruzelier, 2013). Therefore the present study will use neurofeedback with a mindfulness intervention to improve both mindfulness and attentional outcomes.

The Present Study

The present study was designed to test whether practicing mindfulness with and without neurofeedback would improve attentional abilities as measured by higher accuracy on the MOT task. All participants completed two sessions of MOT task (Pylyshyn & Storm, 1988) before and after either a mindfulness or relaxation intervention. All participants also completed a measure of trait mindfulness, the Five Facet Mindfulness Questionnaire-short form (FFMQ) (Bohlmeijer, Klooster, Fledderus, Veehof, & Baer, 2011) and the State Mindfulness Scale (Tanay, & Bernstein, 2013). A third of participants underwent mindfulness training using the seated meditation portion of Kabat-Zinn's (1994) Mindfulness Based Stress Reduction program while wearing an EEG headband and receiving neurofeedback; a third of the participants underwent the same portion of the Mindfulness Based Stress Reduction program while wearing the EEG headband but did not receive any neurofeedback; and, a third of the participants served as controls and performed a relaxation task while wearing an EEG headband and did not receive neurofeedback.

Successful tracking of multiple objects requires enhanced and sustained attention for selected objects and suppression of distractions in the attentional field (Bettencourt & Somers, 2009). Mindfulness enhances attention and awareness (MacLean et al., 2011) and decreases subjectability to distraction (Jha et al., 2015). Neurofeedback can improve mindfulness and attentional outcomes in novice participants (Gruzelier, 2013). Therefore, it is hypothesized that participants undergoing the Mindfulness Based Stress Reduction program with neurofeedback will show greater attention abilities and lowe r distractibility, as indicated by higher accuracy in performance on the MOT Task.

Hypotheses

Tthe effect of mindfulness training with and without neurofeedback on attentional performance on a multiple object tracking task was the focus of this study. We tested two hypotheses for this study. First we hypothesized that participants in the mindfulness conditions with and without neurofeedback will have a greater increase in accuracy scores on the post intervention MOT task compared to the participants in the control condition. More specifically we hypothesize that participants in the mindfulness condition receiving neurofeedback will have the highest increase in post-intervention MOT scores, followed by participants in mindfulness condition not receiving neurofeedback and lastly by the participants in the control condition. Second, we hypothesized that participants with higher pre-existing levels of trait mindfulness, as evident by their score on the FFMQ, will have higher pre-intervention MOT accuracy scores than participants with lower scores on the FFMQ. This study used two manipulation checks to ensure that a state of mindfulness was experienced by the participants in the mindfulness conditions on a cognitive and neural level. The first manipulation check tested whether the mindfulness intervention was successful in bringing about an increased cognitive state of mindfulness. The mindfulness intervention is considered successful if the pre vs. post difference in State Mindfulness Scale scores are higher for the participants in the mindfulness conditions with and without neurofeedback and remain unchanged for the control condition. The second manipulation check tested whether the mindfulness intervention was successful in bringing about a state of mindfulness on a neural level. Participants in the mindfulness conditions should demonstrate higher power in the alpha and beta frequency bands compared to control during the mindfulness intervention. Though previous research has demonstrated a change in theta for mindfulness intervention, changes have only been reported in very experienced meditators. For the intended sample population for this study we do not expect to observe this change.

Methods

Participants

Ninety male and female undergraduate students from introductory psychology courses were recruited through the San Jose State University Sona-System in exchange for course credit. Students not wanting to participate in research were given the option to complete a library assignment. Participants were at least 18 years of age, with self-reported normal to corrected-normal vision and reflected San Jose State University demographics for age, ethnicity and socioeconomic status. Demographic information was not otherwise collected.

Materials

In order to test the effect of mindfulness on attention, a portion of the Mindfulness-Based Stress Reduction program (Carmody et al., 2009) along with a MOT task (Pylyshyn & Storm, 1988) was used. To further examine the relationship between mindfulness and MOT as well as to account for previous knowledge and experience with mindfulness within groups, the Five Factor Mindfulness Questionnaire-short form (Bohlmeijer et al., 2011) and State Mindfulness Questionnaire (Tanay, & Bernstein, 2013) were used. For this experiment, two-thirds of the participants underwent the seated meditation portion of the Mindfulness-Based Stress Reduction program and the last third listened to an audio book of J.R Tolkien's The Hobbit prior to a second block of the multiple-object tracking task. This audio book condition was meant to serve as a relaxation condition and The Hobbit has been successfully used as a control condition in previous mindfulness research (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Participants were quasi-randomly assigned to groups, with an effort made to maintain even group distribution. All participants completed the Five Facet Mindfulness Questionnaire and State Mindfulness Questionnaire.

Mindfulness based stress reduction program. The Mindfulness Based Stress Reduction program (MBSR) originally developed by Kabat-Zinn (1994) consists of eight, two hour sessions of mindfulness training that consist of a guided body scan attention exercise, sitting meditation and yoga. This program typically occurs over eight weeks and an emphasis is given to open awareness mediation in which one's field of awareness is expanded to include anything that appears within consciousness. For this study, only the sitting meditation portion was used, totaling 20 minutes (Carmody et al., 2009). During the seated meditation, participants were told to sit in an alert, upright, relaxed posture, bring their mind to the present and focus on the breath. Audio instructions prompted participants to "*Sit upright and dignified with your shoulders back so that breathing feels easy. Take a few moments to become aware of the body in this seated position, and of the breath.*" Instructions for thoughts, inhaling and exhaling were provided, telling participants to *"Focus on the sensation associated with breathing, cool air moving down* *past the nostrils, the rise and fall of the belly, the movement of the air in and out of the body."* and "*Sitting here we may find our minds wandering, our attention captured by things other than the breath. We do not need to become attached to any of these thoughts, simply guide your attention back to the breath."* Participants sat in a relaxed position and listened to audio instructions on a computer in the laboratory and will followed the guided directions for the practice. See Appendix A for the complete text of this program.

Multiple object tracking task. The MOT task is a cognitive task used to study attention, perception, and memory in the visual system. The task used for this study was based on Pylyshyn and Storm's original tracking multiple independent targets paradigm (1988). In the first phase of the experiment, participants read instructions and were shown two demonstration trials. Afterward, participants were given the opportunity to ask any questions about the instructions; then, the researcher asked participants to explain in their own words in detail what they will be doing to ensure explicit clarity of task instructions. At the start of each trial, participants saw 10 identical circles in a display. At the beginning of each trial, five of the circles flashed briefly for 2.5 seconds indicating that these are the target circles to be tracked; target circles then stopped flashing and then all circles started moving for six seconds. The circles were contained in a bounded outlined box; the independent trajectory of each circle is in a straight-line motion path to the edges of the box. The boundary of the box had a buffer zone built in it so that when a circle approaches the boundary it bounces off the buffer before hitting the boundary and moving in a ricochet motion to another side of the box. Circle trajectories could also overlap with each other; when that happens one circle is briefly eclipsed by the other circle. As the circles move, the participant needed to track the original five flashing target circles until the circles stop moving. At this point one of the circles will be highlighted in red and the participant indicated whether the red circle was one of the original flashing circles or not by pressing the left mouse button for originally a target or the right mouse button for not originally a target, giving the participants a 0.5 chance of either a correct or incorrect response. Meaning if a participant lost track of a target and was forced to guess, they had a 50% chance of answering correctly. Participants needed to score an overall accuracy of greater than 50% (that of chance) for inclusion in the data analysis. After each response, a message appeared informing the participant whether their response was correct or incorrect. Then they pressed the "+" key to continue to the next trial. There were two blocks in this experiment, the first contained 50 trials and the second contained 45 trials for a total of 95 trials, including 10 practice trials in the first block and 5 practice trials in the second block. The multiple object tracking task was generated in C++ using the Open GL Libraries and run on a Dell PC. The stimuli were presented on a 53 x 30 cm BenQ XL2420T flat-screen LCD monitor with a pixel resolution of 1920X1080. Participants sat in a chair approximately 57 cm from the monitor. Total time to complete both blocks was approximately 22 minutes. Participants took a break in between blocks to undergo either a meditation or relaxation intervention. After completion of all trials participants were asked to verbally describe what they did during the experiment and any kind of strategy they used and how difficult they found the task. These questions were asked as a validity check and to check for outliers. Based on the responses to these questions, outliers were defined as those whose self-described behavior of what they did during the experiment did not match stated instructions. Internal consistency rating for the MOT task has been found to have an alpha coefficient equal to .81 with an inter-item correlation of .18, indicating this is a reliable measure of attention (Skogsberg, 2009). See Figure 1 for an example of the stimulus display.

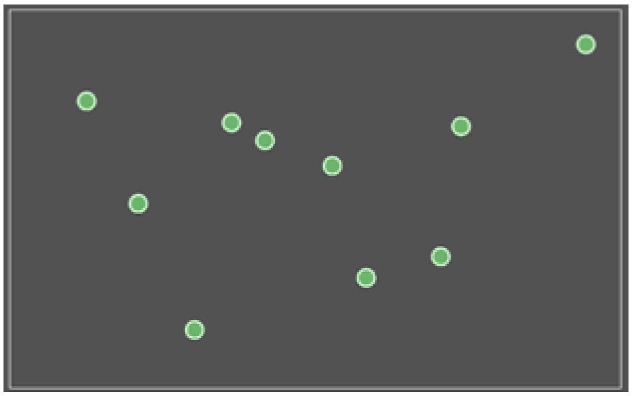

Figure 1. Sample display for Multiple Object Tracking paradigm.

Five factor mindfulness questionnaire-short form. The FFMQ – Short Form (Bohlmeijer et al., 2011) is a 24-item questionnaire assessing a person's existing level of mindfulness in five categories. There are five items that assess *nonreactivity to inner experience* with statements such as, “I watch my feelings without getting carried away by them” and “Usually when I have distressing thoughts or images, I can just notice them without reacting.” There are four items that assess *observing thoughts and feelings* with statements such as, “I notice the smells and aromas of things” and “I pay attention to physical experiences, such as the wind in my hair or sun on my face.” *Acting with awareness* is assessed with five items such as, “I find it difficult to stay focused on what's happening in the present moment” and “I rush through activities without being really attentive to them.” *Describing with words* contains five items posing statements such as, “I find myself doing things without paying attention” and “It seems I am 'running on automatic' without much awareness of what I'm doing.” *Nonjudgement of experience* is assessed by five items containing statements such as, “I tell myself I shouldn't be feeling the way I'm feeling” and “I tell myself I shouldn't be thinking the way I'm thinking.” Responses to statements are on a five-point likert-scale with one being “never or very rarely true” and five being “very often or always true.” Participants filled out the questionnaire before the experiment. The Five Factor Mindfulness Questionnaire has been tested and validated for internal consistency and has alpha coefficients ranging from .75 to .91 by item (Baer et al., 2006). See Appendix B for the complete questionnaire.

State mindfulness scale. The State Mindfulness Scale (SMS) is a 21-item scale assessing a person's current state of mindfulness at the time of the experiment. This questionnaire was given at the beginning and end of the experiment to serve as a validity check that the mindfulness intervention during the experiment was successful in bringing about a state of mindfulness. This scale assesses mindfulness on two levels, the body and the mind, with items such as, “I was aware of what was going on in my mind,” “I noticed physical sensations come and go,” and “I changed my body posture and paid attention to the physical process of moving.” Responses to statements were on a five-point likert-scale with one being “Strongly Disagree” and five being “Strongly Agree.” The State Mindfulness Questionnaire has been tested and validated for internal consistency and an overall Chronbach's alpha of .95 and alpha coefficients of .94 for items assessing mindfulness of the mind and .88 for items assessing mindfulness of the body (Tanay,

&Bernstein,2013). See Appendix C for the complete questionnaire.

EEG muse device. Neural activity was recorded and neurofeedback was given using a Muse EEG device (InteraXon Inc, Ontatio, Canada). The Muse device is a commercially available product that is currently on the market as a mindfulness training device. It is marketed as a brain sensing headband that acts as a personal meditation assistant. The fidelity of this device was validated by looking at the technical specifications of the device, testimonials on researcher and developer forums by other researcher who had successful used the device in a research context and by consulting with a neuroscientist in the field with expertise in EEG. In the present study, we used the Muse product as marketed with the following exceptions. For participants in the experimental conditions not receiving neurofeedback, the auditory feedback was turned off and the device was only used as an EEG headband to record neural activity. Additionally, the device has the ability to synchronize to an application on a smart device that can play instructions for the meditation. These instructions were not be used; instead a recording of the seated meditation portion of the MBSR program was played. The MBSR was chosen, due to its cited validation and reliability for use in a mindfulness intervention.

Muse is a wireless headband that examines frontal cortex activity with four channels at the following locations: Tp9, Fp1, Fp2, Tp10. While using the headband during meditation, the Muse device provides auditory feedback in real time by translating brain signals into sounds of wind. When the mind is calm and settled, as determined by a built-in algorithm, the participant heard the sound of calm and settled winds, when the mind is active the wind sounds will pick up and blow louder. Feedback is based on the frequency and amplitude of the person's brain waves compared to their baseline for an active mind. Generally speaking, when the mind is calm, power is higher in the alpha and beta frequencies, and lower at other frequencies, such as gamma. While practicing mindfulness, if the mind wanders and becomes more active, the brain will shift from greater alpha power, for instance to another frequency band such as greater beta power. The device uses the difference in activity patterns to provide feedback accordingly. Participants in all three conditions were fitted with the headband and did a one-minute calibration. Some participants receive auditory feedback, while others did not. Participants in the mindfulness with neurofeedback condition were told that the headband will sense their brain activity and provide auditory feedback which will help them with the meditation intervention. They were instructed that the ultimate goal in receiving the feedback was to hear and maintain calm wind sounds, and if they heard the wind sounds picking up and getting louder to direct their attention back to the instructions of the MBSR program. Muse records and provides raw EEG data and thus allowed for experimental-based assessment of changes in the delta, theta, alpha, beta and gamma bands. Ultimately a successful mindfulness session was confirmed by greater power in alpha and beta waves for each participant. (For more information regarding the technical specifications of this device see www.choosemuse.com).

Procedures

Recruited participants arrived at a designated room on the San Jose State University campus and were given a consent form to read over and sign. All participants filled out the Five Facet Mindfulness Scale and the State Mindfulness Scale, taking approximately 15 minutes to complete both, after which they received instructions for the MOT Task. All participants completed 40 experimental MOT trials. Two-thirds of the participants were randomly assigned to partake in the MBSR program for 20 minutes and one-third listened to The Hobbit for 20 minutes. All participants were fitted for the EEG headband, participants in the mindfulness with neurofeedback condition were then guided through a one-minute baseline assessment. Participants in the mindfulness with neurofeedback condition also received real time neurofeedback during the mindfulness intervention. For the participants in the mindfulness without neurofeedback condition, the researcher turned the neurofeedback off. All participants received verbal instructions from the researcher to sit comfortably, and wait for the audio for either the MBSR program or The Hobbit. Immediately after either 20 minutes of mindfulness or The Hobbit, the Muse Device headband was removed and all participants completed another 40 experimental trials of MOT. Participants completed 95 total trials of the MOT task total, requiring roughly 22 minutes to complete. After completing the MOT task the researchers verbally asked participants the MOT validity questions. All participants then completed the State Mindfulness Questionnaire a second time, taking approximately 5 minutes to complete. After completing the questionnaire participants were debriefed and thanked for their participation. The entire time to complete experimental procedures was approximately 75 minutes.

Results

Multiple Object Tracking

Table 1 shows the descriptive statistics for MOT accuracy by condition and Figure 2 shows a graphical representation of results. In this study we tested the hypothesis that a brief mindfulness intervention could increase attentional capacity in a multiple object tracking task. The independent variable, intervention condition, consisted of three levels: the mindfulness with neurofeedback group, the mindfulness group without neurofeedback, and the control group. The dependent variable is this study was MOT accuracy. Accuracy was measured as the number of correctly identified trials out of all possible trials; higher scores equal greater accuracy. The quasi-independent variable of time period consisted of two levels: pre-intervention MOT accuracy and post intervention MOT accuracy. This was a 2 (pre-intervention, post-intervention) X 3 (mindfulness with neurofeedback group, mindfulness without neurofeedback group, control group) mixed factorial design. A repeated measures ANOVA was used to analyze the main effects of time period, the main effect of intervention condition and the interaction of time X condition. Results showed a nonsignificant main effect of time, $F(1, 87) = 2.15$, $p > .05$, indicating that pre-intervention MOT scores (M=28.54, SD=3.97) did not significantly differ from post-intervention scores (M=29.10, SD=3.90). There was a nonsignificant main effect of condition $F(2, 87) = .26$, $p > .05$. On average participants in the mindfulness without neurofeedback condition did not differ (M=28.95, SD=6.07) than those in the mindfulness with neurofeedback (M=29.07, SD=6.07) and control (M=28.45, SD=6.07) condition. There was a nonsignificant interaction effect between time and condition, F (2, 87) =2.61, *p* =.08.

Table1

Descriptive Statistics for Pre and Post Intervention MOT Accuracy Scores by Condition

Condition	Pre-intervention		Post-intervention	
	M	*SD*	*M*	*SD*
Mindfulness with neurofeedback	27.87	3.84	29.77	3.81
Mindfulness without neurofeedback	28.50	4.39	29.40	3.79
Control	28.77	3.66	28.13	4.09

Note. N=90. MOT accuracy was scored according to the total number of trials answered correctly out of 35. Higher numbers represent higher accuracy.

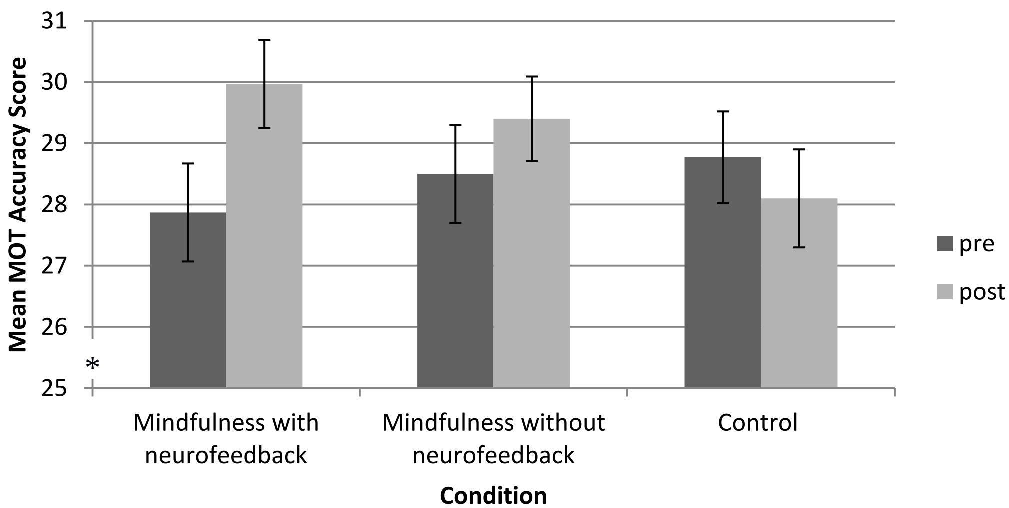

Figure 2. Pre and post intervention mean MOT accuracy scores by condition. Error bars represent the standard error. Higher mean scores indicate higher accuracy. N=90. *p<.05.

Given that the interaction between of time and condition approached significance (p=.08), further analyses were run to differentiate between conditions. Pre and post intervention MOT accuracy scores were analyzed for each condition. There was a significant difference for the mindfulness with neurofeedback condition t (29) = -2.54, *p*<.05, indicating that there was a significant increase from pre to post MOT accuracy scores in this condition. There was a nonsignificant difference for the mindfulness without neurofeedback condition t (29) = -1.10, p>.05, from pre to post MOT accuracy scores. There was a nonsignificant difference for the control condition t (29) =1.22, p>.05, from the pre to post MOT accuracy scores. These results show that MOT accuracy scores increased significantly in only the mindfulness with neurofeedback condition, indicating that the MBSR program combined with neurofeedback produced the only significant increase in attentional capacity on the MOT task.

Internal reliability for the multiple object tracking paradigm was assessed using a measure of split-half reliability. Figure 3 shows the correlation scatterplot for the result. In order to compare individual performance between the pre-intervention MOT task and the post-intervention MOT task, pre MOT scores were collapsed across all three conditions and post MOT scores were collapsed across all three conditions and analyzed using Pearson's correlation. Results indicated a significant correlation between pre and post MOT scores across conditions, r=.60, *p*<.001. This indicates that individual performance was consistent between pre MOT (*M*=28.65, *SD*=4.23) and post MOT (*M*=28.91 *SD*=4.12) sessions and further validates that attentional ability was assessed the same in both pre and post sessions.

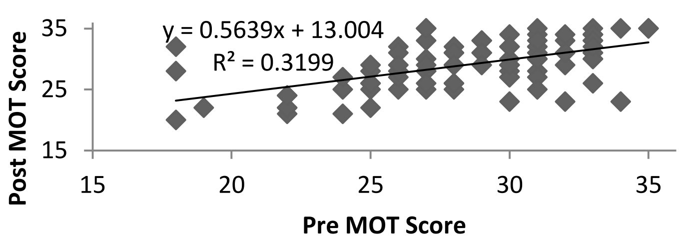

Figure 3. Scatterplot of Pearson's correlation for assessing split half reliability in MOT

task. N=90; *p<.001.

State Mindfulness Analysis

Table 2 shows the descriptive statistics for pre and post intervention SMS score by condition; Figure 4 shows a graphical representation of results. The State Mindfulness Questionnaire was given to all participants at the beginning and end of the experiment to serve as a validity check that the MBSR program used in the mindfulness with and without neurofeedback conditions was successful in producing greater feelings of mindfulness on a cognitive level compared to control. For this scale, lower scores represent greater level of mindfulness. A 2 (pre, post) X 3 (neurofeedback, mindfulness, control) mixed repeated measures ANOVA was run to assess the main effect of time, the main effect of condition and the interaction effect of time X condition. Results showed a significant main effect of time, F (1, 87) = 35.0, p<.001, such that SMS scores decreased significantly from pre (*M*=50.77, *SD*=11.76) to post-intervention (*M*=41.72, *SD*=10.25). There was a nonsignificant main effect of condition, F(2, 87) = .19, p>.05. Participants in the mindfulness with neurofeedback (*M*=46.57, *SD*=8.27), mindfulness without neurofeedback (*M*=45.48, *SD* = 8.27) and control conditions (*M*=46.68, *SD*=8.27) did not significantly differ. There was a significant interaction between time and condition, F (2, 87) = 4.24, p<.05 indicating that the degree to which participants increased in mindfulness was a result of the intervention condition they were in.

Table 2

Descriptive Statistics for Pre and Post Intervention State Mindfulness Scale Total Scores by Condition

Condition	Pre-intervention		Post-intervention	
	M	*SD*	*M*	*SD*
Mindfulness with neurofeedback	54.07	16.80	39.07	9.48
Mindfulness without neurofeedback	49.40	6.41	41.57	10.47
Control	48.83	9.54	44.53	10.64

Note. N=90. The State Mindfulness Scale was a 7-point Likert Scale, scores could range from 21 to 105 with lower scores representing higher levels mindfulness.

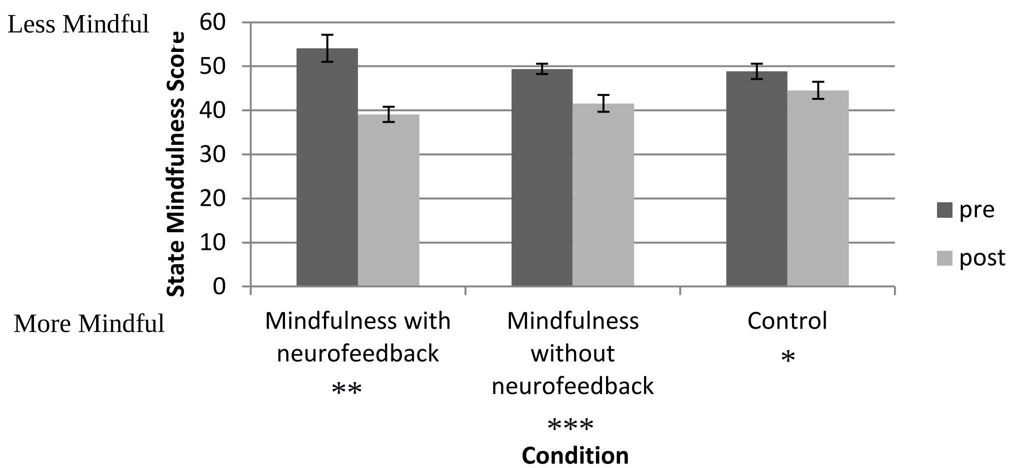

Figure 4. Pre and post intervention SMS scores by condition. Error bars represent standard error. The lower the score the greater the level of mindfulness. N= 90. *p<.05, ** p<.01 ***p<.001.

Given this interaction a series of analyses were run to further differentiate between conditions. A series of paired samples t-test were run to further test for within subject differences between conditions for pre and post-intervention SMS scores. Results showed a significant difference between pre and post SMS scores for the mindfulness with neurofeedback condition, t(29) = 3.78, *p*<.01, indicating a significant decrease from pre to post SMS scores, representing increased mindfulness in this condition. There was a significant difference in the mindfulness without neurofeedback condition t (29) = 6.10, p<.001 between pre and post SMS scores, indicating increased mindfulness in this condition. There was a significant difference in the control condition t(29) = 2.25, *p*<.05 between pre and post SMS scores, representing increased mindfulness in this condition. Results of these paired samples t-test show that mindfulness, as indicated by the score on the State Mindfulness Scale, significantly increased from pre to post-intervention in all three conditions.

To distinguish between the mindfulness with and without neurofeedback conditions a 2 (pre-intervention, post-intervention) X 2 (mindfulness with neurofeedback, mindfulness without neurofeedback) mixed factorial ANOVA was run. Results showed a nonsignificant interaction between time and condition F(1,58) = 1.09, *p*>.05. To test for differences between the mindfulness with neurofeedback and control conditions, a 2 (pre-intervention, post-intervention) X 2 (mindfulness with neurofeedback, control) mixed factorial ANOVA was run. Results showed a significant interaction between time and condition F(1,58) = 4.69, *p*<.05, indicating that the difference in pre and post intervention SMS scores was due to the type of intervention treatment received. To test for differences between the mindfulness without neurofeedback and control conditions a 2 (pre-intervention, post-intervention) X 2(mindfulness without neurofeedback, control) mixed factorial ANOVA was run. There was a nonsignificant interaction between time and condition F(1,58) = 2.36, *p*>.05. Together the results of these 2-way ANOVAS show the only significant difference in pre and post intervention SMS scores in the mindfulness with neurofeedback condition compared to control.

EEG Analysis

Table 3 shows the descriptive statistics for EEG data by condition for the alpha and beta band. Figure 5 shows a graphical representation of results. Raw EEG data were collected from participants in the mindfulness without neurofeedback and control conditions; due to limitations of the Muse device, EEG data were not collected on the mindfulness with neurofeedback condition. We were left with data from 50 participants, of which four were excluded for missing data as such the following analyses were conducted on 46 participants. These data served as a manipulation check to determine whether that differences in mindfulness between groups were associated with group differences in neural activity. Based on prior EEG findings, we predicted that participants in the mindfulness without neurofeedback condition would show greater power in the alpha and beta bands than those in the control condition. Our analyses included a three-way mixed ANOVA that examined the influence of the following independent variables: condition (mindfulness without neurofeedback group and control group), EEG channel location (left hemisphere and right hemisphere), frequency band (alpha, beta, delta, gamma, and theta). The dependent variable measured was power. The Muse device consisted of four channels at Tp9, Fp1, TP2, and Fp10. EEG power in each channel was measured throughout the 20 minute intervention and then averaged in each channel across time, resulting in mean power for each frequency band in each channel. Given that we had no a priori hypotheses about channel location within hemisphere, power values from the TP9 and Fp1 channels were combined to evaluate left hemisphere activity, and power values from the TP2 and Fp10 were combined to evaluate right hemisphere activity; this was done individually for each of the five frequency bands.

Table 3
Descriptive Statistics for alpha and beta power by condition

Condition	Alpha		Beta		
	M	*SD*	*M*	*SD*	N
Mindfulness without neurofeedback	1.16	2.21	.54	.24	21
Control	.57	.25	.53	.28	25

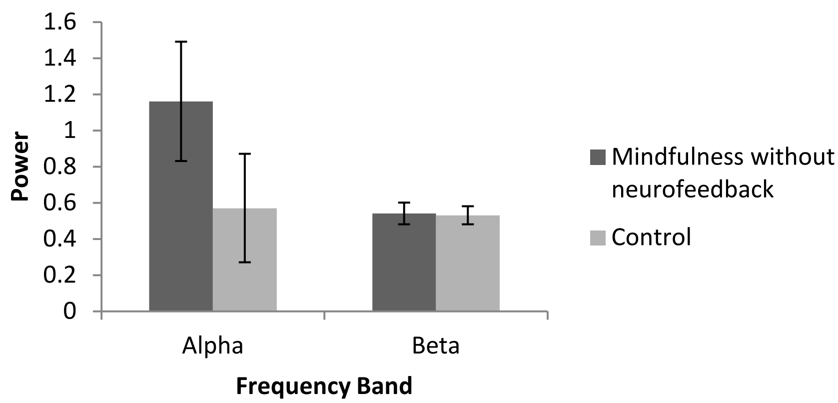

Figure 5. Mean alpha and beta power by condition. Error bars represent standard error. N=46.

The data were analyzed using a 2 (left hemisphere, right hemisphere) X 5(alpha, beta, delta, gamma, theta) X 2 (mindfulness without neurofeedback, control) mixed factorial ANOVA to test for differences in power by hemisphere, frequency band, and condition. Mauchley's test of sphericity was met for frequency band, $\chi2(9)=90.02$, $p<.001$ and the interaction of frequency band and location, $\chi2(9)= 149.75$, $p<.001$; therefore those results are reported using the Greenhouse-Geisser correction. Results showed a significant main effect of frequency band, $F(1.95, 78.06) = 41.21$, $p < .001$. Neither the main effect of location $F(1,40) = .46$, $p > .05$ nor condition, $F(1, 40) = .23$, $p > .05$ were significant. Additionally, none of the two or three-way interactions reached significance (all *p*'s >.05).

Previous research has shown that the alpha and beta bands show the greatest increase during a mindfulness state. Therefore, although our statistical analyses did not reveal a significant group X frequency band interaction, we were interested in performing exploratory analysis to evaluate the differences in alpha and beta power between mindfulness without neurofeedback and control conditions. We hypothesized that the mindfulness condition would show greater alpha and beta power compared to controls. In order to test this hypothesis an independent samples t-test was run to compare group differences in power in the alpha and beta bands. Results of the independent samples t-test showed that there was no significant difference for alpha power $t(44) = 1.32$, $p > .05$ between the mindfulness without neurofeedback and control conditions nor was there a significant difference for beta power $t(44) = .12$, $p > .05$, between the mindfulness without neurofeedback and control conditions.

Trait Mindfulness

Figure 6 shows the scatterplot for the correlation for trait mindfulness and pre-intervention MOT accuracy. The FFMQ was giving to all participants at the start of the experiment to account for pre-existing trait mindfulness and its effect on the pre-intervention MOT task. There were two outliers within FFMQ scores who scored much lower than average. These two scores were removed and the Pearson's correlation was rerun with 88 participants, this however did not change the significance of the result (*p* >.05) therefore the original statistical are reported. We hypothesized that participants having a higher pre-existing level of mindfulness would perform better on the pre-intervention MOT task. Scores from the FFMQ were the predictor variable and accuracy scores from the pre-intervention MOT task were the criterion variable in a correlation analysis. Pearson's Correlation analysis was run to determine the relationship between pre-existing levels of mindfulness and pre-intervention MOT scores. Results revealed a nonsignificant correlation between FFMQ scores and pre-intervention MOT scores, $r(90)=.04$, $p>.05$. Indicating that participants with a higher level of pre-existing mindfulness did not have greater accuracy on the pre-intervention MOT task. There were two outliers in FFMQ scores who scored much lower than average. These two scores were removed and the Pearson’s correlation was rerun with 88 participants, this however did not change the significance of the result (p>.05) therefore the original statistical are reported here.

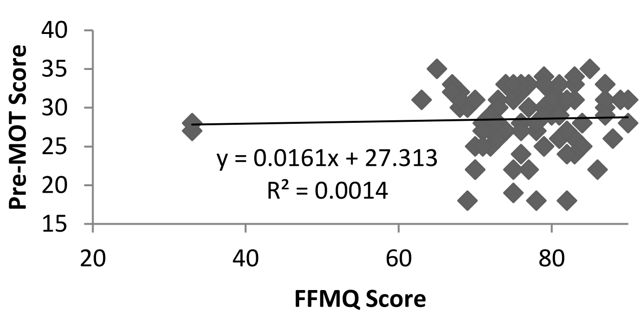

Figure 6 .Scatterplot of the correlation between trait mindfulness and pre-intervention MOT accuracy. Higher FFMQ scores represent higher trait mindfulness. N=90.

Discussion

The purpose of this study was to examine if and how a mindfulness intervention could increase attention and perception to tracking multiple objects. Previous research had shown that practicing mindfulness using the MBSR program could broaden one's perceptual awareness by increasing the ability to enhance and sustain visual attention to target stimuli while simultaneously decreasing susceptibility to distraction (Kabbat-Zinn, 1994; Lutz et al., 2008). A goal of the present study was to fill a gap in the current knowledge; the effect of mindfulness on divided attentional abilities, with the multiple object tracking task. We predicted that participants having undergone a mindfulness intervention with and without the aid of neurofeedback would improve on the post-intervention MOT task compared to controls. Furthermore, since mindfulness can be both a state and a trait (Cahn, & Polich, 2013), we believed that participants with a greater trait level of mindfulness, as measured by the FFMQ, would perform better on the MOT task before any intervention.

The Effect of Mindfulness on Multiple Object Tracking

The present study did not reach significance for an effect of mindfulness modulating divided attentional capacity on the MOT task. However, result were close to significance (p=.08) and follow up tests confirmed that multiple object tracking performance significantly increased from pre to post test across the mindfulness with neurofeedback condition but not the other conditions. Multiple object tracking requires target enhancement, sustained visual attention and distractor suppression in order for successful tracking (Doran, 2010). The practice of mindfulness involves focusing one’s attention on internal states, with cultivating, enhancing and sustaining attention being some of the main goals (Carmody et al., 2009). The mechanism through which this is thought to work is by increasing a mindfulness practitioner's ability to become aware of the pre-perception biasing factors that affect perception such as arousal changes, attitudes and thoughts (Brown et al., 1984). This pre-perceptual awareness is in line with Pylyshyn's FINST model that states that object tracking requires a pre-attentive first step of object indexing which acts as an internal reference bound to the object independent of position. Neurofeedback has been shown to enhance mindfulness outcomes in novice participants (Brandmeye & Delmore, 2013). Therefore, our results support the theory that practicing mindfulness with neurofeedback can increase the ability to enhance and sustain visual attention and reduce distractibility on a MOT task. This may occur by increasing pre-perceptual awareness for object indexing that is required for object tracking. Our results further extend the knowledge of the effect of mindfulness' ability to enhance visual attention by lending support to the idea that a brief mindfulness intervention with neurofeedback can increase divided visual attentional abilities. This is important because divided attention is more applicable to a real world setting.

The lack of significant findings in the mindfulness without neurofeedback group was, however, unexpected. We predicted that while mindfulness with neurofeedback would have the greatest impact on attentional increase, mindfulness training without neurofeedback would still increase attentional ability on the MOT. The ability of a mindfulness practice to increase attentional capacity has been widely proven in previous research (Jha et al., 2015; Cardena et al., 2014; Moadab, 2013). However, mindfulness can be a difficult state to achieve, even for experienced practitioners. The process involves turning off the brain's natural automatic tendencies and instead purposely controlling and focusing thoughts on internal states (Lutz et al., 2008). It is possible that even given auditory instructions from the MBSR, that without the aid of neurofeedback, participants may have struggled to follow along. The neurofeedback device provided a cue to users when their mind started to become overly active or wander off from the mindfulness instructions, therefore alerting them that their brain's simpler tendencies were taking over and forcing them to direct their attention back to the instructions of the MBSR. Neurofeedback is meant to help participants fine tune their cognitions to improve experimental outcomes. We believe that the difference between the mindfulness with and without neurofeedback conditions explains our result that only the mindfulness with neurofeedback condition significantly improves performance on the post MOT task. Brain activity may have been different for the condition receiving neurofeedback, i.e., stronger alpha and beta power, allowing for a difference in mindfulness experience. However EEG data could not be recorded or examined for the mindfulness with neurofeedback condition. Previous research that suggests a neurofeedback device can improve mindfulness and cognitive practices alike (Brandmeye & Delmore, 2013). Our findings suggest that incorporating neurofeedback into a cognitive training intervention can improve the likelihood of success for the intervention.

The MOT task would have been a foreign task for all participants. Therefore having practice with the task would naturally allow a person to become better at it over time. However, if our results were strictly due to practice effects, we would have expected an increase in performance across all conditions. Given that accuracy numerically decreased in the control condition, we do not expect our results to be due to practice effects.

The Effect of Trait Mindfulness on Pre-Intervention MOT Performance

This study utilized an undergraduate student participant pool that was not pre-screened for mindfulness experience. However, we still wanted to look at pre-existing levels of trait mindfulness to account for differences in pre-intervention MOT performance. We predicted that having a higher pre-existing level of mindfulness would lead to higher performance on the pre-intervention MOT task, but results did not confirm this prediction. Our prediction was supported by previous research that indicates that long-term practitioners of mindfulness possess a level of trait mindfulness marked by heightened visual sensitivity as measured by detection and discrimination ability (McLean et al., 2014), greater activation in brain regions implicated in attentional control abilities during task engagement (Moadab, 2013) and predicts top-down attention to visual stimuli. The trait mindfulness measure, FFMQ is scored from 24 to 120, with higher score representing higher levels of trait mindfulness. Scores in our sample were normally distributed and ranged from 33 to 93 with a mean score of 76.5 (*SD*=9.13), indicating a moderate level of mindfulness. It could have been that the items of the FFMQ were not specific enough that most people felt somewhat agreeable for most items. In much of the previous research on mindfulness, effects were found using highly practiced meditators (Bair et al., 2014; Cardena et al., 2014). Thus it could be that a higher, above moderate, level of pre-existing mindfulness would be necessary for a correlation with greater performance on the pre-intervention MOT task. Or our results could lend support to previous research that did not find an effect of trait mindfulness on focused attention (Quickel et al., 2014). Lastly our result calls into question whether mindfulness scales can capture the attentional aspects of mindfulness.

Mindfulness research is still largely in its early phases. It is not known for certain how long the effects of mindfulness practice can last nor over how long a period of time one needs to practice before developing trait mindfulness. These are important questions for the effectiveness of mindfulness training extended into a long-term real world setting. In future directions of this study it may therefore be more helpful to prescreen participants for direct experience with mindfulness training, experience with meditation, yoga and/or tai-chi practice as well with a self-report measure of how strongly participants feel they practice mindfulness in their daily life. This could provide better evidence for the effect of trait mindfulness on divided attention abilities.

The Effect of the MBSR Program on State Mindfulness

We used two validity checks in this study to confirm that the MBSR program brought about feelings of mindfulness on a cognitive and neural level. On a cognitive level, we expected that participants having undergone the MBSR in the mindfulness with and without neurofeedback conditions would increase in mindfulness as measured by the SMS and remain unchanged for the control condition. Results of the mixed factorial ANOVA showed a significant interaction between time (pre,post) and intervention condition; a further series of paired samples t-tests showed a significant increase in mindfulness for all conditions in this study. However an examination of follow up 2X2

ANOVAs revealed that the only significant difference in the increase in feelings of mindfulness to be between the mindfulness with neurofeedback and control conditions, indicating that mindfulness with neurofeedback produced a significant increase from pre- to –post state mindfulness compared to control. We therefore confirmed our prediction that using neurofeedback would produce the greatest increase in state mindfulness. Our results do not support the effectiveness the 20 minute sitting meditation portion of Kabat-Zinn's (1994) Mindfulness Based Stress Reduction program to bring about a state of mindfulness without the additional aid of neurofeedback. This suggests that the auditory feedback from the neurofeedback device was critical for successful mindfulness and cognitive enhancement. Alternatively there could differences in training and expectations of outcomes between the mindfulness with neurofeedback and mindfulness without neurofeedback groups. For instance, receiving neurofeedback made for a different intervention training experience than not receiving it. Additionally a person's expectation that the auditory feedback would help them be more mindful may have contributed to how they self-reported their experience of mindfulness post intervention. Our results do support previous research indicating that using neurofeedback can be one way to improve mindfulness outcomes in novice participants (Gruzelier 2013). Both techniques of mindfulness and neurofeedback facilitate and improve concentration, for which both attentional and cognitive control is necessary. Therefore using neurofeedback in conjunction with the mindfulness meditation portion of the MBSR program increases mindfulness above and beyond the benefits of relaxation in the control condition.

The results of the paired samples t-tests indicated that all participants increased in feelings of mindfulness on a cognitive level; this was unexpected in the control condition. It is possible that the control task, designed to promote relaxation, also gave participants an opportunity for reflection on inner states and promoted concentration and focus, indicative of mindfulness. While these results were not completely in-line with our predictions, results do suggest that an audio listening exercise such as listening to The Hobbit on audio book could be beneficial in terms on increasing feelings of mind and body awareness. Further studies could examine the relationship between audio listening exercises and a focus on inner cognitive states.

Lastly, previous research has been inconclusive on the effectiveness of a brief mindfulness intervention to bring about state feelings mindfulness, with some research lending support (Bonamo, Legerski, & Thomas, 2015), and other research suggesting 20 minutes is not long enough to improve cognition (Johnson, Gur, David, & Currier, 2015). Our results support research suggesting that 20 minutes of mindfulness without neurofeedback is not sufficient for improving attention or bringing about a state of mindfulness. Previous research done on neurofeedback and subjective feelings of state of mindfulness did find a significant relationship between receiving neurofeedback and increasing state mindfulness in both novice and practiced participants (Van Lutterveld et al., 2016). Our results further contribute to the existing body of knowledge on brief mindfulness training indicating that 20 minutes of mindfulness meditation using the MBSR in conjunction with neurofeedback is sufficient for increasing a state of mindfulness and cognition for divided attention task.

The Effect of the MBSR Program on Mindfulness on a Neural Level

In our second validity check, we expected participants having undergone the MBSR to experience greater neural levels of mindfulness compared to controls. For our study we expected mindfulness to most affect alpha and beta frequency bands, leading to increased power in these bands during times of mindfulness. Previous research determined that the alpha and beta frequency bands trained in most cognitive enhancement protocols share many similarities with the frequency bands that show the most significant change during the early stages of meditation practice (Gruzelier, 2013). Our results however could not confirm our prediction. We found no significant changes in the alpha and beta frequency bands by condition, indicating the mindfulness without neurofeedback group did not differ from controls on a neural experience of mindfulness. Due to limitations of the EEG Muse device, we were unable to collect raw EEG data for the mindfulness with neurofeedback condition. Given the MOT and SMS results, this condition experienced the greatest level of mindfulness on a cognitive and behavioral level. Therefore it could be that if we had been able to compare this condition, we may have seen an effect the MBSR on a neural level as well. Additionally, our results suggest that bringing about subjective feelings of mindfulness on a cognitive level is possible in a brief intervention with neurofeedback; however, we did not see this result for the mindfulness without neurofeedback. Having data from both conditions would be necessary to determine if an increase in alpha and beta power was due to the mindfulness intervention or the neurofeedback, which could be a direction for future study. It may also be that bringing about a state of mindfulness visible on a neural level may require more than 20 minutes or more experienced practitioners.

Limitations of the Present Study

The EEG Muse device is marketed as a dual EEG and mindfulness training device. In order to provide neurofeedback to participants, Muse developers used an algorithm for determining mindfulness states. This algorithm is protected by the company; therefore the ability to record raw EEG output during the neurofeedback session would allow the consumer to understand their algorithm. This limitation prevented us from being able to test alpha and beta power for participants in the mindfulness with neurofeedback condition.

Other factors may have given some participants an advantage for a multiple object racking task before any intervention. Previous research has indicated that people that speak more than one language fluently have an above average capacity for divided attention (Bialystok, 2015). This is thought to be the result of greater cognitive flexibility and control in bilinguals. Even when only one language is used, the irrelevant language is also constantly activated. This leads to a need by the brain to continuously control and negotiate two languages (Christoffels, 2014). This ability at the neural level translates into bilinguals' ability to better be able to select goal relevant information from goal irrelevant information. In an audio-visual search task, involving target objects and distractors, bilinguals were faster than monolinguals at locating the target item and showed greater ability to overcome interference from visual distractors and focus their attention on the relevant object. Researchers concluded the results were due to bilinguals' extensive practice in exercising selective attention and cognitive flexibility during language use because both languages are active when one of them is being used (Chabal, Schroeder, & Marian, 2015). In the present study, when participants were asked the three MOT follow up questions, participants were also asked if they spoke more than one language fluently. We found that 53 % of our sample said they spoke more than one language fluently. We ran an independent samples t-test on pre-intervention MOT scores and bilingualism but the result was not significant t (88)=-.60, p>.05. However, the analysis was run on 48 bilingual participants and 42 monolingual participants. This may have not been a large enough sample size to see a significant effect. This could be a direction for future research.

The SMS was given to all participants at the beginning and end of the study, and results of a series of paired samples t-tests indicated that participants in all three conditions significantly increased in mindfulness at the end of the study. It could have been that the three conditions were too similar. During all three intervention conditions participants were alone, in a quiet, dark room and listened to an audio recording. To minimize eye-blink interference for the EEG device, participants in all conditions were told to keep their eyes closed during the intervention. This may have allowed participants in the control condition to focus on inner states similarly to participants in conditions using the MBSR. Participants listening to the audio book in the control condition could have benefited from the effects of relaxation that similar to the benefits of the mindfulness without neurofeedback practice in a 20-minute intervention. Future versions of this study could include a check to see how closely participants tried to follow along with the MBSR.

Implications of the Present Research

Mindfulness has been shown to have numerous physical and cognitive benefits. Most of the present research on mindfulness has used long-term interventions (8 weeks on average) that are generally not practical to a real world scenario. As such the effectiveness of a short-term mindfulness practice remains unclear. Our study suggest that 20 minutes of mindfulness meditation in conjunction with neurofeedback is adequate for bringing about a state of mindfulness on a cognitive level. This has implications for future use in laboratory settings and can be translated to a real world setting. The MBSR is a publicly available, guided, program that does not require a trained professional to proctor or any prior meditation experience. The EEG Muse device is a relatively inexpensive, commercially available, easy to use, mindfulness training neurofeedback device. Our research further validates the use of the MBSR program and Muse device for increasing mindfulness. Mindfulness has been shown to have a strong correlation to overall life happiness (Kabat-Zinn, 2015). Given this finding our results suggest that even 20 minutes of a mindfulness intervention with the MUSE neurofeedback device could improve overall happiness; this could be a topic for future research.

Lastly, another limitation of this study could be the student population that volunteered for the study. Potential participants were able to view a brief description of the study before choosing to sign up. It could have been that participants signing up for the study had an interest in mindfulness which could have affected their results. Wanting to experience mindfulness may have led participants to try harder or to be more engaged with the mindfulness intervention or conversely more disappointed to be assigned to the control condition, compared to less interested participants.

Conclusions and Future Research

In this study we wanted to determine if practicing mindfulness with and without neurofeedback would increase attention and perception ability to a divided attention task of multiple object tracking. Our result that mindfulness with neurofeedback improves attention on the MOT task was validated by follow up tests that indicated mindfulness with neurofeedback does increase attentional capacity in a proceeding cognitive attention task. Future research could examine the length of this effect of mindfulness by using a longer duration between intervention and post-test. Our results that pre-existing levels of mindfulness would be correlated with higher accuracy on the pre-intervention MOT task were not significant. The effect of pre-existing mindfulness on a divided attention MOT task could be examined using a population higher in trait mindfulness, than was used for this study or could examine individual personality differences. Future research could contrast the mindfulness intervention with a condition that promotes feelings counter to mindfulness such as mind-wandering, rumination, or distractibility.

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Appendix A:
Complete text of the 20 minute version of the Sitting Meditation portion of the Mindfulness Based Stress Reduction program (Kabat-Zinn, 1994).

This segment guides you through a meditation with breath as the primary object of awareness. Arranging to spend this time in a comfortable but attentive posture, preferably sitting up without leaning back if that's possible for you. Sitting in a dignified posture head balanced on shoulders, arms and hands resting in a comfortable position and in a time and in a place where you won't be disturbed. This is a time for allowing ourselves to switch from our normal mode of doing and moving and reacting to one of simply being…. Just being attentive to what is happening without your our awareness right here and right now. And as you sit, just noticing sensations of breath… just noticing how your abdomen moves on each in breath and out breath.. the movement of air through your nostrils, a slight movement of chest and shoulders… Jus bringing awareness to whichever part of the breath cycle and whatever part of your body is most vivid. Notice the entire cycle of breath, from the movement of the air coming in and filling the lungs, and extending the abdomen slightly, the movement of air going out.. and being aware of the pause, the stopping point in between the in-breath and the out-breath… the out-breath and thee next in-breadth… It's all one movement. Even through the changing of direction, just noticing where that pauses is, listening to what degree you can be aware of the whole entire cycle. Recognizing that each part of this cycle is different than another part and this time through may be different than the last time through and each time through is unique in some particular way if you pay attention. [Silence 30 seconds] You'll notice your attention from time to time shifting away from breadth. The mind may wander into fantasies, memories, thoughts of the day, worries that you might have, things you need to do. And without giving yourself a hard time, when you notice that's happened, gently but firmly bring your awareness back to the sensations of breathing. The actual physical sensation of breadth as it moves through your body. [Silence 60 seconds] Being aware of where the mind goes… gently shifting your awareness to sensations of breadth, and noticing the tendency to want to control your breathing. [Silence 60 seconds] You may notice there are sounds, in addition to the sounds that come from this recording.. sounds of traffic, movement or something else going on, and just noticing that your attention has moved to that perception of sound. Stay with it just long enough to notice the quality of sound. Sound as vibration, tone, volume or intensity. Being aware of the tendency of the mind to label sound as traffic or as voices or as music. And coming closer to the actual experiences of the sound as it hits your eardrums… Qualities of pitch or rhythm or intensity separating out the actual perception off sound of sound from the labels we put on it. [Silence 30 seconds] And if you've gone off to noticing sound, let your breath be your anchor of awareness so that each time your awareness wanders off just gently come back to breath without judgment or any upset if you can do that. [Silence 30 seconds] Noticing the tendency to have an opinion about things about liking the way things are going right now, not liking it, and finding it uncomfortable. That too can be an object of awareness, just noticing that you have an opinion about things often. So that's my liking mind, just liking things, and there my critical mind saying I would rather have things be different than they are, and that too can be noticed. Building the capacity to notice liking or disliking and not have to do anything about it. How freeing that is. And as you are noticing that happening, just bringing awareness back to the physical sensation of breath wherever it is most vivid for you. Just riding the entire cycle, one cycle after another. [Silence 60 seconds] You may notice sensations of achiness or discomfort… tension in your body and as you notice these sensation of discomfort, of that happens for you, and several things that can be done with such a sensation. One is to simply, shifting a little bit but in doing that, first become aware of the sensation and noticing precisely where the achiness or the tension might be and once you're aware of where that is developing an intention to move and moving mindfully and with full intent to make that motion. That is one way to deal with strong sensations in the body. A second way, and neither is better than the other, is to notice the sensation, noticing it in its fullness, being curious about the extent of it, and how your experience of it is at the moment. The actual physical sensations of tension or of throbbing or of tightness or of pulling or tingling… and the second way of dealing with it is just to notice that it is possible to stay for a moment longer with that sensation and experiences it as pure sensation without the labels of discomfort or tension or achiness, just noticing where it is and noticing your experience of it and staying with it without having to react to it, at least for the moment. Bring your attention right in to it; be curious about it, how big is it, how long is it. What quality does it have? How is it changing over time? [Silence 30 seconds] Perceptions of feelings, frustration, and anticipation, just notice these are thought forms and bring your awareness back to sensation of breathing being curios about breath, observing that no two breaths are exactly the same. [Silence 2 minutes] Seeing if it is possible to have a friendly attitude about whatever comes into your awareness. If your mind has gone off on a thought or a judgment or worry or sensation or a sound, just a friendly way of noticing that this is happening and come back to breath. Recognizing the entire cycle of awareness is important to this experience, including the movement from breath and including coming back to it. [Silence 1 minute]That moment when you realize that your mind is somewhere else other than breath and in that moment seeing if it is possible to have an attitude of celebration of recognition that this is a moment of awareness. You acknowledge yourself, notice that you've gone somewhere else and just easily bring your attention back to breath in a friendly and nonjudgmental way. [Silence 2 minutes] As this meditation comes to an end, recognize that you spent this time intentionally aware of your moment to moment experience, nourishing and strengthening your ability to be with whatever comes your way, building the capacity to opening the senses to the vividness, to the aliveness of the present moment, expanding your skills to be curious and available about whatever presents itself without judgment… And when you're ready, allow the eyes to let some light in if you've had them closed, permitting yourself now to shift or just stretch in whatever way feels comfortable as this sitting meditation ends.

Appendix B:
Five Facet Mindulness Questionnaire-short form (Response on five point likert-scale)

1. I'm good at finding words to describe my feelings.

2. I can easily put my beliefs, opinions, and expectations into words.

3. I watch my feelings without getting carried away by them.

4. I tell myself I shouldn't be feeling the way I'm feeling.

5. It's hard for me to find the words to describe what I'm thinking.

6. I pay attention to physical experiences, such as the wind in my hair or sun on my face.

7. I make judgments about whether my thoughts are good or bad.

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

9. When I have distressing thoughts or images, I don't let myself be carried away by them.

10. Generally, I pay attention to sounds, such as clocks ticking birds chirping, or cars passing.

11. When I feel something in my body, it's hard for me to find the right words to describe it.

12. It seems I am “running on automatic” without much awareness of what I'm doing.

13. When I have distressing thoughts or images, I feel calm soon after.

14. I tell myself that I shouldn't be thinking the way I'm thinking.

15. I notice the smells and aromas of things.

16. Even when I'm feeling terribly upset, I can find a way to put it into words.

17. I rush through activities without being aware of what I'm doing.

18. Usually when I have distressing thoughts or images, I can just notice then without reacting.

19. I think some of my emotions are bad or inappropriate and I shouldn't feel them.

20. I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.

21. When I have distressing thoughts or images, I just notice them and let them go.

22. I do jobs or tasks automatically without being aware of what I'm doing.

23. I find myself doing things without paying attention.

24. I disapprove of myself when I have illogical ideas.

Appendix C:

State Mindfulness Scale (Response on five point likert scale)

1. I was aware of different emotions that arose in me.

2. I tried to pay attention to pleasant and unpleasant sensations.

3. I found some of my experiences interesting.

4. I noticed many small details of my experience.

5. I felt aware of what was going on in my mind.

6. I noticed pleasant and unpleasant emotions.

7. I actively explored my experience in the moment.

8. I clearly physically felt what was going on in my body.

9. I changed my body posture and paid attention to the physical process of moving.

10. I felt closely connected to the present moment.

11. I noticed pleasant and unpleasant thoughts.

12. I noticed emotions come and go.

13. I noticed various sensations caused by my surroundings (e.g., heat, coolness, the wind on my face).

14. I noticed physical sensations come and go.

15. I had moments when I felt alert and aware.

16. I felt closely connected to the present moment.

17. I noticed thoughts come and go.

18. I felt in contact with my body.

19. I was aware of what was going on in my mind.

20. It was interesting to see the patterns of my thinking.

21. I noticed some pleasant and unpleasant physical sensations.