EFFECTS OF MEDITATION TRAINING ON ATTENTIONAL NETWORKS:

A RANDOMIZED CONTROLLED TRIAL EXAMINING

PSYCHOMETRIC AND ELECTROPHYSIOLOGICAL

(EEG) MEASURES

by

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A DISSERTATION

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Meditation has been defined as a "group of practices that self-regulate the body and mind, thereby affecting mental events by engaging a specific attentional set" (Cahn & Polich, 2006). We conducted a randomized, longitudinal trial to examine the effects of concentrative meditation training (40 min/day, 5 days/week for 8 weeks) on top-down, voluntary control of attention with a progressive muscle relaxation training group as a control.

To determine if training produced changes in attentional network efficiency we compared, pre- and post-training, mean validity effect scores (difference between invalid cue and center cue reaction time) in the contingent capture paradigm (Folk et al., 1992). The meditation group showed a trend towards improvement of top-down attention while the relaxation group did not.

Using EEG we assessed the changes in amplitudes of wavelets during periods of mind-wandering and meditation. Periods in which subjects were on- vs. off-focus during the meditation task were identified by asking subjects to make button presses whenever the mind wandered and also at probe tones, if they were off-focus. After training, the episodes of mind-wandering were significantly lower in the meditation group as compared to the relaxation group. Increased amplitudes of alpha and theta EEG frequencies in the occipital and right parietal areas were seen during the meditation task for the meditation but not the relaxation group as an effect of training. A baseline EEG trait effect of reduced mental activity was seen (meditation training: occipital and right parietal areas; relaxation training: only occipital areas).

Within a given meditation session, prior to training, alpha and theta activity was lower in on-focus conditions (occurring immediately after subjects discovered they were off-focus and returned to active focus on the breath/syllable) compared to meditative focus segments. After training, we found higher alpha amplitude in periods of meditative focus as compared to periods of mind wandering for both groups. However, the meditation group showed significantly higher theta amplitude than the relaxation group during the meditative state segments.

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CHAPTER I

INTRODUCTION

Healthcare and Alternative & Complementary Medicine

Alternative and complementary medicine has carved a niche for itself in the health care system of the U.S. and most other countries for a variety of reasons. For example, its cost-effectiveness, its ability to provide solutions to some challenges unmet by western biomedicine, such as integrating care of the mind, body and emotions of an individual, and its ease of administration have made alternative and complementary medicine increasingly popular. Mind and body medicine and, in particular, meditation is being widely practiced (see Kabat-Zinn, 2003 for a review).

Though meditation, or the practice of focusing and relaxing the mind, has been traditionally considered an integral activity in various religious traditions, recent research has suggested that it is helpful in improving emotional well-being and reducing stress, and thus meditation is now a widely practiced psychological intervention used in clinical settings for generating relaxation responses (Benson, Greenwood, & Klemchuk, 1975). Various types of meditation, including concentrative meditation and mindfulness meditation, have been successfully employed in patient populations suffering from a variety of diseases related to or modulated by stress levels. Hypertension, alcohol intake, substance abuse, psoriasis and headaches are some disorders where mindfulness meditation or "the relaxation response practice" (non-religious medical based meditative

practice developed by Dr. Benson) has shown beneficial effects (Benson, Greenwood, & Klemchuk, 1975; Kabat-Zinn et al., 1998). We will now explore definitions of meditation that can accommodate various techniques of meditation and are applicable to the present study.

Meditation- Defining Characteristics

The word 'meditation' is derived from the Latin root 'meditari-' which means to'contemplate or reflect.' Since meditation encompasses a variety of tasks, defining meditation is a challenge. However, meditation techniques may be broadly classified along a continuum, based on the attentional processes involved, with the two poles being identified as concentrative meditation and mindfulness meditation, depending on how attentional processes are employed. Mindfulness meditation focuses on awareness of thoughts and sensations, as a non-attached observer, without judgment, and includes such practices as Zen and Vipassana meditation. Concentrative meditation involves focus on a specific mental or sensory activity, including a repeated bodily sensation such as the breath, or a thought, such as a mantra syllable, and includes yogic meditation and Samatha meditation, as well as aspects of Transcendental Meditation which involve repetition of a syllable (Cahn & Polich, 2006). In the sections below, defining characteristics of meditation will be discussed in terms of behavioral and physiological modulation that occurs as a result of a specific technique.

Meditation, a stress management technique for relaxation enhancement

Practicing certain meditation techniques, including types of concentrative meditation and, mindfulness meditation, such as Transcendental Meditation (TM) or Zen meditation can produce a decrease in muscle tone, respiratory rate and heart rate of the practitioner (Benson, Greenwood, & Klemchuk, 1975). Hence, meditation has often been defined as a wakeful hypometabolic integrated response (Jevning, Wallace, & Beidebach, 1992). Benson (1975) terms meditation as one of the activities generating a relaxation response. However, there are also certain hyperactive styles of meditation, for example, Qi gong, in which excited physiological states are also sometimes achieved. As defined by Shapiro (1982), meditation is a family of techniques which have in common a conscious attempt to focus attention in a non-analytical way, and an attempt not to dwell on discursive, ruminating thought.

Meditation, an altered state of consciousness

Since meditation can bring about a change in the level of consciousness awareness, the relationship of meditation and consciousness has been of interest. Consciousness here is defined as "the neural activity underlying the state of waking awareness" (Eccles, 1994; Woollacott, 2004) Meditation is considered "a psychologically induced altered state of consciousness" (Dietrich, 2003; Vaitl et al., 2005). Meditation has thus been defined as an ancient technique which aims to gain a degree of control over various autonomous psychobiological processes (Davidson & Goleman, 1977) and

changes in states of consciousness associated with meditation have been measured through electroencephalographic (EEG) measures, functional Magnetic Resonance Imaging (fMRI) and other measures of brain activity. The state of consciousness associated with meditation can be voluntarily practiced and can be modified with training.

Meditation, a mental training

Mental faculties like cognition and attention can be trained/ regulated with meditation. Thus meditation has also been defined as a, "group of practices that self-regulate the body and mind, thereby affecting mental events by engaging a specific attentional set" (Cahn & Polich, 2006). Takahashi et al. also endorse a similar view, using the definition, "meditation is an attainment of a restful yet fully alert physical and mental state practiced by many, as a self regulatory approach to emotion management" (Takahashi et al., 2005).

Finally, meditation has been defined as a "mental training" that brings about long term changes or trait changes in cognition and emotion (Lazar et al., 2005; Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004). A definition of meditation put forth by Lutz et al. (2007) is comprehensive and can be applied to different meditative techniques. Meditation is characterized by three features 1) the claimed production of a distinctive and reproducible state that is phenomenally reportable; 2) the claimed relationship between that state and the development of specific traits and 3) the claimed progression

in the practice from the novice to the virtuoso (Lutz et al, 2007). Similarly, Cardoso et al argue that meditation practices use a definite technique involving self-focus skills. Meditation is a self induced practice that produces both- muscle relaxation and logic relaxation (Cardoso, de Souza, Camano, & Leite, 2004). *We are interested in understanding these two components – focused attention (or self-focus as termed by Cardoso) and relaxation and their neural correlates in the attentional networks.*

Research on Meditation- Background, challenges, solutions

Surveys indicate that the use of meditation as an alternative and complementary medicine is increasing (Barnes, Powell-Griner, McFann, & Nahin, 2004; Wolsko, Eisenberg, Davis, & Phillips, 2004). Barnes et al reported that 62% of American individuals in a survey had used mind and body medicine within the survey year and that meditation accounted for 7.6% of mind and body medicine practiced within a year. This reflects an increase in the practice of meditation, and the increase is not only quantitative; studies have applied meditation successfully as a therapy to meet challenges like improving the mental health of HIV positive individuals, treating eating disorders and substance abuse. However, a recent NCCAM report (Ospina et al, 2007) mentions that the physiological and neuropsychological effects of meditation practices require cautious interpretation as only a small number of studies meet the strict criteria of randomized and controlled longitudinal clinical trials, which are the hallmark of the highest levels of excellence in research studies with relation to evidence-based practice. The majority of

the literature compares physiological data from meditation practitioners to a control group and hence the differences between groups can also be attributed to other factors than meditation training, such as self- selection biases. A number of studies have also been limited in generalizability by the use of a waitlisted control rather than a concurrent control in a longitudinal study. Other methodological issues like non-randomization or inappropriate randomization, and lack of blinding reduce credibility of the studies (Ospina, 2007; Jadad, 1996).

As background review, we shall now consider studies attempting to determine neural correlates of meditation and challenges faced by those studies. Thus, we consider factors that influence or should be taken into consideration while designing a research study related to meditation.

Techniques used in meditation studies

Selection of an appropriate technique/tool to measure state and trait effects for the meditation is crucial. The tests or tasks should be sensitive enough to measure the differences before and after training or across the two groups. Various computer-based tasks have been used to measure behavioral or physiological performance (e.g. the Stroop task, a measure of executive attentional efficiency, used by Chan and Woollacott (2007), and the Attentional Network task, a measure of executive, orienting and alerting network efficiency, used by Jha et al (2007)). These tasks typically inform us about the trait changes in meditation practitioners whereas tools like imaging give us ability to look at state changes during meditation.

Imaging is the most suited technique to study the spatial details of the neural substrates of meditation. Studies have reported activation in different neural substrates depending upon the meditation techniques used and the investigation techniques used, with a number of studies reporting that the frontal lobe and parietal lobe exhibit increased activation during meditative compared to baseline resting states (Dietrich, 2003; Lazar et al., 2000; Lehmann et al., 2001; Lou et al., 1999; Lou, Nowak, & Kjaer, 2005; Newberg et al., 2001; Travis, Tecce, Arenander, & Wallace, 2002). However, as meditation is a technique requiring focused internal concentration, usually in a noise-free environment, the high noise levels in magnetic resonance imaging scanners makes one cautious about the ability of individuals to enter a meditative state in this environment, and thus also about the interpretation of experimental results using this method. To help overcome this technical constraint in the use of fMRI, Lazar and colleagues attempted to accustom meditation subjects to the high noise levels in the scanner prior to testing (Lazar et al., 2000).

EEG data provide the temporal resolution required for determining differences in the performance of meditation practitioners on various attention related tasks (e.g. attention blink paradigms) (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Slagter et al., 2007). Alpha waves have an 8 to 12 Hz frequency. They are a characteristic of relaxed wakefulness. Any sensory stimulus will give rise to desynchronisation in alpha waves, also termed as an alerting response. Beta waves (13 to 30 Hz) are seen in frontal regions when a subject is engaged in intense mental activity (Chaterjee, 2000). Theta waves have a frequency of 4 to 8 Hz and are common in children of age two to five..

They are normally found in a state of drowsiness. Delta waves have a frequency between 0.5 to 4 Hz, are common in sleep and in infancy and in conditions like hypoxia and hypoglycemia but rare in adults. Gamma activity is at higher frequency 25 to 70 Hz and it is considered to be associated with coherence in brain activity (Knyazev, 2007).

Normal EEG can be affected by age, blood glucose levels, oxygen and carbondioxide levels, temperature, sensory stimulation, during sleep, narcotics and pathological conditions. In EEGs, we assess electrical activity of (typically pyramidal cells) neurons from the cortical surface. Deeper structures like the brain stem, thalamus and hippocampus cannot be assessed significantly as their contributions to surface electrical activity are poor. EEG is a summation of activity of the synapses of the pyramidal cells, which are oriented perpendicular to the cortical surface (Chaterjee, 2000; Kandel et al, 2004).

However, with the use of dense array EEG (more than 128 electrodes) one can obtain reliable information about the source of surface recorded brainwaves. The data from studies using EEGs to measure brain activity during meditation also adds to the evidence of frontal lobe and parietal lobe activations during meditative states (Aftanas & Golocheikine, 2001; Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004). However, increases shown in these studies are typically in the alpha and/or theta range. One must be cautious in comparing the results of EEG recordings and fMRI data, as increases in EEG slow wave frequencies (i.e., alpha and theta) have been interpreted by Lutz and colleagues (Lutz et al, 2007) as a reduction or inhibition in normal activity, associated with reduced sensory, motor or cognitive processing accompanying a quiet, alert state.

Magnetoencephalography is used to determine source dipoles of brainwaves. Using magnetoencephalography (MEG), Yamamoto et al. (2006) compared the current source dipoles of the brain activity in TM practitioners to a control group. The control group, who hadn't been trained in meditation techniques, performed a task of repeating a non-mantra syllable. The dipoles for the high amplitude alpha waves during TM practice were localized at the anterior cingulate cortex (ACC) and medial prefrontal cortex unlike the control group who did not exhibit high amplitude alpha waves (Yamamoto, Kitamura, Yamada, Nakashima, & Kuroda, 2006).

During a meditation session the regional cerebral blood flow (rCBF) increases, which can be measured via rheoncephalography. Jevning et al. (1996) compared the rCBF in experienced Transcendental Meditators (TM) and a rest control group. They found increased rCBF in the frontal and occipital regions in the TM group, which indicates an increase in cerebral activity in these areas during meditation; they thus concluded that meditation was an altered state of consciousness separate from sleep, since during sleep, the rCBF is decreased (Jevning, Wallace, & Beidebach, 1992).

In a separate study using Photon Emission Tomography (PET) and EEG, Lou et al. (1999) identified changes in regional cerebral blood flow (rCBF) during different types of meditation involving different types of visual, kinesthetic and emotional imagery. Subjects listened to a recording which gave verbal guidance related to visualization, feelings of joy, and experience of limb weight. Results showed that regional blood flow changes varied according to meditative content with meditation on limb weight activating parietal and superior frontal areas, whereas during the experience

of joy, Wernicke's area, the left parietal lobe and superior temporal lobe were activated. Finally, visualization activated the occipital lobe, except for V1. EEG analysis (20 electrodes, total) showed increases in theta frequencies throughout the meditation period (Lou et al., 1999).

Meditation may also cause changes in endogenous neurotransmitter release. Kjaer et al (2002) using Positron emission tomography (PET) scans and simultaneous EEG recordings, observed an increase in dopamine release in the ventral striatum of the basal ganglia complex during yoganidra meditation as compared to a rest condition. The increase in dopamine in the striatal area was correlated with EEG theta wave activity, and decreased blood flow to the prefrontal cortex, supporting the conclusion that the subjects were in a meditative state (Kjaer et al., 2002; Lou, Nowak, & Kjaer, 2005).

Challenges and concerns in meditation research

Ospina (2007) list five major problems associated with previous meditation research in their meta-analysis of published studies in this area. Cohort studies have not taken into account self-selection biases while assembling both an exposed (meditation) group and non-exposed (control) group. The comparison or the control group was similar to the population of interest only in 21% of published studies. In meditation training studies, lack of randomization of subjects between meditation and control groups and lack of blinding on the experimenter or participant's part, in order to curb any biases regarding expected outcome of the study, were also issues of concern. Lastly, a lack of any description of drop out rate in meditation vs. control group training studies was noted by Ospina et al. as a weakness of many longitudinal studies. Due to these

drawbacks the studies had a low score on the Jadad scale, measuring the quality of clinical trials, and thus the generalizability of results from these studies was questioned. We will now give examples of these concerns as seen in previous studies.

Population of interest

Studies have shown high levels of within and across group variability in the population of interest, i.e. meditation practitioners, in terms of length of experience of practitioners, age and type of practice.

Experience of meditator

A number of studies have been conducted on experienced meditators; in order to aim for consistency across subjects in state effects, i.e., experienced subjects can reproduce a deep state of meditation during each testing session. For example, the studies conducted by Sim & Tsoi (1992) and Lou et al (1999) had a single group of experienced subjects. They found that experience (proficiency) in meditation changed the subjective experiences of a meditator, the physiological functioning of the neural substrates and also the anatomical patterning of the underlying structures. In a study designed to measure these differences Lo et al (2003) examined the effect of meditation on brain activity using EEG and correlated it with the subjective experience of the subjects. They state that during meditation sessions, the experienced Zen meditators (more than 11 years of practice) perceived 'inner light' during what they described as a deep stage of meditation. This was correlated with alpha blocking and the emergence of a small amplitude beta

rhythm. The individuals with lesser experience did not report the experience of inner light or the alpha blocking and beta activity (Lo, Huang, & Chang, 2003).

A trait or long-term effect of meditation on cortical thickening was studied by Lazar (2005) in experienced meditators compared to control subjects using structural MRI. The subjects had experience in Insight or Vipassana meditation (a mindfulness based meditation). The control group had no experience in any type of meditation. The meditation group showed an increased cortical thickening in areas that have been previously associated with activation during meditative practice- the right middle frontal superior area, the prefrontal cortex and the right anterior insula. The experience in meditation was found to be positively correlated with the cortical thickening whereas the age matched controls did not exhibit cortical thickening (Lazar et al., 2005).

The above mentioned studies considered total experience of meditators in years; however, in a separate study the amount of daily practice of meditation (min/day) was found to be positively correlated with the ability to focus attention (Chan & Woollacott, 2007). Hence in designing a research study experience and proficiency both should be accounted for.

The control group

In randomized controlled trials, assessment of individuals to assign them to a group is important. The control group is to be matched on various criteria such as age, gender, education, occupation and lifestyle. The control group has to be assigned a comparable activity in a longitudinal study and the control group members should have

an equivalent training experience to that of the experimental group (equal training time, equal access to a teacher, equal belief in the validity of the training procedure).

Waitlisted Control Group Designs: Davidson et al, recruited 25 participants for a mindfulness based stress reduction (MBSR) seven week training program. The control group was of 16 individuals who were waitlisted for MBSR training. Self reports about positive and negative affect, anxiety and EEG changes in anterior electrode sites related to positive affect were assessed before and after training. As compared to the controls, the meditation group reported a significant decrease in negative affect. EEG recordings showed that meditators produced a greater left-sided EEG activation in central sites as compared to the controls.

To study the impact of meditation on the immune system, the researchers vaccinated subjects using influenza vaccine and measured antibody titers created in response to the vaccine, both in the meditation group and a control group at the end of meditation training. In the meditation group, at the end of training there was a rise in antibody titer, which had a positive correlation with increased positive affect, which was also related to an increase in left-sided anterior activation in the brain. Thus meditation enhances immune responses (Davidson et al., 2003). A similar waitlist control design was used by Carlson Linda et al (2001) to study the efficacy of the Mindfulness Based Stress Reduction (MBSR) program on mood and stress management in cancer patients (Linda, Zenovia, Eileen, Maureen, & Michael, 2001). However, using a concurrent control group, instead of a wait-listed experimental group as a control, adds more credibility to the research design since the experiences are the same.

In a cross-sectional study Khare and Nigam (2000) compared EEG data of individuals practicing meditation and relaxation, testing subjects before, during and after a meditation/relaxation session. The meditation group showed prominent alpha activity during meditation whereas relaxers had prominent beta activity. The alpha activity persisted even at the end of the session and on opening the eyes. An unusual finding of this study was the presence inter-hemispheric symmetry in alpha activity since previous studies have shown right hemisphere dominance in alpha activity (Gaylord, 1999; Bagchi, 1957; Wallace 1970). A weakness of the study was that the meditators had a novice level experience (3 months) while the relaxation group was naïve. Thus it is difficult to compare groups with different levels of training in the two techniques (Khare & Nigam, 2000).

Lutz et al. (2004) conducted a study to examine the role of neuronal synchrony as a neural mechanism underlying mental training (meditation) in long-term meditators (Tibetan Monks). A naïve control group with a different cultural background (American) and a different age range (substantially younger) was given instructions similar to loving kindness meditation a week ahead of testing. The EEGs of the long-term meditators showed high amplitude gamma frequency during meditation that was not present in the control subjects, in addition to higher level base-line gamma activity than the control group. The increase in gamma synchrony in meditators was prominently in the midfrontal and the parietotemporal lobes.

Lutz et al. argue that the difference in the baseline EEG characteristics between groups is not due to the difference in ages of the experimental and the control group

(meditation group mean age = 49 years; control group = 21 years). Even when the youngest practitioners in both the groups were compared, the ratio of gamma oscillations to the slow rhythms (4 – 13 Hz) remained higher in the meditators. A better research design would use meditators and controls that were matched as closely as possible on the basis of age, gender, cultural background and education (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004).

Gaylord et al (1989) conducted a study in the black (African-American) adult population to test the effects of one year of training in Transcendental meditation (TM) techniques vs progressive muscle relaxation (PMR) or cognitive behavioral strategies (C) on EEG coherence, stress reactivity, and mental health. They found significant improvements in mental health and reduction in anxiety in the TM and PMR groups. However, only the TM trained group showed increase in alpha and theta coherence in frontal and central EEG electrodes compared to eyes closed rest. Changes were most marked in the right hemisphere. None of the groups showed longitudinal changes in EEG with training. The study design was weakened by not balancing groups for age, education, etc. In addition, EEG coherence showed a positive correlation with IQ post-training. However, during reporting EEG coherence, the researchers grouped all the participants together, irrespective of the activity practiced. Such methods do not contribute towards refuting alternative explanations of the results (Gaylord, Orme-Johnson, & Travis, 1989).

To summarize, in studies of the efficacy of meditation training, a well-matched control group is required to increase the credibility of results. Issues like lifestyle, age,

gender and possibly genetics should not be ignored while matching the groups. In longitudinal studies, a careful documentation of quantitative and qualitative practice during the monitored (e.g. in class) and unmonitored (e.g. at home) phases of the training programs, with the help of logs/journals and possibly objective parameters, like Holter monitoring, is needed.

<u>Attentional networks and control of attention</u>

Meditation training can enhance the ability to attend to an object of focus and ignore distractors (Chan and Woollacott, 2007; Jha et al, 2007). The neural processes underlying attentional control have been widely studied both physiologically and anatomically. Depending upon the specific form of information processing examined and the cortical areas facilitating the information processing, Posner and Peterson (1990) have proposed three attentional networks, including the alerting, orienting and executive control networks. Alerting has been defined as "achieving and maintaining an alert state." Research has shown that the right frontal area and parietal area are associated with the alerting function. Orienting has been defined as "selection of information from sensory input," and executive control has been defined as "resolving conflict among responses." Orienting can be viewed as attentional selection at the sensory input level whereas conflict resolution is attentional selection at the response output level. The superior parietal lobe has been hypothesized as the neural substrate for orienting and the anterior cingulate gyrus and frontal areas for executive function or conflict resolution (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner, 1994; Posner & Rothbart, 1998).

Although evidence supports a degree of independence of these networks, cooperation and interdependence between the networks has also been suggested (Raz & Buhle, 2006).

As an alternative approach to attentional processing models, Corbetta and Schulman have proposed a bipartite attentional network. According to their view, the dorsal attentional network consists of frontal eye fields (FEF), bilateral posterior parietal cortex (PPC), and the intraparietal sulcus (IPS). This network shows neural activations during stimulus selection, response selection and task switching, thus facilitating the endogenous, top-down, voluntary control of attention. The functions of orienting and conflict resolution would be considered part of the voluntary control of attention and hence controlled by the dorsal network of attention. The ventral system of attention consists of the temporoparietal cortex (temporoparietal junction, TPJ) and ventral frontal cortex (VFC). This system carries out stimulus driven, exogenous, bottom-up control of attention. The TPJ acts as a "circuit breaker" and helps in orienting attention to relevant stimuli (Corbetta & Shulman, 2002; Fox, Corbetta, Snyder, Vincent, & Raichle, 2006; Serences et al., 2005).

Studies have highlighted modulation of voluntary attentional control via various processes like drug-effects, hypnosis and meditation (Vaitl et al., 2005). During a focused type of meditation, the impact on the attentional networks has been hypothesized to be temporally divided into two parts, phasic control and tonic control. During phasic control, the prefrontal cortex and frontal eye fields (dorsal attention network) would lead to an initial quieting of both the mind and body. In addition, tonic control is hypothesized to be exerted by the basal ganglia-thalamocortical loop. These circuits are hypothesized

to cause alpha synchronization and maintain a state of 'restful alertness.' If an individual has 'other' experiences than transcending (e.g., awareness of environmental stimuli) it is hypothesized to result in alpha desynchronization (Travis, 2001; Travis & Wallace, 1999). In the present study we are interested in assessing the phasic control or the initial executive control of attentional processing associated with meditation. We also want to explore the trainability of the dorsal attentional network and thereby executive control and orienting.

During meditation, like in any other continuous performance task participants may undergo alternating periods of diffused attention or mind-wandering and focused attention. According to Schooler's theory of mind-wandering, personally relevant goals may be automatically activated and make a participant drift away from a task-related goal (Smallwood, McSpadden, Luus, & Schooler, 2007; Smallwood & Schooler, 2006). It is probable that in previous research on meditation, such periods of mind-wandering were averaged in to the analysis of the data from the meditation session and thereby reduced the clarity of the results. *In the present study we attempt to determine the EEG characteristics associated with on-focus vs. off-focus periods of meditation.*

BRIDGE

In summary, the objective of this research was to determine the effects of meditation training on the efficiency of attentional processing networks, including both short-term state effects and long term trait effects. A small number of studies have been previously performed to examine the effectiveness of meditation training on attentional processing efficiency. Though these studies give some tantalizing evidence regarding the possible improvements in processing within specific attentional networks, both as a result of short effects of meditation on an individual's state (during and immediately after meditation), and longer term effects that indicate carry over of improved processing into performance on activities of daily living, they also suffer from a number of limitations, described above.

Though these initial studies have suggested that meditation can improve attentional network efficiency, the factors and neural mechanisms underlying this improvement are not clear. First, no randomized and controlled clinical trials have been performed, in which the effects on attentional networks of meditation training and a reasonably similar control training were compared. Second, though studies of meditation note that training includes both an element of relaxation and of attentional focus, no one has carefully determined the contributions of these two factors to improvement in the efficiency of attentional networks. Finally, no studies have actually dissected meditation sessions into periods of active concentration vs. periods in which the practitioner was distracted by extraneous thoughts

or by sleepiness. Thus, when recording such physiological correlates of meditation as EEG, it is possible that periods of different types of unfocused attention were averaged in with focused attention, thus reducing the clarity and precision of the results.

To address these issues, a longitudinal pseudo-randomized controlled clinical trial was performed to examine the relative effects of concentrative meditation training vs. relaxation training on attentional network function. This allowed the comparison of the relative contributions of components of attentional concentration vs. relaxation to the neuropsychological and physiological measures of attentional network efficiency. The following tests and measurements were included in pre-test and post-tests. Neuropsychological test: The Contingent Attentional Capture task (Folk et al, 1992; 1994; 2002) for a neuropsychological measure of the efficacy of goal-driven voluntary attentional networks vs. stimulus driven networks (dorsal vs. ventral frontal/parietal attentional systems) and personality state and trait inventories. Electroencephalograms (256 electrodes): to determine the extent to which training in relaxation vs. focused concentration + relaxation is associated with changes in the activity of brain regions associated with specific attentional networks. We hypothesized that participants trained in meditation (including mental/ cognitive relaxation) compared to relaxation alone would show significantly higher efficiency in networks of both executive and goal-driven voluntary attentional systems. In addition, we hypothesized that they would show increased alpha and theta slow wave power in sensory cortex (occipital and parietal) networks associated with decreased activity in these areas (hypothesized to be associated with reduced attention to external stimuli). We also hypothesized that there would higher

be levels of alpha activity during baseline rest as a result of trait effects of meditation causing subjects to remain in a more relaxed state during daily function. We also examined periods within a meditation session when practitioners were on vs. off focus on the concentration task and compared physiological characteristics (EEG) under these identified periods of differential focus.

CHAPTER II

MEDITATION TRAINING AND IMPROVEMENT OF THE ABILITY TO

OVERRIDE ATTENTIONAL CAPTURE

Introduction

Attention and neural systems contributing towards its control

The ability to focus attention on a single task or relevant stimulus with minimal

distraction by extraneous stimuli is an important skill for successfully performing most

cognitive tasks. Attention that is directed by voluntary intention on the part of an

individual to a particular cue is called top-down or goal-directed attention, while

attentional focus that is temporarily controlled by events in the environment, is referred to

as bottom-up or stimulus driven attentional control (Corbetta & Shulman, 2002; Fox,

Corbetta, Snyder, Vincent, & Raichle, 2006)

Studies examining activation of brain areas using fMRI while individuals perform

various attentional tasks, have characterized the specific brain regions involved in

voluntary vs. stimulus driven modes of attention. Top-down voluntary attention is

controlled by the dorsal frontoparietal network that consists of parts of the intraparietal

sulcus and frontal eye fields (FEF) bilaterally, whereas the bottom-up stimulus driven

network is right lateralized and includes the ventral prefrontal cortex (VLPFC) and the

temporoparietal junction (TPJ). The TPJ is believed to act as a circuit-breaker in the

process of disengaging attention (Corbetta & Shulman, 2002). Attentional orienting in visual space is defined as allocating attention to a sensory stimulus (Posner, 1980). Orienting can be measured using various paradigms which measure reaction times to spatial or non-spatial cues (e.g. attentional networks test (ANT), spatial cue paradigm. Attentional capture can be exogenous or automatic (e.g., a flash of light in the periphery of vision). These shifts of attention can be influenced by the features of the target stimuli that are shared by the cue or the distractor. The contingent attentional capture hypothesis states that there is an involuntary shift in attention to a given stimulus event if the stimulus and the task involved share the same properties (Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994; Raz & Buhle, 2006). Orienting attention has been hypothesized to be a function of the interaction of these two systems. The attentional system can be "programmed" to selectively pay attention to a property of a target when the spatial location is unknown. The occurrence of an involuntary shift of attention will depend on the similarities of the properties exhibited by the target and the cue (Folk, Remington, & Johnston, 1992).

The interaction between the dorsal and ventral systems of attention can be assessed through a variety of tasks, including the contingent attentional capture paradigm (Folk, Leber, & Egeth, 2002; Folk, Remington, & Johnston, 1992; Serences et al., 2005). This task was originally devised to investigate the neural basis of the interaction between voluntary attentional control and stimulus-driven attentional capture. Testing the performance of individuals on the contingent capture task reveals their ability to modulate attentional focus, and ignore distracting stimuli. Thus this test can be used to

measure the control of voluntary attention by measuring the impact of attention on post-perceptual processes like response selection.

Evidence for the trainability of attentional skills

Previous research has shown that attention is a flexible and trainable skill. For example computerized training involving attention tasks (e.g. sustained attention, selective attention, orienting of attention and executive attention) have shown improvements in non-trained measures of attentional function like non-verbal complex reasoning tasks in typically developing children and adults and also in children and young adults with attention deficit hyperactivity disorder (ADHD). Green & Bavelier found that individuals playing computer action games demonstrated better attentional abilities at central and peripheral locations both as compared to the non-gamers. La Pera et al. used somatosensory oddball paradigm in elderly individuals to demonstrate trainability of voluntary oriented attention and not automatic attention (Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002a, 2002b; Rueda, Posner, & Rothbart, 2005; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Shalev, Tsal, & Mevorach, 2007) (Green & Bavelier, 2006; Le Pera, Ranghi, De Armas, Valeriani, & Giaquinto, 2005).

In addition to the use of computerized games and programs for attentional training, many clinics and hospitals are using meditation or mindfulness training to improve attentional focus and self-regulation of mental events (Cahn & Polich, 2006; Kabat-Zinn et al., 1998; Linda, Zenovia, Eileen, Maureen, & Michael, 2001). As defined by Shapiro (1982), meditation is a family of techniques which have in common a

conscious attempt to focus attention in a non-analytical way, and an attempt not to dwell on discursive, ruminating thought. Discursive and ruminating thoughts imply digressive ideas which depart from the main focus of attention. In concentrative meditation techniques, attentional focus is maintained on a static or dynamic object (e.g. the breath, a syllable or a visual object) by exerting voluntary control. Hence an element that contributes to improved meditational focus involves attentional training (Dietrich, 2003; Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004) (Chan & Woollacott, 2007). Superior abilities to exert voluntary control of attention in meditation practitioners as compared to non-practitioners have been documented in the above mentioned studies. These abilities have been studied both as trait effects (i.e., long-term changes in attentional function) and also as state effects (i.e., transient changes resulting from a single session of meditation). Various studies have assessed the attentional abilities of meditators behaviorally (Chan & Woollacott, 2007; Jha et al. 2007; Slaghter et al, 2007). One cross-sectional study comparing meditators to age, gender and education-matched controls showed that executive attention (as measured by reduced interference effects on the Stroop task) showed a trait effect of improved function in meditators, and this was correlated with minutes of meditation practice per day (Chan & Woollacott, 2007). A second study examined the ability of meditators to process two temporally-close stimuli, which compete for limited attentional resources, in an 'attentional-blink" experiment. They found a smaller attentional blink after three months of intensive meditation training indicating that meditation training can cause increased control over the use of limited attentional processes (Slaghter et al, 2007).

Though these studies have focused on measuring and defining differences in the attentional abilities of meditation practitioners and non-practitioners, the interpretability of their results for meditation improving attention is difficult due to methodological limitations. For example, self-selection biases and between-group differences in either genetic or environmental factors are possible confounds in correlation studies. In addition most of the longitudinal studies have not used appropriate control training groups with equivalent lengths of training periods on a different type of task, but have used wait-listed control subjects. In this situation, placebo effects (the simple process of administering any treatment) are not taken into account and it is not clear to what extent the particular activity contributes to improvements in attention (Davidson et al., 2003; Lehrer, Woolfolk, Rooney, McCann, & Carrington, 1983). Thus, there is a need for carefully controlled, randomized, clinical trials on the effects of meditation training on attentional processing in individuals.

Finally, previous research characterizing the effects of meditation on mental states of individuals have proposed meditation training as containing both elements of relaxation and attentional focus, being defined as a relaxed yet heightened alert state (Dietrich, 2003). It would be helpful to separate out the contributions of these two aspects of meditation training to assess improvements in attentional function.

Meditation and Contingent Capture of attention

In order to address these issues, the current study used the contingent attentional capture paradigm (Folk et al.1992) to determine if eight weeks of meditation training (40 min/day, 5 days/wk) would influence voluntary top-down attentional control (the dorsal

attentional network) and concomitant abilities to ignore distracting stimuli (the ventral attentional network). The study was designed as a randomized controlled trial, with the control group being trained in progressive muscle relaxation. Meditation training focused attention on the breath whereas in progressive muscle relaxation training attention shifted from one muscle group to another in order to relax the various muscle groups of the body. The study aimed to determine whether any attentional improvements could be specifically attributed to meditation training, rather than a general training placebo effect or relaxation. If an improvement in the cost of invalid cues, after training, was seen only in the meditation group as compared to the relaxation group then according to the attention training hypothesis, meditation training would be associated with enhancing the abilities of the dorsal attention system to overcome reflexive orienting. In contrast, if the same cost of invalid cues was seen in both groups, post-training, then the effect of training would be seen as an outcome of relaxation components in either the trainings or a placebo effect. We hypothesized that meditation training would improve performance on the contingent attentional capture paradigm more than relaxation training, due to the attentional focus involved in meditation.

In order to investigate attentional capture we replicated Experiment 1 and 2 from Folk et al (1992). In this task, subjects are asked to classify a target character, which can occur at one of four locations around the fixation point, as either an 'x' or an '='. On separate blocks of trials subjects are instructed to either respond to an 'abrupt onset' where the target appears with no other characters or to a red target among three other white distractors. In addition, across blocks subjects were provided with different spatial

cues that preceded the onset of the target: either they were given no cue, a central cue (which provides no information about the location of the target, a valid location cue, or an invalid location cue. On abrupt onset blocks, subjects are not surprisingly faster at identifying validly cued targets than no cue targets. Subjects are slower, however, to respond to abrupt onset targets when they are invalidly cued than when there is no cue, suggesting that the invalid cues have "captured" their attention, despite the fact that subjects know they are irrelevant (since these trials are blocked, the subjects know the invalid cues are not informative). In the abrupt onset condition when the cue is invalid it produces a cost on reaction time as it shares the onset property with the target. However in the color target condition, there is no cost of the invalid cue as the subject identifies the target based on the color. With attentional training we would expect that the cost in reaction times for invalid times should be lesser or the benefits of the valid cues should be greater. We expect to see a smaller cost for invalid cues after training in the meditation group as compared to the relaxation group.

<div style="text-align:center">Methods</div>

Subjects

This was a pretraining- posttraining research design. Each participant was tested before and after training under similar testing conditions (same time of day and in the same testing room). Participants (n=30) were recruited from an undergraduate Alternative and Complementary Medicine class. Based on the information provided in a lifestyle questionnaire, the participants were assessed on age, gender, physical activity, sleep, education level and GPA and then pseudo-randomly assigned to either the meditation or

relaxation training group. Subject demographics are shown in Table 1. Physical activity scores were computed based on occupational demands and the exercise regimen followed by an individual. Participants with a history of head injury, concussion or learning disabilities were excluded. Participants with previous experience in meditation (n=2) participated in class activity for the extra-credit opportunity; however their data were not incorporated in analysis.   The participants practiced the assigned activity (meditation/relaxation) for 20 minutes in class and 20 minutes outside class (a total of 40 min/day) for at least 5 days a week. This training regimen was maintained for eight weeks and their compliance with the practice was measured with weekly logs.

Table1. Demographics of the participants in the study

Sr.No		Meditation	Relaxation
1.	Age (Mean)	23.1years(S.D.3.1)	22.8 years(S.D. 4.8)
2.	Gender	12F, 3M	11F, 4M
3.	Physical activity	2.2	2.8
4.	Educational level (years)	15.9	15.8
5.	GPA	3.3	3.2

The participants in both groups were given handouts describing the daily practice of meditation or progressive muscle relaxation before training began. In-class sessions were guided by expert instructors. At the beginning of a session, the meditation group

was instructed to sit in an erect comfortable posture with the spine elongated. The subjects were instructed to focus on the breath and silently repeat the syllable 'Om' on every in-breath and out-breath. The subjects were then intermittently reminded to let go of any thoughts arising and focus on their breathing. Since the subjects focused on their breathing, we define this meditation training as focused attentional training.

The relaxation group was instructed in progressive muscle relaxation, with individuals being instructed to focus on the different muscle groups of the body in succession (starting with muscles of the feet and working upwards toward the face). At the end of the single sequence of relaxation instructions, the participants were instructed to let their mind relax and wander to whatever thoughts arose. None of the participants fell asleep during the relaxation training; however, they reported in weekly logs mind-wandering to relaxing thoughts. To prevent any expectations about the effectiveness of a particular training for improving attentional abilities, the two groups were given information about meditation and relaxation as an alternative medical therapy for stress reduction in class and led to believe that both the training paradigms were equally effective in training. Any biases in the beliefs of participants about training were assessed with the help of an exit questionnaire at the end of the training program.

The participants filled out the KIMS (Kentucky Inventory for Mindfulness Skills) assessment self report after completing the entire training program at the end of the study. The inventory had questions which could assess changes in ability to observe experiences, ability to describe experiences, awareness of experience, and non-judgmental acceptance of experiences.

Procedure

The behavioral task, the contingent attentional capture task (Folk, Remington, & Johnston, 1992) is depicted in Figure 1. The subjects were seated about 40 cm away from the screen. Depending upon the goal-set the subjects had two target conditions: abrupt onset condition and color target condition. In the abrupt onset condition, participants were instructed about the cue-target location relationship and a single 'x' or '=' appeared on the target display. The participants responded to the type of target seen. In the color target condition, the information about cue-target location was known to participants but the instruction was to respond to a red character. Thus, there were four cue-target conditions: the valid cue (target appears in the same spatial location as the precue), invalid cue (target does not appear in the same spatial location as the precue), center cue (the cue was always in the center), and the no cue condition. In each block of trials, the cue condition remained the same and the subjects were informed about the cue condition in advance. Thus subjects were completely aware of the spatial relationship between the cue and the target. (The terms valid and invalid are often used in reference to expectancy information that is given by a cue. In this paradigm we use exogenous cues, and the terms refer only to the relationship between the positions in space of the cue and target.) The subjects were asked to respond to the target character they saw on the display (a left key for 'X' and a right key for '='). Reaction times and accuracy were measured for each trial.
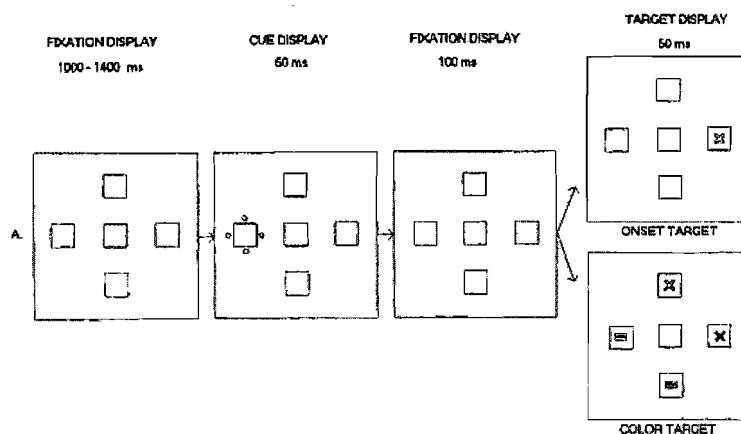
Figure 1. Task display for contingent capture paradigm (from Folk and Remington 1992)

Stimuli were presented on a 36x29cm CRT monitor at 800x600 resolutions with a viewing distance of approximately 40cm. The E-Prime computer program was used to display stimulus sequences and to collect subject responses from a keyboard. Each stimulus sequence consisted of a fixation screen displayed for 1000-1400 ms, a 50 ms cue, a second fixation screen displayed for 100 ms, and finally the target display for 50ms. Although the display disappeared immediately, the next trial was initiated only after the subject generated a response to the previous trial. The fixation display consisted of five squares, each with a side length measuring 1.2 deg visual angle. The squares were arranged as a '+', with a square on the top, bottom, left, right, and center. The four outer squares were each located at a visual angle of 5.1 deg from the center. The boxes were light grey in color, against a black background. The cue display consisted of four small white circles centered approximately .3 deg from the sides of one of the five boxes. Cue circles subtended a visual angle of .36deg. The target display

consisted of the original fixation display, with either the symbol 'X' or '=' appearing inside one of the squares. The target symbols subtended a visual angle of .5 deg and were colored white.

Design

This was a pre-training- post-training research design. The dependent variables measured were reaction times and accuracy. Reaction times, measured in milliseconds, are a quantitative variable, whereas accuracy, a qualitative variable, was coded numerically, i.e. 1 for accurate responses and 0 for inaccurate responses. Within subject independent variables were time, cue condition, and target conditions, which are all qualitative variables. Time refers to testing time and had two levels, pre-training and post-training. Cue condition had four levels depending on the spatial location of cues, no cue, center cue, invalid cue, and valid cue. Depending on the shape of the target there were two target conditions, 'x' target and '=' target. However, these two target conditions did not bring about any statistically significant impact so are reported together. The between subjects factor was the training group which had two levels: meditation group and relaxation group. Using the above mentioned design we assessed the impact of training on reaction times and accuracy under various cue and target conditions across both the training groups.

Results and Discussion

Accuracy analysis

The overall accuracy pattern on pre-training testing was similar to the original study (Folk, 1992). There was no significant change in accuracy as a function of training. The results are summarized in Table 2.

Table 2. Accuracy as a function of Target-Property condition and Training

		Onset Accuracy			
		No Cue	Valid	Invalid	Center
Meditation	Pre	0.93	0.94	0.96	0.95
	Post	0.93	0.95	0.95	0.96
Relaxation	Pre	0.94	0.92	0.92	0.92
	Post	0.96	0.96	0.92	0.92

		Color Accuracy			
		No Cue	Valid	Invalid	Center
Meditation	Pre	0.91	0.93	0.92	0.92
	Post	0.93	0.93	0.90	0.93
Relaxation	Pre	0.91	0.93	0.92	0.91
	Post	0.92	0.85	0.89	0.88

No significant interaction effect of training (time) or type of training (group) was seen ($F_{(1, 23)} = .498$). No significant effect of cue or condition was found on accuracy and there was no significant cost of invalid cues on accuracy or a benefit of valid cues on accuracy. However, we explored for a possibility of a speed- accuracy trade off in the next section of reaction time analysis.

Reaction Time Analysis

Global effect on speed

We will first discuss the effects of the abrupt onset condition. In this condition there is a contingent capture of attention as the target property (abrupt onset) and task-set is the same. Table 3 shows the mean of reaction times pre- and post-training for both meditation and relaxation groups for each of the cue conditions in the contingent attentional capture task.

Table 3. Reaction times (in ms) as a function of training and cue conditions

| | | Onset RT | | | |
		No Cue	Valid	Invalid	Center
Meditation	Pre	408.8	397.3	489.9	432.2
	Post	396.1	391.6	463.8	431.0
Relaxation	Pre	427.3	419.1	478.2	460.6
	Post	412.5	408.2	455.5	428.9

| | | Color RT | | | |
		No Cue	Valid	Invalid	Center
Meditation	Pre	477.29	454.32	483.80	466.06
	Post	459.12	435.38	478.26	452.61
Relaxation	Pre	473.11	475.52	486.35	488.96
	Post	460.02	444.42	482.95	452.97

Reaction times beyond +/- 3 Std. Dev with respect to the mean of each subject's mean reaction times were excluded from analysis. No significant interaction effect of time*group was found for any of the four cue conditions: no cue condition ($F(1, 23)<1,$), valid cue condition ($F(1,23)<1$), invalid cue condition ($F(1, 389)<1$), and center cue condition ($F(1, 23)=1.09$, $p>.05$, p=.306). Thus, an overall speeding or slowing of reaction times was not seen ruling out a practice effect. From Table 2 and Table 3 we see

that in the valid cue condition the groups were faster but their accuracy was lower, whereas in the invalid cue condition or no cue conditions the accuracy was greater but reaction times were slower. This suggests the subjects were conservative in making their responses.

Effect of misdirected or invalid cues on task performance

The cost of an invalid cue (the slowing of reaction times when the cue is invalid) is the difference between the reaction times required for the invalid cue condition and the center cue condition. We used the center cue condition as a control condition as it does not help in orienting or conflict resolution but serves the purpose of alerting the subject, unlike a no cue condition. The costs of invalid cues are shown in Table 4.

Table 4. Cost of invalid cue as a function of target-property condition

		Onset	Color
Meditation	Pre	57.7	17.7
	Post	32.7	25.7
Relaxation	Pre	17.6	-2.6
	Post	26.6	30.0

The cost of an invalid cue is greater for the onset target condition as compared to the color target condition, which is similar to what would be expected from the contingent capture hypothesis. Figure 2 depicts the costs of invalid cues and the benefit of valid cue as a function of training and group. We will discuss the onset target condition in the following section.
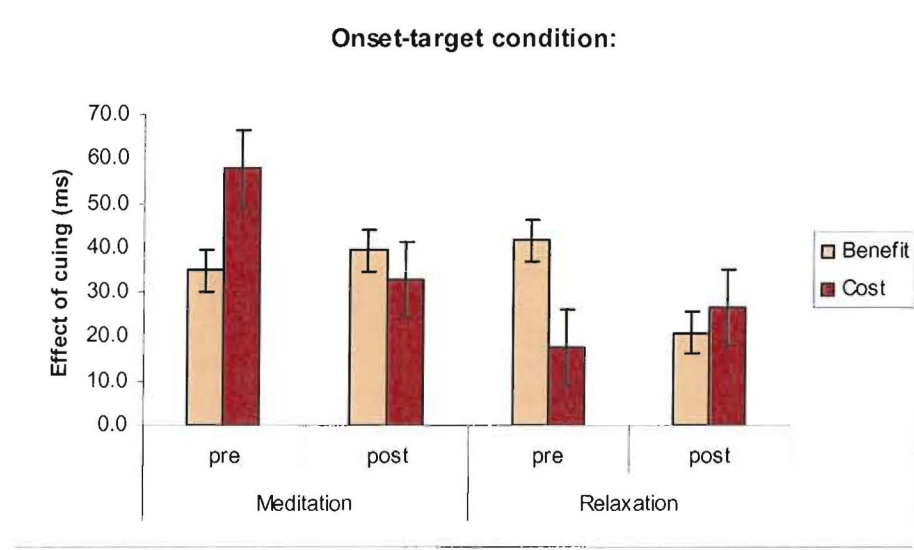
Figure 2. The effect of cuing as a function of training and group

Change in costs of invalid cues

On collapsing all the subjects into one group, no significant main effect of training was seen (F $(1, 23)$ <1). We tried to assess the impact of training group on the cost of invalid cues. We did not see significant differences across the groups (F $(1, 23)$ = 2.42, p=.133). However, from figure 2, we find a trend towards reduction in cost of the invalid cue in the meditation group and no such trend in the relaxation group. These results are to be interpreted with caution as we see a difference in the cost of invalid cues across the two groups before training (Time 1). The two groups were carefully matched based on their lifestyles and hence almost identical costs and benefits of cue conditions were expected at the beginning of the training. However, surprisingly, the meditation group showed a larger cost of invalid cues as compared to the relaxation group.

It is possible that since the cost of invalid cues in the relaxation group was small there was no opportunity to observe improvement even if one had occurred. Considering medians of the cost of invalid cues of the respective groups, we selected a subset of trials to rule out the differences. The higher end of the relaxation group and the lower end of the meditation group were compared with relation to their own costs with paired samples T-test. The meditation group (lower than median) did not show any significant change (t (5) =.104 p=.92); neither did the upper half whereas the higher than median relaxation group did show a significant change in the cost of invalid cues (t (1)=44.49 p=.014). The possibility that there was no room for change, due to the low cost of the invalid cue at time 1, cannot be ruled out. Hence we need to interpret these results with caution.

Effects of valid (positive) cuing

We assessed the change in benefits as a function of training with repeated measures ANOVA. There was no significant impact of training alone when all the subjects were collapsed into one group (F(1,23)<1). No interaction effects were seen when we examined the impact of group on positive cuing (F (1, 23)= 1.27 *p*=.270).

For Color target Condition:

This condition is a non-contingent capture condition. Similar to the original study we did not find any change in the cost of invalid cuing for the color target condition. A mixed effect ANOVA was computed to assess the effect of training (pre-training and post-training) across both the groups (meditation, relaxation) on the cost of invalid cuing for the color target condition. No significant group*time interaction was found (F (1, 23)

<1). No main effect for time or group was found (F(1,498)= .191, p= 662) and (F(1,23)<1).

Exit Questionnaire

The participants reported about their beliefs both related to meditation and relaxation training, irrespective of the training group they belonged to. A one way ANOVA was computed to assess the beliefs (biases) of the participants for meditation and relaxation. The two groups did not show any significant differences ($F(1,28)=.620$, $p=.438$) for meditation or relaxation training ($F(1,28)= .543$, $p=.468$). The possibility of biases and beliefs of the subjects influencing the training and compliance to the training is thus ruled out.

General Discussion

This randomized controlled study examined the efficacy of an eight-week concentrative meditation training as compared to progressive muscle relaxation training on the enhancement of top-down voluntary control of attention, as measured by the contingent attentional capture task (Folk et al, 1992; 2002). Using relaxation training for the control comparison group allowed us to determine the specific contributions of training in attentional focus vs. relaxation (two components of meditation training) to any improvements in attentional abilities.

Results showed a trend towards reduction in cost of the invalid cue in the meditation group and no such trend in the relaxation group. High performance levels in the contingent attentional capture task and other similar tasks have been shown to be associated with activity in the dorsal posterior parietal cortex and in frontal cortex,

whereas increased attentional capture by distracting stimuli is associated with activity in the temporo-parietal junction and the ventral attentional system. Given this, the current findings suggest that meditation training improves the performance of the dorsal posterior parietal and frontal attentional network (Folk et al, 2002; Corbetta & Schulman, 2002; Serences et al, 2005), and its ability to overcome the influence of attentional capture by the ventral attention system.

The results of the present study support those of Chan et al (2007) who used a cross-sectional study of meditators vs. non-meditators to assess executive attentional function, using the Stroop task. They found that meditators showed significantly less interference on the Stroop task than non-meditators. High levels of performance on the Stroop task have also been shown to be associated with activation of the dorso-lateral prefrontal attentional network along with decreased engagement of the ventral attention system (Harrison et al, 2005; Kaufmann et al, 2005)

In a second study investigating training-induced changes in attentional abilities of a meditation training group versus a control group (receiving no training) Jha et al (2007) reported better orienting abilities in the meditation group compared to the control group post-training, using the attentional network task (ANT) (Fan, McCandliss, Sommer, Raz, & Posner, 2002). Functional brain imaging using the attentional network task showed frontal and parietal area activation during orienting components of the ANT task and similar tasks (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Thiel, Zilles, & Fink, 2004). It is of interest that this study did not show differences between groups when comparing orienting effects pre vs. post-training, possibly due to large practice effects

within the ANT task when it is repeated. But in the present study, we found a trend towards improvement in the orienting ability of the meditation training group, as expressed in their improved ability to suppress invalid stimulus-driven distraction post-training. The meditation techniques used in these studies were different from each other along with the experience of the participants. These factors may have contributed to the different findings in these two studies.

These results also show a similarity to other studies using different attentional training paradigms. Effects of attentional training using the oddball paradigm (embedding infrequent targets and distracters into the stimulus train) have been studied in elderly subjects by Pera et al. The researchers found that voluntarily oriented attention could be trained but the automatic (involuntary) attentional system was not trainable (Le Pera, Ranghi, De Armas, Valeriani, & Giaquinto, 2005).

Study Limitations

In spite of its careful design, the present study has some limitations. Due to the fact that the training study was embedded within a university class of about 35 individuals, the number of participants in each training group was small (15) and hence the study does not have a high degree of statistical power. As a guideline for future studies we computed power analysis (alpha=.05, power=.80) and the sample size required is about 60+ (30 each group) total subjects. The training period of eight weeks which was accommodated within one academic term may need to be longer in order to bring about sufficient change in concentration abilities and thereby increase in performance on the contingent

attentional capture task. In a study with a similar sample size, examining the effects of meditation (yoga) on attentional abilities in children with attention deficit hyperactivity disorder (ADHD), Jensen and Kenny (2004) also found similar small effect sizes, with a trend towards significance in improvement on the DSMIV, the inattentive subscale.

Supporting the hypothesis that longer periods of meditation training may be necessary to show larger effect sizes, it has been reported by Rani and Rao (1996) that better attention regulation abilities occur in children who had the experience of at least one year experience with meditation practice. Travis (2002) also report increased alertness/preparedness on cognitive tasks in long-term meditation practitioners. Hence we hypothesize that a longer duration training period would increase the effect size of the meditation training on performance of the contingent attentional capture task (Travis, Tecce, Arenander, & Wallace, 2002). It is likely that even after incorporating all the above mentioned suggestions one might not see significant results as the task itself may be insensitive to the changes brought about by meditation training.

In conclusion, this randomized controlled study show some suggestion of evidence supporting the hypothesis that meditation training improves voluntary top-down attentional control, which has previously been shown to be associated with activity in the dorsal frontal-parietal attentional network. It also suggests that the primary component of meditation training contributing to this effect is the element of concentrative focus, rather than relaxation. This type of concentrative training may thus be a useful educational tool in improving attentional performance in both healthy young adult and patient populations.

CHAPTER III

A RANDOMIZED CONTROLLED TRIAL COMPARING CONCENTRATIVE

MEDITATION VS. RELAXATION TRAINING: IMPACT ON MENTAL FOCUS

AND EEG CHARACTERISTICS

<u>Introduction</u>

Meditation involves a wide range of techniques which aim to increase control over and the automaticity of psychobiological processes. Meditation is thought to involve a group of practices that allow greater efficiency in self-regulation of the body and mind, "thereby affecting mental events by engaging a specific attentional set" (Cahn & Polich, 2006; Davidson & Goleman, 1977). The goal of meditation is often described as the attainment of a restful yet fully alert physical and mental state, and it is practiced by many individuals as a self regulatory approach to emotion management (Takahashi et al., 2005). Meditation is also defined as a form of "mental training" that brings about long-term, i.e., trait changes in cognition and emotion (Lazar et al., 2005; Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004). Trait changes in attentional abilities as a result of meditation training are reported in several recent cross-sectional studies (Chan & Woollacott, 2007; Jha, Krompinger, & Baime, 2007). Hence it is of great interest to examine the underlying neural activity of specific meditative states and resultant self-regulatory, emotional, or cognitive changes.

Meditation is often defined as a seemingly paradoxical state of restful alertness, having a relaxation **and** a concentration component. This paradox is exemplified by the fact that Benson defined meditation as a relaxation response (Benson, Greenwood, & Klemchuk, 1975). However, evidence also suggests that certain meditation techniques enhance concentration or focused attention and hence a state of increased alertness. In at least the early stages of meditation training this requires effort and therefore increased cognitive activity in regulatory areas of the brain (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Jha, Krompinger, & Baime, 2007; Slagter et al., 2007). Brain imaging studies of changes associated with attentional tasks have shown increases in activity compared to baseline resting states during various types of meditation (Lazar et al., 2000; Lou et al., 1999; Newberg et al., 2001) in the dorsal-lateral- prefrontal cortex and parietal regions. These regions have been associated with voluntary or top-down control of attention.

There have been very few studies examining the contributions of relaxation vs. mental focus to the mental states produced by meditation training, and these have been limited to evaluations of the training effects through personality and psychological inventories (Smith et al, 1996; Jain et al, 2007). For example, one study examined differences between meditation, relaxation and other alternative and complementary medicines in a subjective fashion using an 82- item wordlist to examine the individual's perceptions of changes in emotional state as a result of the therapy (Smith, Amutio, Anderson, & Aria, 1996). They showed that there were specific subjective differences in subjects' perceptions of the emotional states induced by meditation vs. relaxation. A

second study by Jain et al (2007) showed that both meditation and relaxation training reduced psychological distress and increased positive mood, compared to a control group; however the meditation group showed larger effect sizes for positive mood changes. In addition, only the meditation group showed significant decreases in distractive and ruminative thoughts compared to the control group. Though these studies suggest some possible differences between the two types of training, third person or objective studies about differences in brain activity induced by mental focus techniques used in meditation vs. relaxation have not been performed.

A number of cross-sectional studies (Aftanas & Golochikine, 2001; 2002; Lutz et al, 2004; Slagter et al., 2007; Travis, 2001) have examined differences in EEG characteristics among individuals with different levels of meditation experience compared to control subjects, comparing resting states to states of meditative focus. For example, Aftanas & Golocheikine showed that long term practitioners showed an increase in theta-1 (4-6 Hz), theta-2 (6-8 Hz), and alpha-1 (8-10 Hz) band power, when comparing rest conditions with meditation, whereas the short term practitioners' group did not show any changes in meditation vs. resting states of activity (Aftanas & Golocheikine, 2001). A comparison of meditation to rest conditions in meditators using an assessment of non-linear dynamic complexity suggested that during meditative states irrelevant networks were being "switched off" and thereby allowing the maintenance of focused attentional states (Aftanas & Golocheikine, 2002). A second study (Hamada et al, 2006) also showed that during meditation compared to resting states, slow alpha and

fast theta power increased along with an increase in parasympathetic activity in long term meditators.

Lutz et al (2007) note that both alpha and theta frequency EEG amplitude increases can be an index of attentional processing. For example, it is possible that localized increases in these slower EEG frequencies reflect cortical tuning involving selective inhibition of cortical zones not required for task-related processing (Cooper et al, 2003; Klimesch, 1999; Lutz et al, 2007). In addition, data on attentional anticipation (Fox et al, 1998) have shown that when subjects anticipate an upcoming auditory stimulus, there is increased alpha power over parieto-occipital cortex compared to when a visual stimulus is anticipated, suggesting inhibition in the occipital area when auditory stimuli are expected. This suggests that increased alpha and theta frequencies during meditation compared to baseline indicate reduced attentional processing in associated brain areas. Reports about the changes in alpha and theta frequencies in meditators have been widely documented. Hence in the present paper we focus on formulating and testing hypotheses on these two frequencies.

In another study examining a very different set of EEG frequencies, Lutz et al (2004) found that the EEGs of expert (Tibetan monks with 10,000-50,000 hrs experience over 15-40 yrs,) compared to novice (1 week meditation experience) meditators showed high amplitude gamma (25-42 Hz) frequency during meditation that was not present at baseline. As the total time of meditation experience increased the ability to generate gamma oscillations (at primarily mid-frontal and parieto-temporal regions) increased along with long distance phase synchrony. However, the researchers used control and

experimental subjects that were significantly different in age (meditation group, 49 years; control group, 21 years) and also the experimental subjects varied in their experience in meditation. This was the first study to show the presence of high frequency gamma EEG activity in meditators. The authors speculate that this is in part due to the highly trained meditative abilities of these Tibetan monks and may reflect changes in attentional and affective processes. The combined results of the above studies suggest that meditation training is correlated with 1) increases in alpha and theta activity in experienced meditators, indicating reduced attentional processing in these areas as attention is removed from external stimuli and internally generated thoughts are reduced and 2) in gamma activity in specialists in meditation.

Though these studies provide interesting evidence about EEG characteristics associated with meditation, they are cross-sectional in nature, and thus it is not clear if these results are due to meditation training itself or to a selection bias of individuals who choose to practice meditation. There have been very few carefully designed longitudinal randomized controlled studies examining changes in EEG characteristics associated with meditation training. For example, control groups need to be trained concurrently with meditation groups, matched in terms of demographics and given comparable control training tasks; almost no previous studies have fulfilled these criteria.

In addition, many previous studies have used few EEG electrodes and therefore did not have a good representation of activity across the whole brain (e.g., parietal, frontal, etc) (e.g., Davidson et al., 2003). High density spatial sampling using 128 or

more EEG sensors provides reliable and detailed information about cortical potential distribution at the scalp (Srinivasan, Nunez, Tucker, Silberstein, & Cadusch, 1996).

A final issue related to studies of meditation that needs to be addressed more carefully is the fact that most studies measure physiological characteristics during a long time period within the meditation session, thus with an implicit assumption that subjects are always on focus during this time. However, if meditation is similar to other continuous performance tasks which require attention, it would involve periods of task-focused attention alternating with periods in which the mind wanders to other thoughts or sensations (Smallwood, McSpadden, Luus, & Schooler, 2007; Smallwood & Schooler, 2006). In order to more carefully study periods in which subjects were on focus during a meditation task, and to determine if these periods increased with training, it would be useful to create a paradigm which allowed researchers to identify when subjects were on focus and to determine if these focused periods increased as a result of training.

The present study aims to determine the contributions of the components of relaxation vs. mental focus to changes in brain activity associated with meditation training. We thus trained one group in concentrative meditation (using mental focus as the primary tool of meditation practice) and trained a second (control) group in relaxation alone, without any mental focus component. The study examined changes in EEG characteristics of both groups associated with 8 weeks of training (40+ min/day, 5 days/wk). In order to address weaknesses of previous meditation research this study was designed as a randomized controlled trial with the two groups match on demographics

and given concurrent and comparable training. To more accurately compare activity across different brain regions we used a 256 electrode EEG system.

In addition, periods in which subjects were on-focus during the meditation task were identified, by asking subjects to make button presses whenever the mind wandered to other thoughts or became drowsy, in order to determine if periods of focused meditation increased as a result of training and to compare EEG characteristics of relaxation trained vs. concentration trained subjects during these periods of focus. Finally, subjects were asked to respond to probe tones which occurred at random points in the meditation task, by pressing a button if they were off-focus at the time of the probe. This allowed the detection of additional points of mind-wandering which subjects were not initially aware of.

We hypothesized that participants trained in meditation (with its emphasis on returning the mind repeatedly to the object of focus) would show significantly reduced episodes of both mind-wandering and of probe-caught mind wandering compared to the relaxation group, at post-training. We also hypothesized that meditation training, but not relaxation training would result in increased alpha and theta power in the occipital and parietal areas as a result of a decreased sensory attentional processing. As parietal networks are also associated with top-down goal-directed control and the suppression of bottom-up stimulus driven attentional capture, we also would expect a decreased need to activate the left dorsal parietal networks with increased practice and automatization of concentrative techniques. In line with previous studies indicating changes in right sided **baseline** alpha power in meditators, we also hypothesized increases in this area for

baseline activity (Cahn & Polich, 2006; Hager et al., 1998), suggesting that focused attention generalizes to baseline periods as well.

Methods

Participants (n = 30) were recruited from an Alternative and Complementary Medicine class conducted at the University of Oregon, following approval from the Office of Human Subjects. Participants were compensated for their time with extra credits for the class. In order to ensure homogeneity between groups, participants were asked to respond to a demographic and lifestyle questionnaire and were then pseudo-randomly assigned to either the meditation or relaxation training group after matching group demographics primarily for age, gender, physical activity educational experience, grade point average (GPA) and hours of sleep/night. Table 5 shows subject demographics for the two groups.

Table 5. Demographics of the participants

		Meditation	Relaxation
1.	Age (Mean)	23.1±3.1 yrs	22.8 ±4.8yrs
2.	Gender	12F, 3M	11F, 4M
3.	Physical activity score	2.2	2.8
4.	Educational level	15.9 yrs	15.8 yrs
5.	College Grade Point Average (all A's = 4.0)	3.3	3.2
6.	Sleep (hours)	7.6	6.7

Physical activity scores were graded on a scale where a score of one was sedentary and five was athletic. To compute a physical activity score, we took into consideration amount of exercise performed, type of exercise and also activity done during daily chores (such as school, work etc.) Thus the population under consideration here was moderately active.

Training Program

An 8 week training program in meditation and relaxation was conducted as part of an Alternative and Complementary Medicine class (n=30). The participants in the meditation training focused on the breath and a silently repeated verbal point of focus, the syllable 'Om' during every (inhalation) in-breath and (exhalation) out-breath while in a comfortably seated position. The subjects were given the option of using the syllable 'hum' instead of 'Om', if they felt uncomfortable repeating a syllable that they were not

familiar with. However, none of the participants reported use of the alternate syllable. The relaxation group was instructed to progressively relax their muscles from toes to face and finally let their mind wander in a comfortable lying or sitting position. Based on reports from Chan and Woollacott (2007), length of the activity for each group was targeted at 20min/day in class and 20min/ day outside class for at least 5 days/week. The in-class training session was a guided or instructed practice led by an expert instructor. Handouts for the instructions for out of class practice were given to the participants. In-class compliance was checked with the help of daily attendance records. Compliance for out of class activity was checked with weekly logs describing min/day of practice and also the qualitative experiences of the practice. We had asked participants to practice a minimum of 40min/day, 5 days a week and so a weekly average of 200min was expected. The actual meditation time for the two groups was 170 min/week for the meditation group and 199 min/week for the relaxation group.

Exclusion Criteria

Individuals with any previous training in meditation or who currently practiced meditation were excluded from the study. Individuals with any known neurological disorders or psychiatric disorders were excluded.

Apparatus

A 256 electrode dense array Hydrocel EEG system from Electrical Geodesics Inc was used to record EEG data. The sensor net of the system has a regular distribution of electrodes across the head surface. The EEG was digitized at 250 samples per second.

The data were referenced to a vertex electrode. E-prime was used to introduce auditory probe tones and instruct the participants. Netstation 4.2 was used to collect and analyze the data from EEG recordings along with Matlab programs.

Testing Procedure and Protocol

The participants were tested twice after informed consent procedures were followed, once at pre-training and once at post-training. The participants were advised to refrain from nicotine and caffeine on the day of testing in order to control for any effects produced on brainwaves by these substances. During a two minute rest block, the participants were instructed to sit with their eyes closed and allow their minds to wander and to give no button press responses even when the mind wandered. There were a total of three rest blocks of two minutes each, alternating with two mental focus blocks, which were each ten minutes in length. During the first mental focus block, the subjects were asked to keep their eyes closed and to focus on the breath while repeating the syllable 'Om'. Button press responses were generated by the subjects when they noticed that their mind was wandering or they became sleepy and lost focus. This condition is referred to as the self-report condition (SRC). A segment with no button press responses meant that the participant thought he/she was continually focusing on the task during that period.

Periods with no button presses were defined as the 'meditative condition'. It is possible that subjects showed mind-wandering during this time, but were unaware of it. To determine the extent to which this was the case, ten randomly delivered auditory probe tones were introduced during the second mental focus block. The subjects generated a

button press in response to the tone if they felt they were off task. This condition was referred to as the probe-caught condition (PCC). During the second mental focus block, as in the first mental focus block, subjects were also asked to generate a button press response if they were off-task irrespective of the probe tone. In the present paper, we discussed the findings of the meditative period (periods with no button press) and the averaged findings of the three rest state blocks to determine effect of training.

Statistical Analysis

Button Press Responses: Using SPSS version 15, a repeated measures ANOVA was computed to assess the impact of training (pre-training, post-training) on button press responses and their association with probe tones (responses in first mental focus block, responses in second mental focus block, responses with tone, responses without tone and tones with no response) across both groups (meditation and relaxation).

EEG: Using EEG segments when subjects' mental state was characterized as on-focus (no mind-wandering), a repeated measures ANOVA was computed to assess the impact of training (pre- training, post-training), frequencies (delta, theta, alpha, beta) in three regions (frontal, occipital and parietal) considering laterality (left, right, midline and entire) across both the groups (meditation and relaxation) on the amplitude of the wavelets.

<u>Results and Discussion</u>

Behavioral response

  The self reports of mind wandering conducted via button press responses during mental focus blocks were compared before and after training across both the groups. The reduction in number of button presses from pre-training to post-training in the mediation group was higher than in the relaxation group, The meditation group post-training button presses were .75 of the original session (9.7 compared to 12.9 and the relaxation group post-training presses were .94 of the original session (16.9 compared to 18). These results suggest an improvement in ability to focus attention in the meditation group as compared to the relaxation group. However, there was no interaction effect of training/time*group (F (1, 21) = .00, p=.95). There was no main effect of training/time (F (1, 21) =.023, p=.88). A significant Group*Response interaction is seen (F (5,105) = 2.8; p=.018). As a follow-up analysis, a one-way ANOVA showed significant differences in responses without tone in the first mental focus block after training across two groups (F (1, 21) = 4.33, p=.05). This implies that, at Time 2 (post-training), the episodes of mind-wandering in the meditation group were lower than for the relaxation group. Although we do not see an effect of time, we do see an effect of type of training. Table 6 shows button press data for the two groups. In the original reading comprehension paradigm, responses in the first block represent information related to meta-cognition. Probe caught (response to tone) responses and responses without tone in the second block represent meta-awareness. The current adaptation of the original paradigm informs us about meta-

cognition and meta- awareness. In addition, it informs us about on task (no response to tone) states.

Table 6. Button press responses

| | Meditation | | Relaxation | |
	Pretraining	Post training	Pretraining	Post training
Mental Focus 1	12.91	9.73	18.08	16.92
Probe caught (response to tone)	5.27	4.73	4.75	4.67
Awareness (response without tone in second mental focus)	6.18	9.09	11.75	12.33
Total Mental focus 2	11.45	13.45	16.05	17.00
On Task (no response to tone)	4.73	5.27	5.33	5.33

In the second mental focus block, participants expected probe tones (participants were unaware of the timing of probe tones, but were aware that they would be probed) and hence responses without a tone in the second mental focus block indicate awareness of the conscious experience of mind-wandering. To explore the extent to which the meditation vs. relaxation trained groups improved in their ability to detect mind wandering (reduction in the number of times probe tone presentation was associated with the presence of mind wandering) we examined the probe tone data. In the meditation group, button-press responses in this segment show an increase from 6.1 to 9.0 (an increase of 50%), but the relaxation group did not show a similar increase in awareness. This could indicate an increased ability to detect mind wandering; however, we cannot rule out that it might also indicate an increase in mind wandering itself. However, the

probe caught condition in the meditation group showed a slight decrease (pre training-5.2 to post training- 4.7) in number of responses as a result of training, and this was not the case in the relaxation group. However, since the number of responses (or no response to tone) is very low, those data are to be interpreted with caution.

EEG

Analysis of EEG wavelets was done using Netstation 4.2d and Matlab programming. The data segments with no button press responses were marked and segmented out from the raw files, with each segment 7s in length. Using waveform tools, eye-blinks and eye movement artifacts were removed. Artifact detection and bad channel marking was done using waveform tools and visual inspection. Due to artifacts from eye movements, we could not include data from twelve subjects. Bad channels replacement and re-referencing were done before the raw data were transformed into wavelet files. When re-referencing was done, the data were referenced to an estimated non-arbitary zero voltage site. Montages were defined selecting clusters of electrodes from the occipital, frontal and parietal regions. We have not incorporated temporal electrodes in the present study. In addition, we examined left, right and midline electrode clusters within each region. Figures 3-6 (a and b) show the electrode cluster maps and wavelet files (jtf files) used. For Figure 6, the X axis represents time 0-7 secs and the Y axis represents 0-25 Hz frequency. A higher magnitude of amplitude is in a red color and a blue color signifies lower amplitudes of frequency.
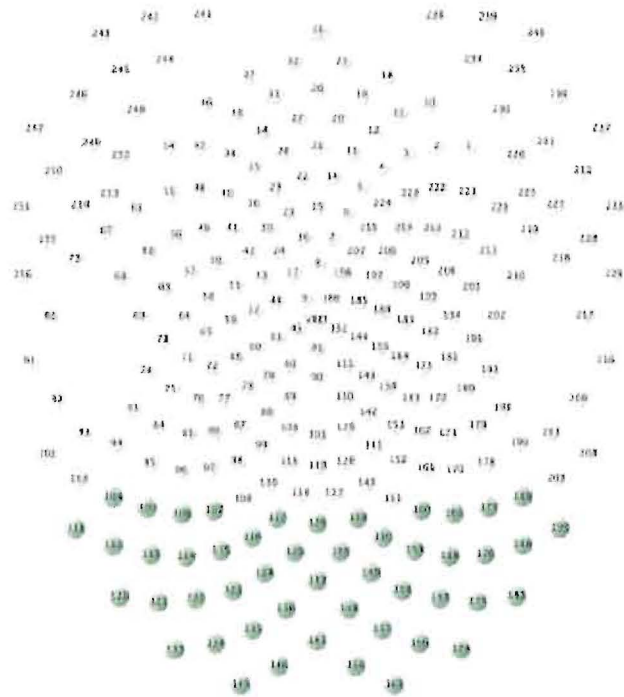
Figure 3. Occipital (Entire) electrode cluster.
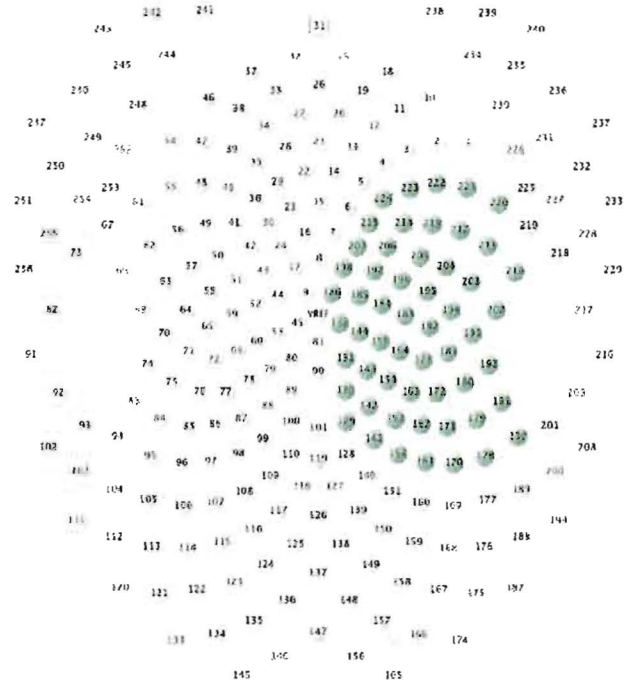
Figure 4. Parietal (right) electrode cluster
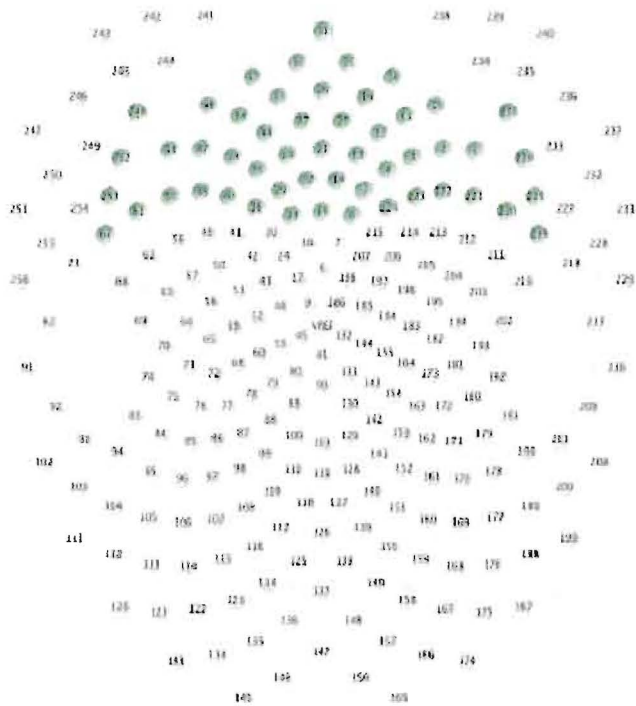
Figure 5. Frontal electrode cluster

EEG data analysis

The dependant variable used in the EEG analysis is amplitude of the wavelets. The independent variables manipulated were time (pre-training and post-training), group (meditation, relaxation), region (Frontal, Occipital, and Parietal) and laterality (left, right and midline). Band or frequency of the wavelets had four levels (delta, theta, alpha and beta.). The task condition under consideration in the present paper has two levels: on task during on-focus blocks and average rest period.

The analysis for two conditions, meditative state and rest, were computed to measure the impact of training on the amplitude of wavelets across scalp electrode groups and across frequency bands in 7 second epochs of EEG without a button press. The

amplitudes during the meditative condition were normalized with respect to the averages of the resting state amplitudes for each frequency and region during the pre-training test session.

For meditative segments a repeated measures ANOVA was computed to assess the impact of training (pre- training, post-training), frequencies (delta, theta, alpha, beta) in three regions (frontal, occipital and parietal) considering laterality (left, right, midline and entire) across both the groups (meditation and relaxation) on the amplitude of the wavelets. A significant interaction was seen for time*band* region*group (F $(6, 96)$ = 2.32, p=.046). A significant interaction was also seen for band*time*region*laterality (F $(18, 288)$ = 3.194 p=.00).
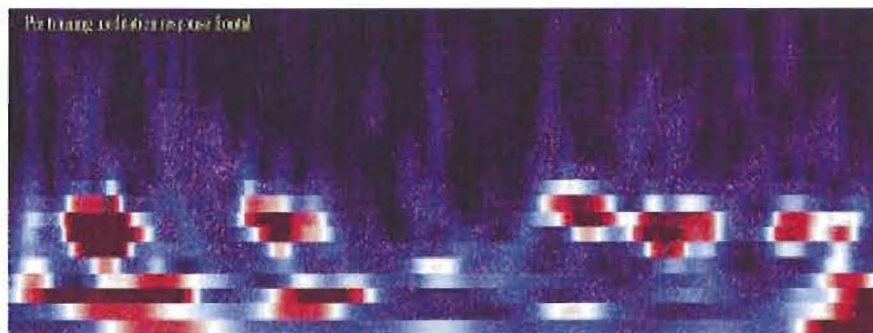
Figure 6a. Wavelets from frontal electrode cluster in focused attention state, prior to training.
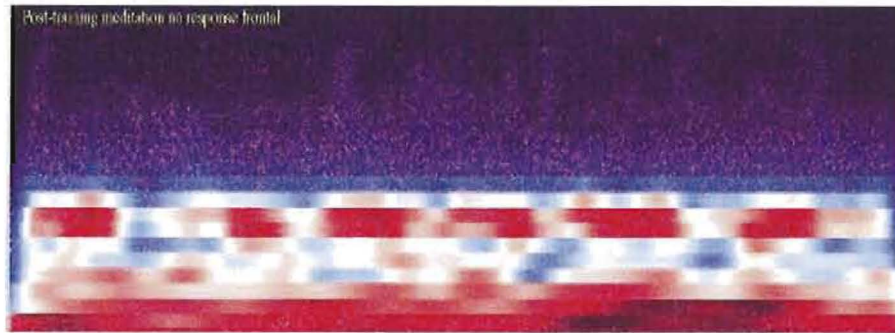
Figure 6b. Wavelets from frontal electrode cluster in focused attention state, after training.

Region-wise analysis

To determine changes that occurred in each region, as a follow-up analysis, we computed a repeated measure ANOVA for each region. In the occipital and parietal electrode cluster, a significant interaction time*frequency*laterality was seen (occipital – $F (9, 144) = 3.84$, p=.021; parietal- $F (9, 144) = 3.86$, p=.02). Also a significant interaction between frequency* group was found (occipital- $F (3, 48) = 3.08$, p=.05; parietal- $F (3, 48) = 3.62$ p=.032). These results imply a significant effect of training on frequency and laterality. To further understand the impact of time we conducted a follow-up analysis.

Time-wise analysis

A paired t-test (pre training- post training) was computed to measure the impact of training across the two groups. A significant difference was seen in theta (pre-post) and alpha (pre-post) frequency in the meditation group but not in the relaxation group, as

you see in Figures 7 and 8. Significant differences are noted in the Table 7. Note that alpha frequencies showed training associated increases in amplitudes for both occipital and right parietal regions, while theta frequencies showed similar increases for only occipital regions.

Table 7. Change in alpha and theta amplitudes as a function of time

	Theta	
	Meditation	Relaxation
Occipital	$t(8)=-2.53$ p=.03	$t(8)=-1.69$ p=.129
Occipital RT	$t(8)=-3.08$ p=.015	$t(8)=-2.07$ p=.07
Occipital Mid	$t(8)=-2.59$ p=.03	$t(8)=-1.94$ p=.088
	Alpha	
Occipital	$t(8)=-2.675$ p=.028	$t(8)=-1.43$ p=.189
Occipital RT	$t(8)=-2.87$ p=.021	$t(8)=-1.6$ p=.138
Occipital Mid	$t(8)=-2.73$ p=.026	$t(8)=-2.00$ p=.08
Parietal RT	$t(8)=-2.92$ p=.019	$t(8)=-1.835$ p=.104

Effect of Training on Theta frequency in Occipital electrode cluster
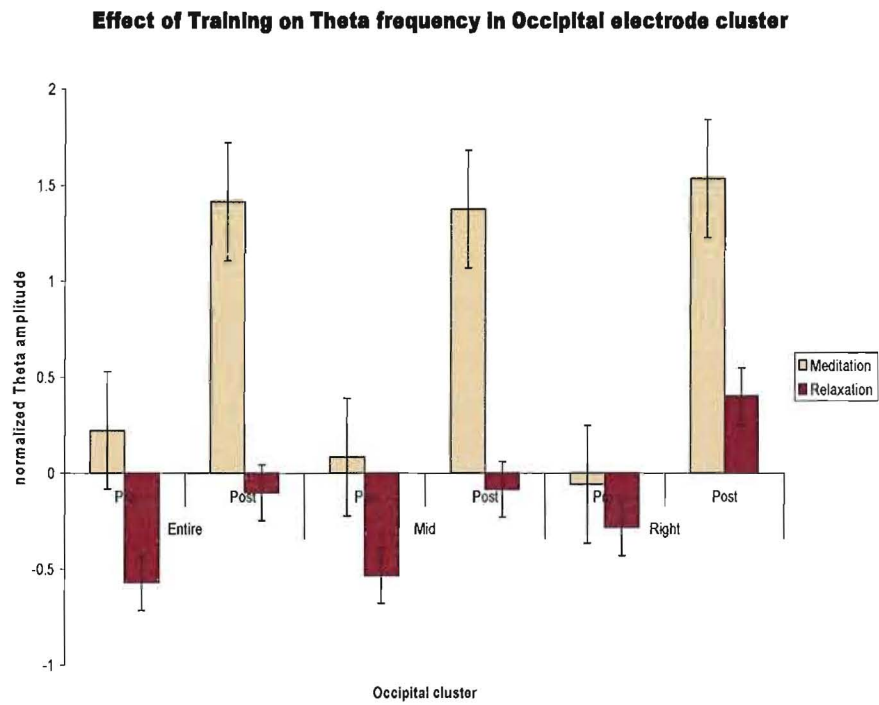
Figure 7. Effect of meditation vs. relaxation training on normalized theta frequency amplitude for the occipital electrode cluster. The column from left to right include the entire occipital cluster, the midline occipital cluster and right occipital cluster.

Effect of Training on Alpha frequency
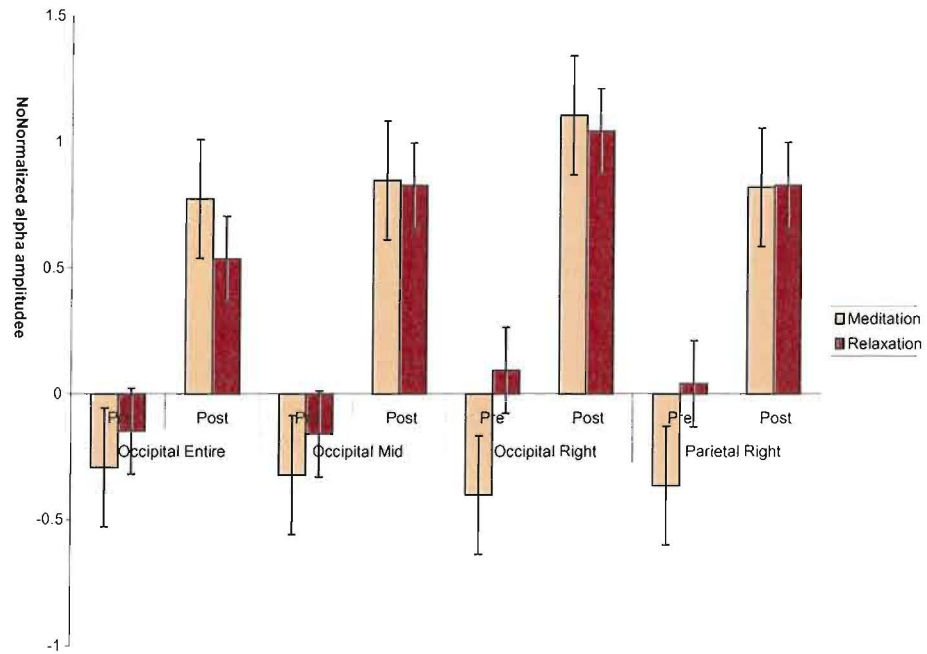
Figure 8. Effect of meditation vs. relaxation training on normalized alpha Hz amplitude for occipital and right parietal electrode clusters. The columns from left to right include the entire occipital cluster, the occipital midline cluster, the right occipital cluster and the parietal cluster

Resting state analysis

To assess whether there were changes in baseline resting conditions across the two groups, we computed a repeated measures ANOVA with the following factors: time (pre- training, post-training), frequencies (delta, theta, alpha, beta), in three regions (frontal, occipital and parietal), considering laterality (left, right, midline and entire) across both the groups (meditation and relaxation). A significant interaction for time* band* region* lateral was seen (F (18, 288) = 6.103, p=.00). A significant difference in

amplitude of alpha frequency (pre training vs. post training) was found, and this was observed for the occipital lobe clusters of electrodes for both the groups on follow-up analysis. It was also observed for the right parietal electrode cluster for the meditation trained group (See Figures 9 and Table 8).

Table 8. Change in resting state EEG amplitude as a function of training for meditation and relaxation groups

	Meditation	Relaxation
Occipital	T(8)= -2.37 p= .04	t(8)=-3.17 p=.006
Occipital LT	T(8)= -2.08 p=.07	t(8)= -3.15 p=.01
OccipitalRT	T(8)=-2.47 p=.039	t(8)= -2.58 p=.032
OccipitalMid	T(8)=-2.48 p=.038	t(8)= -4.30 p=.002
ParietalRT	T(8)=-2.64 p=.03	t(8)=-2.12 p=.058

Rest Condition: Effect of training on Alpha amplitude
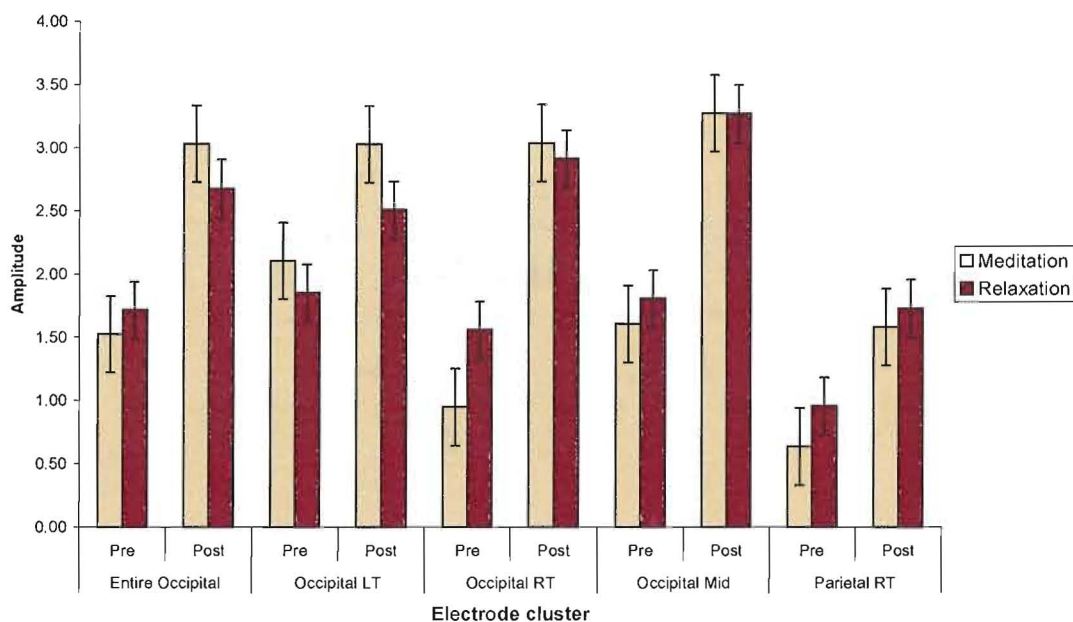
Figure 9. Effect of meditation vs. relaxation training on baseline alpha Hz amplitude for occipital electrode clusters. The columns from left to right include the entire occipital cluster, the left occipital cluster, the right occipital cluster, the midline occipital cluster and the right parietal cluster.

General Discussion

This randomized controlled study examined the efficacy of eight-week concentrative meditation training as compared to relaxation training on both behavioral measures of focus and on EEG characteristics associated with a meditation task. To improve the strength of conclusions drawn from the results of the study, the protocol included a control group which was carefully matched to the experimental group for

subject demographics, and which received concurrent and comparable training (in relaxation). The results highlight fine-grained behavioral and neurological changes brought out by this short-term meditation training.

Behavioral changes in the meditation group as compared to the relaxation group at post-training testing included a decreased number of button-press responses, which was used to indicate when individuals noticed that the mind was off-focus. Since these data do not indicate the actual number of times that mind-wandering occurred, and since previous research has also shown that mind-wandering may occur during focused tasks well before an individual becomes aware of it (Smallwood et al, 2007), we also used randomly presented probe tones and asked subjects to note if the mind was wandering at these points in time, in addition to their otherwise noted points of being off-focus. After training, the episodes of mind-wandering were significantly lower in the meditation group as compared to the relaxation group ($F(1,21)= 4.33$, $p=.05$). These data further support the previous results indicating that the meditation group improved more than the relaxation group in their ability to maintain focus as they had few mind-wandering episodes after training.

Using EEG data we also aimed to explain the extent to which improvement in mental relaxation vs. focused concentration skills contributed to changes in brain activity associated with meditation.

Increase in amplitude of alpha and theta frequency EEG

An increase in the amplitude of alpha frequency EEG was seen in the occipital region and in the parietal region in the meditation group as compared to the relaxation

group as an effect of the 8 weeks of training. Few studies have reported a change in alpha amplitude as a longitudinal effect of meditation training (Satyanarayana, Rajeswari, Rani, Krishna, & Rao, 1992). However, these results are similar to previous cross-sectional studies comparing meditators and non-meditator control groups, in which this effect has been consistently found when comparing baseline activity to meditation periods (Aftanas & Golocheikine, 2001; Banquet, 1973; Khare & Nigam, 2000; Litscher, Wenzel, Niederwieser, & Schwarz, 2001). In cross-sectional studies of subjects trained in the relaxation response, compared to control individuals, an increase in alpha EEG amplitude has also been found (Jevning, Wallace, & Beidebach, 1992).

A training associated increase in EEG theta wave amplitude was seen only in the occipital region in the meditation group as compared to the relaxation group. Increases in EEG theta amplitudes have also been found in previous cross-sectional studies of meditators compared to control subjects (Banquet, 1973; Travis, Tecce, Arenander, & Wallace, 2002).

Lutz et al (2007) note that most previous cross-sectional studies have shown proficient meditators showed an increase in both alpha and theta power from base-line activity when compared to control subjects, along with minimal evidence of EEG-defined sleep. They also note that both alpha and theta activation increases can be an index of attentional processing. For example, it is possible that localized increases in these slower EEG frequencies reflect cortical tuning involving selective inhibition of cortical zones not required for task-related processing (Cooper et al, 2003; Klimesch, 1999; Lutz et al, 2007). In addition, data on attentional anticipation (Fox et al, 1998) have shown that

when subjects anticipate an upcoming auditory stimulus, there is increased alpha power over parieto-occipital cortex compared to when a visual stimulus is anticipated.

As a number of previous cross-sectional studies of meditators have shown increases in frontal area EEG alpha amplitudes, it was surprising to find no significant effects of meditation or relaxation training on alpha amplitudes in this area. However, it is possible that this is due to the difference in study design between this and previous cross-sectional studies. As this was not a cross-sectional study, but a training study, we were comparing alpha activity during a focused-concentration (meditation) session at two points in time, prior to daily training and after 8 weeks of training, rather than comparing alpha power during meditation and base-line periods. It has already been shown that even novice meditators (with minimal prior experience) show increased frontal alpha activity during meditation when compared to base-line activity correlated with decreased blood blow in inferior frontal areas (Kasamatsu and Hirai, 1966; Cahn & Polich, 2006). We thus might expect this of both of the training groups, even in the first test-session, as they are performing a meditation concentration task requiring a quiet and focused state of mind.

As theta activity has been associated with drowsiness or wake-sleep transitions in studies of the wake-sleep cycle, researchers in the past have questioned whether increased theta amplitudes during meditation are due to simply moving toward a drowsy state of consciousness or the sleep state. This argument has been countered in meditation studies by showing that meditators show minimal evidence of EEG-defined sleep (Corby et al, 1978). In our own study, subjects were asked to press separate buttons for episodes

of drowsiness vs. mind-wandering to other thoughts. Out of the entire set of subjects only two subjects pressed the button for drowsiness at all (one pre-testing and one post-testing) which is less than 1% of trials. This is a clear indication that the subjects felt alert during the EEG testing sessions.

Lateralization

A right lateralized increase in EEG alpha wave amplitude was seen in the parietal region in the meditation group as compared to the relaxation group for both resting and focused meditation testing sessions. From the research noted above, this suggests that the right parietal cortex was showing reduced activation as compared to the left parietal cortex as a result of meditation training. It is of interest that in a PET (photon emission tomography) study of changes in regional brain activation of meditators, compared to resting baseline, Lou et al (1999) showed correlations between abstract sensations of joy during meditation and increased activation of the left compared to the right parietal lobe.

It has also been shown that the right intraparietal junction area is involved in attentional modulation (Serences et al, 2005). If it is true that increased alpha and theta slow wave activity is associated with reduced activation of a brain area, this would imply that, as subjects improved their attentional abilities with meditation training, they relied less on active attentional control, as attentional modulation became more automated with practice.

Changes in Base-line EEG characteristics

Results also showed an increase in alpha amplitude in the baseline (rest state) in both the meditation and relaxation trained groups for occipital areas and additionally in the meditation group for the right parietal area. These results suggest that this component of change represents resting state improvements in both relaxation and meditation groups, and thus may be partially a training effect correlated with the relaxation component of meditation training. In cross sectional studies, changes in resting activity associated with meditation training compared to a control group have been reported by Anand et al (1961) for a concentrative form of meditation and by Lutz et al (2004) for expert monks trained in Tibetan Buddhist meditation using a form of meditation based on inducing feelings of non-referential compassion. The Anand et al. (1961) cross-sectional study also showed an increase in alpha activity at baseline for the meditators compared to the control group. In the case of the Tibetan monks practicing the use of a "non-referential compassion meditation," which does not use a focus of concentration, the study showed higher resting levels of gamma activity compared to control subjects. As the Lutz et al (2004) study used an entirely different type of meditation than that trained in this and other studies examining concentrative meditation, this may partially explain the differences in results. The present results appear to show the first evidence of changes in baseline alpha activity reported in a *longitudinal* study comparing meditation and relaxation training. This is of interest, as a central goal of meditation practice is to transform the baseline state of experience into one that is closer to that of meditation (Lutz et al, 2007).

Limitations

Though this study was a randomized controlled trial using training groups with similar demographics and concurrent training procedures, specific limitations of the study should be noted. Though 30 participants (15 per group) enrolled in the study and completed the meditation training, two participants in spite of finishing training did not participate in the second testing session due to personal reasons. During data analysis, testing sessions of 12 subjects were found to have sufficient artifact to be unusable, and thus only 50% of participants were actually used for analysis. This reduced the statistical power of the study. In addition, the training was only 8 weeks in length, and it is has been shown that there is a correlation between meditation induced EEG and behavioral modifications and length of practice (Lutz et al, 2007). Thus we would expect to see larger changes if a longer training period had been possible. Finally, the task used in the pre- and post-training sessions was similar to that used for training for the individuals involved in the concentrative meditation trained group. Thus, one would expect that they might become more proficient in the mental focus task after eight weeks of training. However, in support of this feature of the study, a main aim of the study was to determine the extent to which relaxation components of training vs. concentration components of training were keys to associated improvements in focus as a result of meditation.

In conclusion, this randomized controlled trial showed that eight weeks of training (@ 40 min/day for 5+ days/wk) in meditation as compared to progressive muscle relaxation was correlated with an increased ability to focus (i.e., reduced episodes of mind-wandering) during a concentrative meditation session for meditation trained vs.

relaxation trained individuals at post-training. This was accompanied by increased amplitudes of alpha and theta EEG frequencies in the occipital and right parietal areas during the concentrative meditation task for meditation but not relaxation trained individuals. In addition, resting amplitudes of alpha EEG activity increased for both meditation and relaxation trained subjects in occipital areas, with additional increases in the right parietal areas for meditation trained individuals. Taken together these results suggest that meditation training 1) was correlated with a meditation-induced state effect of an increased ability to suppress mental activity in these areas during focused concentration and also 2) a trait effect of reduced mental activity in occipital and right parietal areas during rest. Finally, relaxation training also produced a trait effect of reduced activity in the occipital areas at rest.

BRIDGE

In the previous paper/chapter, we examined data from a randomized controlled study examined the efficacy of an eight-week concentrative meditation training as compared to relaxation training on both behavioral measures of focus and on EEG characteristics associated with a meditation task. Using EEG data we aimed to explain the extent to which improvement in focused concentration skills contributed to changes in brain activity associated with meditation. Subjects were asked to press a button whenever they went off focus in their meditation task, and only segments in which subjects were in meditative states (mind-wandering segments removed) were compared pre- and post-training, in order to limit the analysis to periods of quiet alertness and focus.

In the present paper, we expand our area of EEG analysis to compare periods in which subjects were on-focus vs. off-focus (i,e, concentrating on the meditation task, vs. finding their mind had wandered to other thoughts/sensory stimuli or had become drowsy). This is an area of research that has been neglected in previous meditation studies, as analyses were typically performed on long time segments within a meditation session, assumed to be a homogenous period of focused concentration. However, it is now acknowledged that individuals do not typically have the ability to remain focused on a single object of concentration indefinitely and the mind typically goes through periods of mental wandering or sleepiness (Smallwood & Schooler, 2006). Thus, in previous studies of meditation, when researchers were recording such physiological correlates of meditation as EEG, it is possible those periods of unfocused attention (both mind-

wandering and sleepy/drowsiness) were averaged in with focused attention, thus reducing the clarity and precision of the results. The present paper thus clarifies this issue and also examines changes in the characteristics of these states compared to baseline resting states as a result of training.

CHAPTER IV

ATTENTIONAL REGULATION IN MEDITATION: COMPARISON OF EEG

CHARACTERISTICS DURING PERIODS OF ON- VS OFF-FOCUS

<u>Introduction</u>

Meditation has been defined as a tranquil, yet fully alert mental and physical state

which is practiced by individuals as a self- regulatory approach to cognitive and

emotional management and to the achievement of mental focus and clarity (Takahashi et

al., 2005; Luskin, 2004). In support of this definition, research has shown that the

performance of meditation practices has a positive correlation with psychological health,

including increased efficacy of attentional networks and emotional clarity (Harinath et

al., 2004).

A fundamental technique underlying meditative practice is the cultivation of

sustained attention. During meditative practices, discursive and ruminating thoughts are

avoided and attention is sustained on an object of focus (Shapiro, 1982). Using Wilkins

counting test for sustained attention, enhancement of sustained attention as a trait effect

in long term meditators vs. short term meditators has been reported by Valentine and

Sweet (1999).

In an exploration of the effects of meditation on attentional regulation Tang et al

(Tang et al., 2007) performed a randomized controlled trial comparing meditation

training to relaxation training. They found that the efficiency of the executive attentional

network (as measured by the attentional network task) improved in the meditation but not the relaxation trained group.

In order to determine the neural correlates of the effects of meditation on regulation of attentional focus, Brefczynski- Lewis et al (2007) used fMRI to examine the activation of a network of brain regions of both meditators and age-matched non-meditators while practicing a concentrative form of meditation. They demonstrated that in response to distracting sounds used to probe the meditation, meditators had reduced activation of brain regions related to discursive thoughts and emotions and more activation of fronto-parietal regions, insula, thalamic nuclei and basal ganglia, which are brain regions controlling response inhibition and attention (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007).

An alternative tool to the use of imaging is that of electro-encephalography (EEG). EEG studies related to meditation have been performed since at least the 1960s, using spectral analysis and most studies of concentrative forms of meditation have observed increased alpha (8-12 Hz) and/or theta (4-8 Hz) frequencies compared to baseline states mainly over frontal and central electrodes (Anand et al, 1961; Hirai 1974; Kasamatsu & Hirai, 1966; Fenwick, 1987; for reviews see Lutz et al, 2007; Delmonte, 1984; Shapiro & Walsh, 1984).

For example, one of the earliest studies (Hirai, 1974) indicated increases in alpha and theta amplitudes in proficient practitioners particularly over the frontal lobes, compared to baseline. This has been observed in recent studies (Takahashi et al, 2005) as well, with research comparing resting states to meditation states in Zen meditators, and

showing increases in fast theta and slow alpha power predominantly in the frontal area. The authors proposed that the increased alpha EEG in the frontal area reflected enhanced internalized attention. Travis (2001) also noted that higher EEG alpha amplitude and higher alpha coherence were associated with deeper states of meditation, in which participants focused on the breath and a syllable of focus.

Alpha frequency in an EEG is actually present in most human adults during the wakeful resting state, with eyes closed, and reflects a tonic synchronization of a broad group of neurons (Lutz et al, 2007; Klimesch, 1999; Nunez et al, 2001; Slotnick et al, 2002). A decrease in alpha power has often been associated with increased attentional demands of a task, with different neural networks showing local oscillations at different frequencies, which are usually higher (more than 12 Hz); thus high levels of alpha activity have been considered as reflecting a relaxed mind.

However, a number of studies (Cooper et al, 2003; Foxe et al, 1998; Lutz et al 2007) note that alpha activity can paradoxically increase in specific brain regions when an individual is focusing attention on an object or holding information in memory; this thus indicates that these frequencies may also be involved in mental states of attention or working memory. According to this view, alpha frequency EEG indicates active inhibition of cortical regions that are not relevant to the task (Ward, 2003). Thus in meditation, active focus on the breath or another object may lead to an active inhibition of many brain processes (e.g. sensory and motor information and other objects of focus) along with increased alpha frequencies in non-task related cortical areas, thus facilitating task performance.

Though a number of these studies have examined changes in attentional regulation in meditators compared to controls, there are very few studies that have attempted to examine the meditation session in detail and to separate out periods of mental focus from periods in which the mind was distracted from the task by other thoughts/ sensory stimuli or by becoming drowsy. Thus, when recording such physiological correlates of meditation as EEG, it is possible that periods of unfocused attention (both mind-wandering and sleepiness or drowsiness) were averaged in with focused attention, thus reducing the clarity and precision of the results.

During meditation, similar to any continuous performance task often used in psychological testing paradigms, when an individual does not conform to the pre-defined goal set, she experiences episodes of mind-wandering. For example, recent innovative research by Smallwood et al (Smallwood & Schooler; 2006; Smallwood et al, 2007) has shown that for other continuous performance tasks which require focused attention, participants undergo periods of attention alternating with periods in which the mind wanders, leading to failures in task performance. The research suggests that during this time executive components of attention shift, often unintentionally, from the primary task of focus. The paradigm they use to study mind wandering is adaptable to meditation performance and thus can help delineate periods of focus vs. mind-wandering within a meditation session.

This study takes advantage of this paradigm to determine the extent to which EEG characteristics of meditation differ in periods when subjects are in an alert and relaxed meditation state, vs. when the mind is wandering or drowsy and how each of these differs

from the immediate return to focus after a mind-wandering episode. The study also examines the extent to which EEG characteristics within these focused vs. unfocused periods compare to baseline levels of activity, and the manner in which this changes as participants go from unpracticed novices to beginning meditators, as a result of 8 weeks of meditation practice. As reported in a previous paper (Joshi et al, submitted) we examined data from a randomized controlled study comparing an eight-week program of concentrative meditation training vs. relaxation training for naïve subjects who had no previous experience in meditation.

We hypothesized that in pre-training test sessions that EEG alpha and theta activity (indicators of relaxed focus) would show higher levels of activity when subjects were in a meditative state, compared to an off-focus state. We also hypothesized that when subjects immediately returned to focus, alpha and theta activity would also be lower than in the meditative state, as they would be making an effort to return to concentrating on the breath and repeated syllable.

We also predicted that, if learning meditation requires effort in mental focus, during pre-training session participants would show low levels of alpha and theta activity compared to baseline eyes-closed rest. We hypothesized that after meditation training, there would be higher alpha and theta amplitudes in periods of alert attention as compared to periods of mind wandering. We further predicted that after training alpha and theta activity would be greater in the meditation trained group compared to the relaxation trained group, as the skill had been practiced for eight weeks by the meditation group and mental effort for focus would be reduced. However, we predicted that these

levels would remain low compared to those observed in previous studies of long-term practitioners of meditation, who had reached much higher skill levels in mental regulation.

Methods

Training program

Participants (n= 30, mean age 23 yrs) were enrolled for an eight week training program in meditation and progressive muscle relaxation from an alternative and complementary medicine class offered at the University of Oregon. After approval from the office of Human subjects, information about demographics, sleep, substance abuse, physical activity level was gathered. Participants were assessed for their lifestyles and were pseudo-randomly assigned to either the meditation (12 F, 3 M, mean age: 23.1 $\pm$3.1 yrs) or relaxation (11F, 4 M, mean age: 22.8 $\pm$4.8 yrs) training group. The participants were shown research evidence that both meditation training and progressive muscle relaxation training are alternative and complementary medicines with positive health outcomes and hence were led to believe that both types of training should be efficacious.

During training, all the participants were asked to practice the assigned activity for 40min/day at least 5 days a week. In class instructed/guided activity was 20min/day and the participants practiced outside class for a minimum of 20min/day. To have consistency in the instructions of in-class and out of class practice sessions, the participants were given handouts of instructions. The participants reported their practice compliance via weekly logs. Meditation training instructions focused on sitting in a

posture with the spine lengthened and shoulders wide, focusing on the movement of the breath while repeating the syllable "om" with the in-breath and the out-breath. Participants were told that if the mind wandered, to gently bring the awareness back to the breath and the syllable. And if the mind became completely still and the repetition stopped, that was fine as the goal of meditation was a still, focused state of mind.

Testing session

The participants were tested prior to and after training. During a testing session, the participants were seated 40 cm away from a computer screen with eyes closed and their hands on a button pad and face comfortably placed on a chin rest. EEG data during the session were collected using a 256 electrode Electrical Geodesic Inc. system. Instructions about the task were given at the beginning of the session. Each session was divided into five blocks – three rest blocks of two minutes each alternating with two mental focus blocks of ten minutes each. During each mental focus block, the task of the subject was to silently repeat the syllable 'om' to herself and focus on the breath. The participants were instructed that if they went off-task then as soon as they became aware of it, they should generate a button-press response. An individual can be off-task due to two possible reasons, mind wandering thoughts and sleepiness. These were indicated by two separate button press responses (L for mind-wandering; R for sleepiness).

Data Analysis

The data were collected using Netstation 4 software and analyzed using the same software along with Matlab analysis programs. Data segments of 14s, which included a

response at 7 s (indicating the subject was off-focus), were segmented out from the raw files. Data 2s on either side of the responses were removed from analysis in order to remove EEG changes caused by the motor command of the button press occurring during that period. Artifacts from eye movement and eye blinks were deleted using the netstation bad channel replacement software. Occipital, frontal and parietal electrode montages were determined by grouping electrode clusters in corresponding scalp locations. Wavelet analysis was computed using Netstation 4.

For EEG analysis, the dependant variable was wavelet amplitude. Independent variables were mental states (on-focus vs. off-focus vs. rest vs. meditative state), time (pre-training, post-training), type of training (meditation and relaxation), frequency (alpha, theta), and region based electrode clusters (frontal, parietal and occipital). Statistical analysis was done using SPSS version 15 software. A repeated measures ANOVA was computed and a Huynh-Feldt correction was applied wherever applicable.

<u>Results and Discussion</u>

Pre-training session

We hypothesized that in pre-training test sessions that EEG alpha and theta activity (indicators of relaxed focus) would show higher levels of activity when subjects were in a meditative state, compared to an off-focus state. As training had not yet occurred, we predicted that there would be no differences between subject groups. We computed a repeated measures ANOVA to determine the impact of condition (meditative state, rest, on-focus and off-focus) on mean alpha amplitude in the electrode clusters, prior to training. A main effect of condition was seen in the frontal electrode cluster,

$(F(3,27)=21.76, p=.00)$ (Figure 10), the occipital electrode cluster $(F(3,27)=17.71, p=.00)$ (Figure 11) and the parietal electrode cluster $(F(3,27)=26.01\ p=.00)$ (Figure 12). There was no effect of group. Thus, as we had hypothesized we observed an increase in alpha amplitude in meditative states as compared to an off-focus state in both subject groups.

In the three electrode clusters, we also computed repeated measures ANOVA to examine the impact of condition on mean theta amplitude, prior to training. No significant effects were seen in the frontal and parietal electrode clusters. In the occipital electrode cluster, only a main effect of condition $(F(3,27)=3.5, p=.04)$ was seen (Figure 13) indicating a higher theta amplitude in the meditative state as compared to off-focus states in both groups.
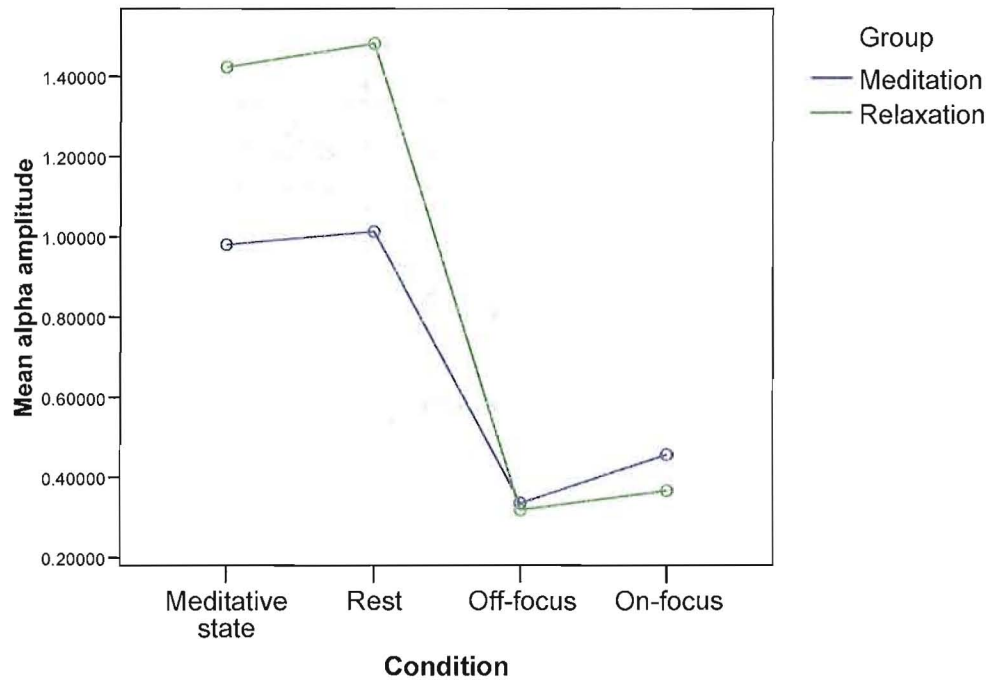
Figure 10. Changes in mean alpha amplitude as a function of condition in the frontal electrode cluster prior to training.

Pre-training: Effect of Mental Condition on Alpha amplitude in Occipital electrode cluster
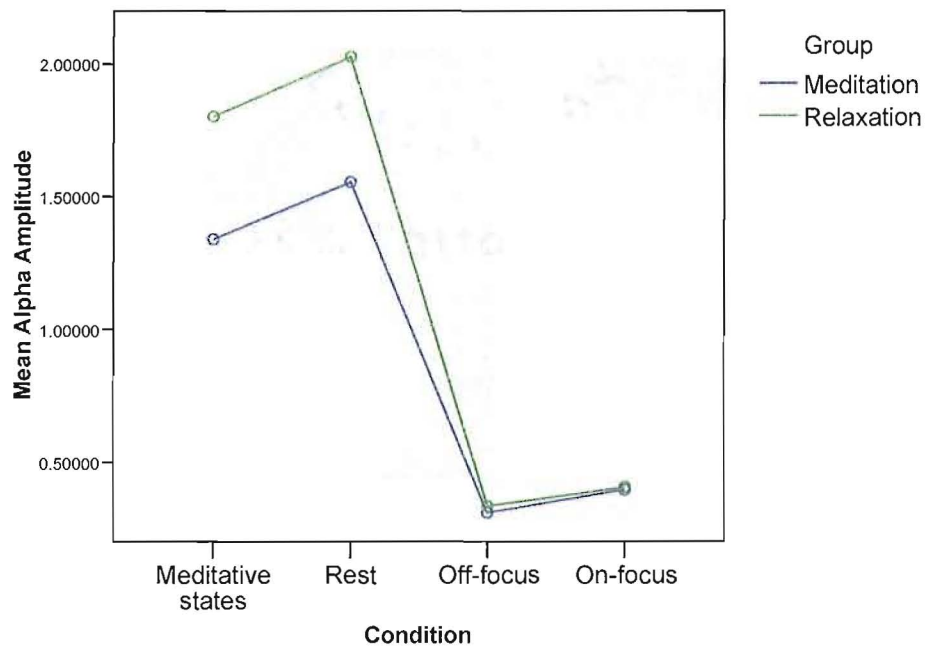
Figure 11. Changes in mean alpha amplitude as a function of condition in the occipital electrode cluster prior to training.
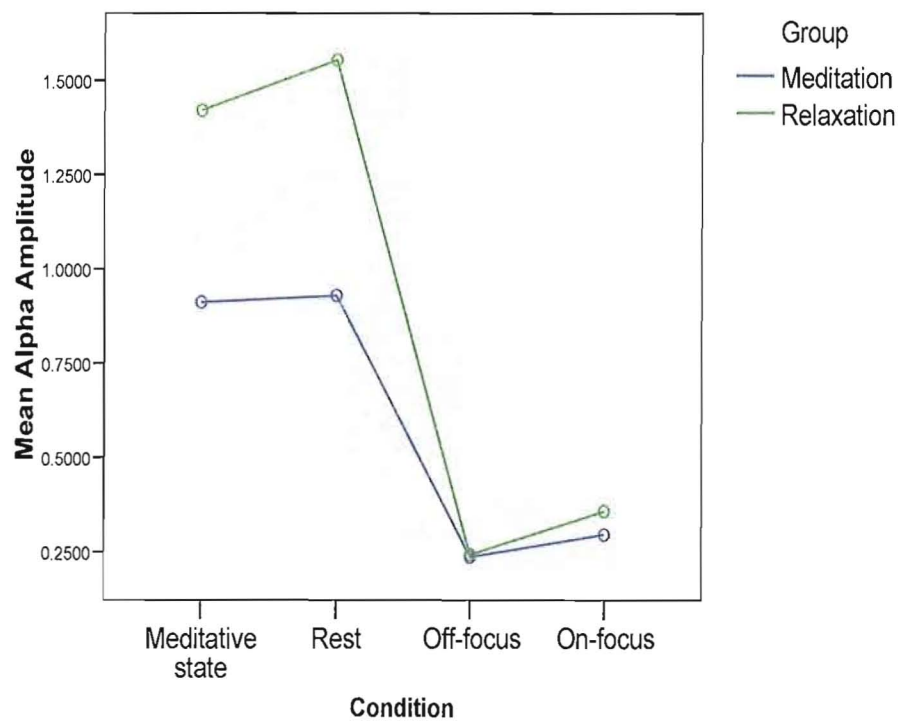
Figure 12. Changes in mean alpha amplitude as a function of condition in the parietal electrode cluster prior to training.

Pre-training: Effect of Mental condition on theta amplitude in Occipital electrode cluster
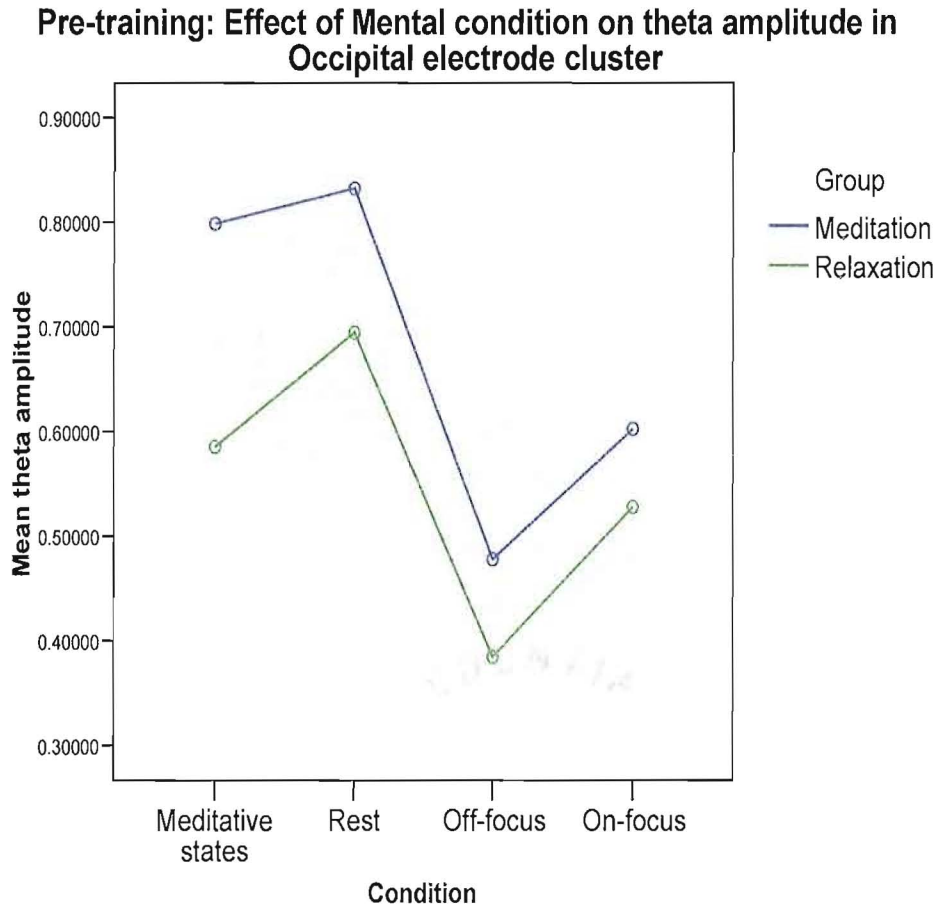
Figure 13. Changes in mean theta amplitude as a function of condition in the occipital electrode cluster prior to training.

We also hypothesized that 1) when subjects immediately returned to focus, alpha and theta activity would also be lower than in the meditative state, as they would be making an effort to return to concentrating on the breath and the repeated syllable and 2) if learning meditation requires effort in mental focus, that during pre-training session participants would not show higher levels of alpha and theta activity compared to baseline eyes-closed rest. In fact, during meditative state segments that did not include a

button press (indicating off-focus period and subsequent return to focus) EEG characteristics showed no difference from base-line rest (F (1, 16) =.04, p=.829). In addition, subjects showed a significantly lower alpha and theta amplitude in the off-focus and immediately subsequent on-focus conditions compared to either the baseline rest condition or the ongoing meditative segments. In the frontal electrode cluster, alpha amplitude in the off-focus condition as compared to a meditative state (t(12)=4.5 p=.00) or rest state was significantly lower (t(12)=5.0 p=.00) irrespective of group. In the on-focus segments that immediately followed off-focus segments, alpha amplitudes were lower than for the meditative state (t(10)=4.2 p=.002) or rest state (t(12)=4.5 p=.00). In the occipital electrode cluster, the theta amplitude in the off-focus condition was significantly lower when compared to meditative (t(12)=4.0 p=.002) or rest (t(10)=4.8 p=.001) states. This confirms our hypothesis that the off-focus state and the immediate return to focus both involve mental activity

Post-training session

We further hypothesized that after meditation training, there would be higher alpha and theta amplitudes in periods of alert attention as compared to periods of mind wandering, and that this would be greater for the group trained in meditation than the group trained in relaxation. We computed repeated measures ANOVA for determining the impact of mental condition (meditative state, rest, on-focus and off-focus) on mean alpha and theta amplitude, after training. For alpha amplitude, in the frontal and parietal electrode clusters, a significant Condition*Group interaction (frontal: F (3, 39)= 3.5, p=.02; parietal: (F (3, 39) = 2.88, p=.04)) was seen for alpha amplitude (see Figures 14,

15) As compared to the off-focus condition we found an increase in alpha amplitude in the meditative condition and on-focus condition.

In the meditation group, while comparing mean alpha amplitudes of meditative states and the on-focus states that occurred immediately after mind-wandering (off-focus), a significantly higher alpha amplitude in the meditative states was found (frontal: t (5) = 3.2, p=.02; parietal: (t (5) =2.8, p=.01). A significantly higher alpha amplitude in the rest state as compared to the off-focus state was also found (frontal: t(5)=2.6, p=.04; parietal: (t (5) = 3.6, p=.01).

In the relaxation group, the mean alpha amplitude for the meditative state was also higher than for the off-focus state (frontal: t (9) =4.9, p= .001; parietal: t (9) = 4.7, p=.00) and the on-focus state (t (9) = 4.7, p=.001). The mean alpha amplitude for the rest state was also significantly higher than off-focus (frontal: t (9) =5.6, p=.00; parietal: t (9) =5.6, p=.00) and on-focus condition (frontal: t (9) = 5.5, p=.00; parietal: t (9) =5.4, p=.00). These results show that for frontal and parietal electrodes in both the meditation group and the relaxation group the meditative state and rest condition show normal relaxation effects involving high alpha and theta activity compared to periods of mind-wandering (off-focus).

For theta amplitude, in the frontal electrode cluster, a significant interaction condition* laterality* group (F (9,117) =2.6, p=.039) was seen. The meditation group showed a significantly higher theta amplitude than the relaxation group, after training, during the meditative state segments (frontal: F(1,19)=6.8, p=.01), frontal midline: F(1,19)=9.5 p=.007) and rest state.

In addition, in the meditation group, an increased frontal midline theta as compared to the right frontal electrode cluster was seen in meditative states (t (9) = -2.1, p= .05). A significant decrease in mean theta amplitude was seen in the rest condition as compared to the meditative states (t (9) =2.7, p=.04). This increased midline theta activity indicates reduced mental activity in the frontal area in meditators during the meditative state as compared to rest conditions (see Figure 16).

**Post-training: Effect of condition on Alpha amplitude in frontal region**
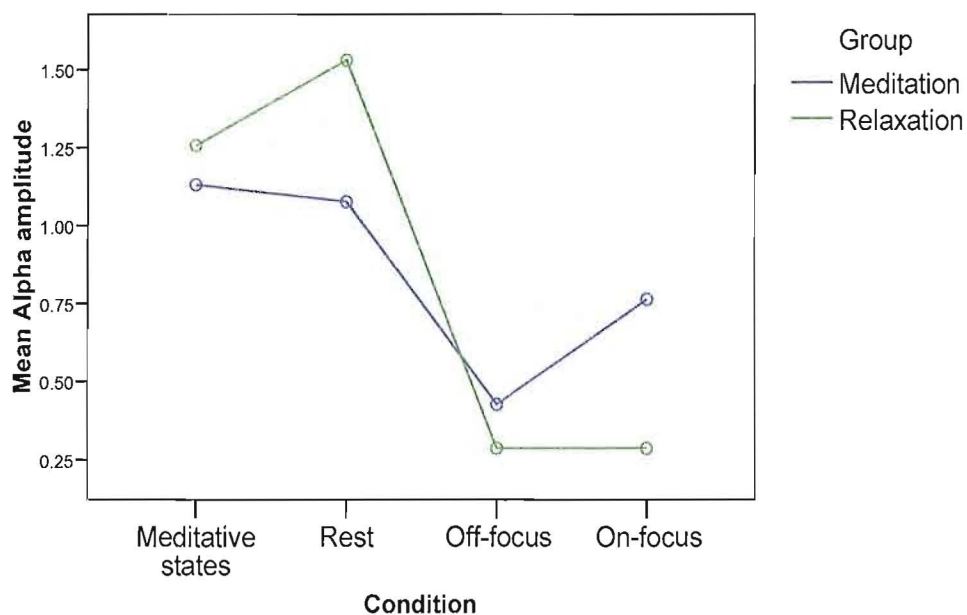
Figure 14. Changes in mean alpha amplitude as a function of condition in the frontal electrode cluster after training.

**Post-training: Effect of Mental Condition on Alpha amplitude in Parietal Electrode cluster**
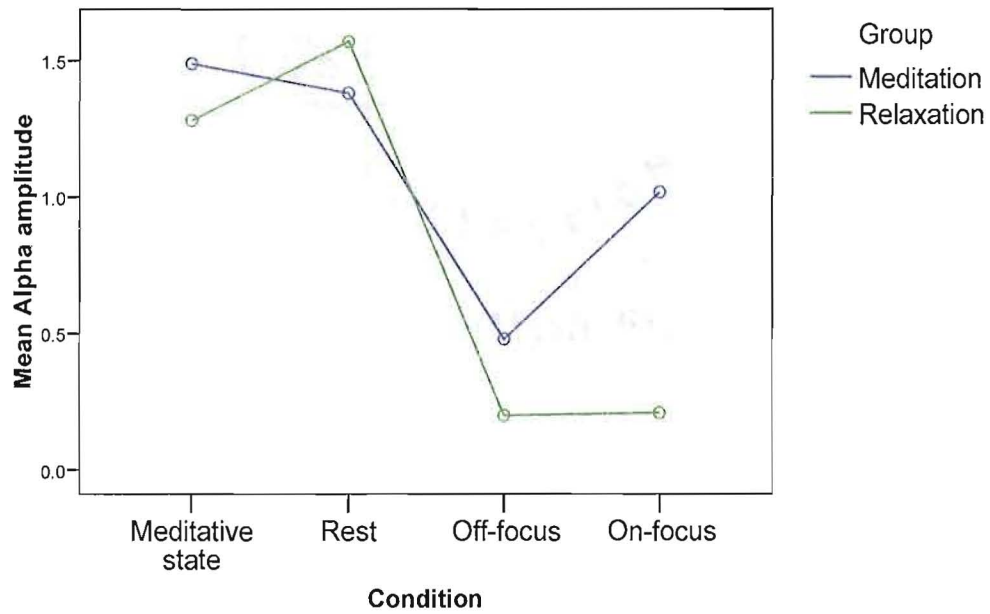
Figure 15. Alpha amplitude as a function of mental condition in the parietal electrode cluster after training

Post-training: Effect of condition on mean theta amplitude after training
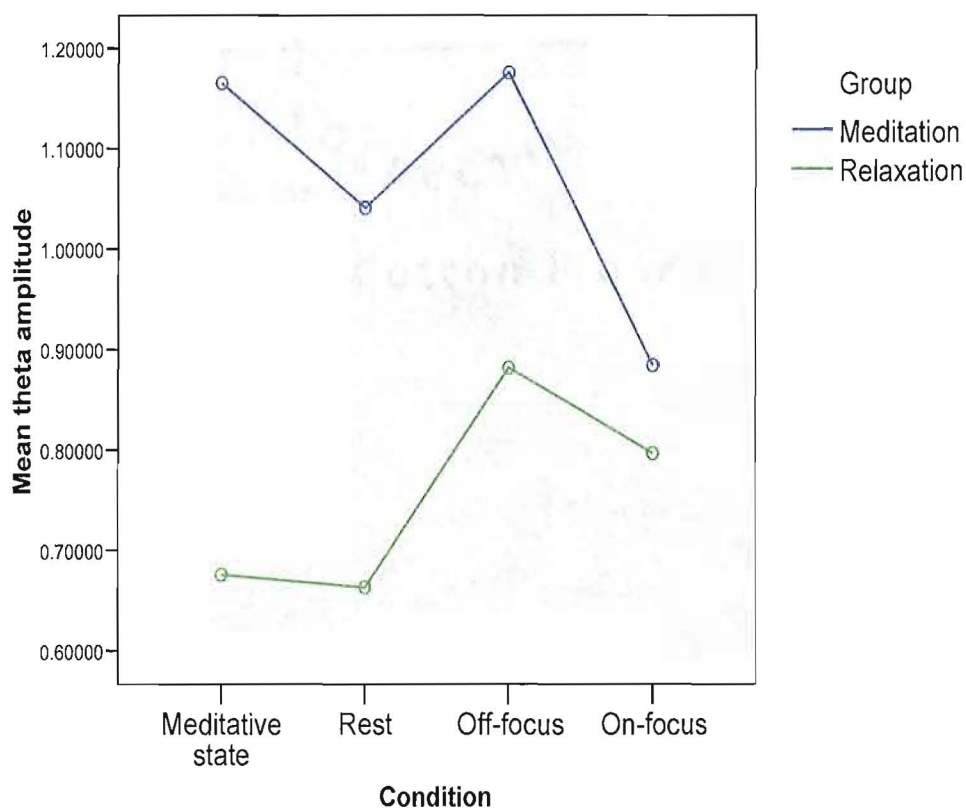
Figure 16. Changes in mean theta amplitude as a function of condition in the frontal electrode cluster

Discussion

Though a number of previous studies have examined EEG characteristics associated with meditation and shown changes in attentional regulation in meditators compared to controls, there are very few studies that have attempted to examine the meditation session in detail and to separate out periods of mental focus from periods in which the mind was distracted from the task. In this study we have applied a paradigm

used to study mind-wandering in other contexts Smallwood et al (Smallwood & Schooler; 2006; Smallwood et al, 2007), to the task of meditative focus. This study takes advantage of this paradigm to determine the extent to which EEG characteristics of meditation differ in periods when subjects are in an alert and relaxed meditation state, vs. when the mind is wandering or drowsy and how each of these differ from the immediate return to focus after a mind-wandering episode. The study also examined the extent to which EEG characteristics within these focused vs. unfocused periods compare to baseline levels of activity, and the manner in which this changes as participants go from unpracticed novices to beginning meditators, as a result of 8 weeks of meditation practice. As reported in a previous paper (Joshi et al, submitted) we examined data from a randomized controlled study comparing an eight-week program of concentrative meditation training vs. relaxation training for naïve subjects.

As we hypothesized, EEG alpha activity (indicators of relaxed focus) in pre-training test sessions showed higher levels of activity when subjects were in a meditative state, compared to an off-focus state for frontal, parietal and occipital electrode clusters (p=.00). This was also the case of theta activity in the occipital cluster (p=.04).

In addition, when subjects immediately returned to focus after an off-focus period, alpha activity was lower than in the meditative state (p=.002). We predicted that this would be the case, as they were asked to refocus the mind on the breath and the repeated syllable, as soon as they discovered they were off focus, and this task produces mental activity associated with the effort of concentration.

Results also showed that during pre-training test sessions in which subjects were practicing mental focus for the first time, they showed low levels of alpha and theta activity compared to baseline eyes-closed rest (alpha: (p = .00), theta: (p=.00)), supporting the hypothesis that, if learning the techniques of focusing the mind on the breath and on a repeated syllable that underlie meditation requires effort in mental focus, then alpha and theta levels should be low during this first practice condition.

Results supported the prediction that after meditation training, there would be higher alpha and theta amplitude in periods of alert attention as compared to periods of mind wandering (off-focus) (p = .02) We further predicted that, after training, alpha and theta activity would be higher in the meditation group compared to the relaxation group (p=.01). However, we predicted that these levels would remain low compared to those observed in previous studies of long-term practitioners of meditation, who had reached much higher skill levels in mental regulation.

Changes across mental conditions

Though previous studies have not compared EEG characteristics during focused vs. unfocused segments of a meditation session, a number of previous studies have compared EEG characteristics during meditative states and resting baseline conditions (Anand et al, 1961; Hirai 1974; Kasamatsu & Hirai, 1966; Fenwick, 1987; for reviews see Lutz et al, 2007; Delmonte, 1984; Shapiro & Walsh, 1984). They have found an increase in alpha and/or theta amplitude during meditative states, and our results support those findings.

Many previous studies have considered baseline resting states as equivalent to mind-wandering, as individuals are not asked to focus the mind in any way or perform a mental task (Mason et al., 2007). If this is the case, one would expect to see no difference or minimal differences in baseline resting states and segments in which subjects noted that their mind was wandering and they were off-task. The data in the present study show that these two conditions are significantly different for alpha frequencies. Hence we believe that the off-focus condition is different from baseline resting states. One reason for this may be that the off-focus condition is limited to segments in which the subject had identified that the mind was actively engaged in thoughts. It is possible that baseline rest periods also include many segments in which the mind is in a relaxed quiescent state.

A number of studies have also concluded that the higher alpha and theta power they found in participants' meditative states as compared to baseline were due to focused concentration. For example, Aftanas and Golosheikin (2003) state that alpha and theta activities reflect the activity of multifunctional neuronal networks selectively associated with processes of cognitive and affective activity. The results of this study suggest that the high alpha and theta amplitudes during meditation may instead reflect reduced cognitive activity, and that it is only in the early periods of meditation or when the mind has begun to wander, that subjects must renew cognitive activity to begin to focus again on the breath and the repeated syllable in an active way. After repetition has occurred for a period, we suggest that it becomes more automatic and mental activity is again reduced.

Post-training effects on alpha and theta amplitudes

Prior to training no group differences in alpha or theta amplitudes were seen during participants' attempts at meditative focus, as might be expected with age and education matched naïve subjects in both groups. However, after training, theta activity was higher in the meditation group compared to the relaxation group in the meditative state in the frontal cluster (p=.01). In addition, the meditation group showed increased theta amplitude in the meditative state compared to the resting baseline state, suggesting reduced activity during meditation. Surprisingly, theta, (but not alpha) amplitudes in the meditators during the off-focus condition were equivalent to those in the meditative state.

The decreased theta amplitudes for the on-focus periods compared to meditation or rest, both before and after meditation training could be related to an alerting effect that has also been reported in the literature during attentional tasks. Fan et al. have reported a decreased theta power in the alerting network after a warning signal while performing the Attentional Network Test (Fan et al., 2007). Although we eliminated from analysis any meditation session segments that included auditory tones and no visual cues were present, alerting mechanisms may have been triggered due to meta-awareness processes, signaling that there had been an occurrence of mind-wandering, causing a decrease in theta power in the on-focus condition. However, before this reduction in theta activity can be identified as an alerting effect more research in comparing on-focus vs. off-focus conditions is needed.

Study Limitations

Though the design of this study was specifically created to examine differences in EEG characteristics during different states that may occur during meditation, including, quiet mental focus, un-focused periods and the immediate return to focus, this also creates a paradoxical limitation to the study, as the instructions to the meditators required them to periodically make button presses as a result of their monitoring of mental activity. This has a probably effect of making their meditative state less quiescent than if they were allowed to simply focus within, as they were making repeated button presses during the 10 minute segments.

The strength of the study was also reduced by the limited number of subjects whose data contributed to the final results. During data analysis, testing sessions of 12 subjects were found to have sufficient artifact to be unusable, and thus only 50% of participants were actually used for analysis. The statistical power of the study would be enhanced by increased participant numbers.

Summary

In summary, this study is one of the first to perform a meditation training experiment in which the meditation session was examined both before and after training in detail, in order to separate out periods of mental focus from periods in which the mind was distracted from the task. Results indicated that EEG alpha and theta activity (indicators of relaxed focus) in pre-training test sessions showed higher levels when subjects were in a meditative state, compared to an off-focus state. In addition, when subjects immediately returned to focus after an off-focus period, alpha activity was lower

than in the meditative state suggesting that the effort to refocus the mind required mental effort.

Finally, prior to training no differences in alpha or theta amplitudes were seen between the relaxation and meditation groups during participants' attempts at meditative focus; however, after training, theta activity was higher in the meditation group compared to the relaxation group in the meditative state. This suggests that the training in relaxed mental focus improved the ability of the meditation group to reduce mental activity

CHAPTER V

GENERAL DISCUSSION

Meditation and Issues Related to Methodology

Physiological and psychological effects of meditation practice have been studied using quantitative variables for the last few decades. However, thought the results of these studies have been of interest, a large number of the studies have not met strict criteria of scientific research involving clinical training trials. For example, in a study initiated by the National Center of Complementary and Alternative Medicine, Ospina et al. (2007) note that the results of the majority of studies on the efficacy of complementary forms of medicine cannot be generalized as the quality of the studies was not carefully controlled.

Ospina et al (2007) noted that many studies were not randomized controlled longitudinal trials. In addition, there was often no blinding to prevent biases on the experimenter's part and also no mention of drop out rates. In order to conduct a methodologically superior and refined study with credible results, in the present study, we have incorporated the above mentioned suggestions. The experimenters were blinded about the type of training a participant received during the data collection phase. The study used state-of-the-art technology for characterizing EEG frequencies, involving wavelet analysis, which offers the ability to examine frequencies of brainwaves over a period of time. This study also took into consideration attention training principles.

Meditation as an Attention Training Program

Meditation is termed as attentional training. Sohlberg and Mateer (2001), state that attentional training involves repeated activation and stimulation of attentional systems which in turn brings about enhancement of attentional skills. Improving attentional skills impacts other cognitive abilities such as memory. The authors have noted five principles for attentional training which are important in designing therapies related to improvement of attention:

1. A treatment model should be based on attentional theory.

2. Therapy activities should be organized working from basic processes to more complex processes.

3. Sufficient practice should be included in the training design.

4. An attentional training should be designed in relation to the performance responses from participants, thus customizing the training to the individual.

5. Attentional training should encompass activities of daily living.

A good meditation training program should incorporate these principles of attentional training. In our present training program, we have tried to follow these principles. Meditation training entrains voluntary, sustained attention (Jha, Krompinger, & Baime, 2007). This in turn facilitates regulation of habitual behaviors, which is of therapeutic value in disorders related to substance abuse, attentional deficits, emotion regulation or eating disorders. Since the population under consideration was college students who had no experience in meditation, we have used a basic technique involved in many meditation

studies of repeating a syllable and focusing on the breath. Selection of complex activities such as qi-gong or dancing meditations was deliberately avoided as we intended to train students in a basic meditation process (principle 2). Sufficient practice was ensured with the help of daily logs (principle 3). Since the training program was a part of an Alternative and Complementary Medicine class, we did not have an option of customized training to each individual. However, meditation training allowed participants to choose a posture of their choice (half-lotus posture, easy cross-legged posture on the floor or seated on a chair) keeping their spine upright (principle 4). The participants had a choice to silently repeat a syllable, "Om" or "hum," depending on their preference. Other activities of daily living, such as walking or eating, can be done in a meditative fashion. However, since it would be a potential confound for the outcome of the study, we did not instruct the participants to do other meditative activities during the day (principle 5). Thus, the training program did not add variations which would confound results. There was no variation in the extent of the two training paradigms. We will now discuss the impact of meditation on attentional networks, discussing the theoretical background for the study.

<u>Summary and Significance of Results</u>

We aimed to assess the trainability of the voluntary attention system on behavioral and electrophysiological parameters. Using the contingent capture paradigm by Folk and Remington (1992), we compared pre- and post-training, mean validity effect scores (the difference between invalid cue reaction time and center cue reaction time) for this attentional task. The meditation group showed a trend towards improvement of top-

down attention while the relaxation group did not. Although these results do not attain statistical significance due to group performance differences that existed pre-training, these results could serve as a baseline for future studies.

It would be interesting to determine the role of meditation as an effective therapy in clinical populations who have slower reaction times when performing tasks requiring intensive use of attentional resources, such as children with ADHD or populations with depression. It would also be interesting to have post-training comparisons, in studies of meditators with different levels of experience (in total hours of meditation) vs. controls, to determine the amount of training that is required to bring about changes in attentional networks.

As an electrophysiological measure of the changes brought about by the training program, we examined the changes in the amplitudes of wavelets during rest, periods of mind-wandering and meditation. The participants were instructed to repeat the syllable Om and focus on the breath. If they were off task either due to thoughts or drowsiness, they signaled this mental shift via a button press response.

After training, the episodes of mind-wandering were significantly lower in the meditation group as compared to the relaxation group. An increase in amplitudes of alpha frequencies in the occipital and right parietal areas were seen during the meditation task for the meditation group whereas in the relaxation group an effect of training was seen in occipital electrode cluster.

When we considered the state effects of meditation, pre-training we did see an impact of condition or mental state on the amplitudes of frequencies in the EEG wavelets.

In the meditative state, alpha and theta amplitudes were higher as compared to the rest state. During the periods when the participants were just returning their focus to the breath (on-focus period), we observed a decrease in alpha and theta activity as compared to the rest or meditative state conditions. After training, we observed an effect of type of training (group) and condition on the alpha and theta amplitudes. The meditation group had higher theta amplitude in the meditative state as compared to the relaxation group.

The state effect of meditation has not been studied previously through asking individuals to report on vs. off-focus periods within a meditation session. These results also suggest that the episodes of on-focus and off-focus within a test session are similar to those found in other mental exercises, such as reading, and hence the practice of mental focus during meditation is rightly termed attentional training. Actively suppressing unwanted thoughts is a function of the dorso-lateral prefrontal cortex (Anderson & Green, 2001). We thus hypothesize that during meditation training the dorso-lateral prefrontal cortex may be actively engaged in attentional processing. However, further studies are required to explore the validity of this hypothesis.

<u>Future Directions</u>

The present study validates the methodology used in meditation and attention related research and may serve as a pilot study for future studies. The importance of awareness and precision in the reporting of mental states during meditation or other attentional tasks cannot be overemphasized in the present data-set. It is possible that novice meditators are unaware or inattentive to the identity of their changing mental states. Hence a similar paradigm should be run with expert meditators to compare results

with those found with this study of meditation training in novices. As a longitudinal study, changes in the attentional efficacy of newly recruited monks within a monastic tradition who stay in a meditative practice over a long period of time could be examined at regular intervals (i.e., bi-yearly).

Meditation is often considered to be an alternative and complementary medicine which can be to treat patients with stress-related mental and physical disorders. The therapeutic significance of meditation in relation to these disorders needs to be carefully examined. Also the suitability of a patient for meditation practice, the amount of practice (dosage), and customized meditation techniques for patient populations (e.g., moving meditations such as tai chi, vs. sitting meditations) should be determined based on careful studies. Hence studies related to patient populations, which use similar paradigms or variations on this paradigm comparing different types of meditation practice, will facilitate the determination of the therapeutic value of meditation.

APPENDIX A

MEDITATION INSTRUCTIONS

Day 1

We'll be meditating in a few minutes, but let's first go through some of the basics of a comfortable, well-aligned sitting posture.

Your sitting bones (the nobs on the pelvic girdle) and your legs (or feet, if on a chair) are the steady foundation for your posture. If you balance evenly on the sitting bones it will help support the natural inward curve of the lower back. To find the right balance, check to see if your knees are even with our hips, or higher.

If you are sitting on the floor and the knees are higher than the hips, you will need to put a cushion under your hips to find the right balance.

If you are sitting on a chair, place both feet flat on the floor, approximately hip-width apart and parallel to one another. Place your ankles directly under your knees. If your feet don't reach the floor, you can stabilize your feet by placing a folded blanket or a cushion under them.

Let your hands rest on your thighs so that your upper arms can release freely down from your shoulders to your elbows. You can rest your hands palms down on your thighs, or in on your lap, palms up, one hand on top of the other.

Gently elongate the spine. You can imagine your sitting bones releasing down into the earth as your body releases upward.

Now relax the jaw, and feel the back of the neck gently lengthen. The neck is relaxed. Your face and eyes are soft. The tongue is relaxed on the floor of your mouth. The shoulders are wide, the chest is open, and slightly lifted.

If your body becomes uncomfortable while you are meditating, it is fine to adjust your posture. Simply do it slowly and gently to maintain your meditative state. You change the position of your legs or bring your knees up and together in front of you before reassuming your meditation posture.

If you sit on a chair, choose one that will support your sitting upright so that you can remain attentive. You may want to sit forward on your chair or place a cushion between the small of your back and the back of the chair

Bring your awareness to the natural flow of your breath. Allow your ribcage to gently expand in all directions as you breathe in and breathe out. Let the breath move naturally. If you experience tension any where in your body, place your awareness there and breathe into it. Let the body feel relaxed and light.

And now you can begin to repeat the syllable, OM silently with your breath.

OM as you breathe in, and OM as you breathe out. Let this syllable vibrate inside you, bringing your focus inward. Simply rest in the experience of the syllable repeating itself with your breath. Om as you breathe in. Om as you breathe out.

And if thoughts come up, simply let them go by like clouds in the sky and bring your mind back to the breath and the syllable OM.

Rest in that place of stillness.

Meditate.

Day 2- until end of training

And now we'll be meditating.

If you are sitting on a chair, you can place your feet firmly on the floor about hip width apart.

If you are sitting on the floor, sit in a comfortable cross-legged position.

You can close your eyes. Feel your back gently elongate upwards - from the base of your spine to the crown of your head.

Let your neck relax and become soft.

Your shoulders are wide.

Your chest is open.

Place your hands on your thighs, palms down, or in your lap

Now begin to pay attention to your breath.

Let your breath become soft and expanded.

And now you can begin to repeat the syllable, OM with your breath.

OM as you breathe in, OM as you breathe out.

And if thoughts come up, simply let them go by like clouds in the sky and bring your mind back to the breath and the syllable OM.

Rest in that place of stillness.

Meditate.

(20 minute meditation)

You can slowly come out of meditation. And when you are ready you can open your eyes. Now, keeping in that still state, take up your journal and write a few notes to yourself about what you experienced in meditation. Did you notice any changes in the feeling in your body, in your mental or emotional state, in your awareness?

And when you are finished with your writing, simply note the amount of time you meditated in you log.

RELAXATION INSTRUCTIONS

Now we'll be going through our guided relaxation and then continuing to relax for a while longer.

You can lie down on the floor on your back with your arms outstretched about 6 inches from your side and your palms facing up, and your feet about 12 inches apart.

Or if you are more comfortable sitting, you can simply rest in a chair with your feet flat on the floor and your palms in your lap or on your thighs.

Now bring your awareness to your feet and totally relax the muscles of your feet.

Let your ankles sink down to the floor.

Relax your calf muscles.

Let your knees sink down to the floor.

Relax your thigh muscles.

Let the hips sink down to the floor.

Relax the muscles of your abdomen and your lower back.

Relax the muscles of your chest and your upper back.

Take your awareness to your hands and fingers. And let them totally relax.

Let the wrists sink down to the floor.

Relax your forearm muscles.

Let your elbows sink down to the floor.

Relax your upper arms.

Let your shoulders sink down to the floor.

Your neck muscles are totally relaxed.

Now take your awareness to the muscles of your face, and let the face become soft and relaxed.

The eyes soften down into the eye sockets.

And let the jaw completely relax.

Now simply rest in a relaxed state, letting your mind wander as it likes.

If you fall asleep that is fine.

This is simply a time of rest and relaxation.

(20 minute relaxation)

You can slowly open your eyes. Now, keeping in that state of relaxation, take up your journal and write a few notes to yourself about what you experienced. Did you notice any changes in the feeling in your body, in your mental or emotional state, in your awareness?

And when you are finished with your writing, simply note the amount of time you relaxed in you log.

APPENDIX B

LIFESTYLE QUESTIONNAIRE

Subject ID Number _____

1. Age _____

2. Occupation
a. What is your occupation? _____

b. In general, how much cardiovascular / strength activity do you engage in while doing your job?

1--------------------2--------------------3--------------------4--------------------5
None   Low Level   Consistent   Consistent   Consistent
              easy   but easy   Moderate   Strenuous

3. Gender   female   male

4. Educational Experience
a. Number of years of grade school /high school education.

1-------2-------3-------4--------5--------6--------7--------8--------9--------10-------11-------12
1st grade 12th

b. Number of years of post-graduate education (after high school).

0-------1-------2-------3--------4-------5--------6--------7-------8--------9-------10

c. SAT Scores. Verbal _____   Quantitative _____

d. High School Grade Point Average (estimate) _____

e. College Grade Point Average (estimate) _____

f. If you attended college, what was your major? _____

g. If you attended graduate school, list your degree and major. _____

h. How much time per week do you spend reading (in hours)?_____
i. Is English your Native Language? Yes / No
j. If no, at what age did English become your primary language? _____

5. Weight, Dietary, and Health Questions
a. Weight (in pounds) _____
b. Height (in feet and inches) _____
c. Frame size.   Small   Medium   Large
d. What do you consider your ideal weight?   _____
e. Are you a vegetarian?   Yes / No

f. In general, how would you rate your eating habits?

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

Very Unhealthy	Somewhat Unhealthy	Not especially Healthy or Unhealthy	Mostly Healthy	Very Healthy

g. How many times a week would you say that you consume the following items?

Fresh Fruit
0-------1-------2-------3--------4--------5--------6--------7--------8--------9-------10
Fresh Vegetables
0-------1-------2-------3--------4--------5--------6--------7--------8--------9-------10
Vitamin Pills / Supplements
0-------1-------2-------3--------4--------5--------6--------7--------8--------9-------10
Organic Food
0-------1-------2-------3--------4--------5--------6--------7--------8--------9-------10
Fast Food
      0-------1-------2-------3--------4--------5--------6--------7--------8--------9-------10

h. Which of the following best describes how you feel about your physical health?
1. I am currently in poor health (major physical illness and low level of fitness)
2. I am currently somewhat out of shape, but in acceptable health.
3. I am currently in average shape, and in acceptable health
4. I am currently in good shape, and in good health
5. I am currently in outstanding shape, and excellent health.

6. Do you currently have any chronic illness /illnesses? If so, please list.

_____

7. Are you currently taking any forms of medication? If so, please list.

_____

8. Have you ever been formally diagnosed with a learning disability or attention deficit disorder?   Yes / No.   If yes, specify_____

9. Have you ever had a head injury that resulted in a concussion?

Yes / No.   If yes, specify _____

10. Do you have or have you ever had a disease, condition or other circumstance that led to brain surgery or that will require brain surgery in the future (e.g., tumor, stroke, disease, wound)?

Yes / No.   _ If yes, specify _____

11. Are you colorblind?   Yes / No

TOBACCO USE
Which of the following best describes your history of tobacco use?
a. Lifetime Abstainer
b. Occasional Smoker (e.g., one cigarette, cigar, or pipe a month, or less)
c. Former Smoker.   (e.g., you have not smoked in 6 months or more)
d. Trying to Quit (e.g., you have significantly reduced cigarettes for more 1 week or more).
e. Experimenting (e.g., just started…smoking often, but not sure it's a habit)
f. Current Smoker

If you have ever smoked or used tobacco, please answer the following questions.

How long have you smoked in years/ months? _____

Please Estimate the number of each item you CURRENTLY use PER WEEK.
Cigarettes _____
Cigars _____
Pipes _____
Chewing Tobacco (in cans or bags) _____
Nicotine Gum (in pieces)_____

If you currently smoke, how long ago did you have your last cigarette?

_____ (list date and exact time)

How would you rate your CURRENT desire to have a cigarette at this moment?

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

Satisfied /	Low Desire /	Moderate	Definite Craving	Strong Desire/
No desire	Take it or leave it	Desire	But not too bad	Will have a cigarette right away when you leave.

ALCOHOL USE
Which of the following best describes your history of alcohol consumption?
a. Lifetime Abstainer
b. Occasional Drinker (e.g., one to three drinks a month)
c. Former Drinker.   (e.g., you have not consumed alcohol in 6 months or more)
d. Trying to Quit (e.g., you have significantly reduced alcohol for more 1 week or more).
e. Experimenting (e.g., just started drinking alcohol)
f. Current Drinker (one or more drinks per week on average)

If you have ever drunk alcohol, please answer the following questions.

How   long   have   you   been   drinking   alcohol   (months   /   years)?
_____

Please estimate the number of each item you CURRENTLY use PER WEEK.

Beer (in 12 oz units)
0-------1-------2-------3--------4--------5--------10--------15-------20-------30------40 or more
Whiskey (in 1 shot units)
0-------1-------2-------3--------4--------5--------10--------15-------20-------30------40 or more
Wine (in 1 glass units)
0-------1-------2-------3--------4--------5--------10--------15-------20-------30------40 or more
Mixed Drinks (in number of drinks)
0-------1-------2-------3--------4--------5--------10--------15-------20-------30------40 or more
Other Alcohol not listed
0-------1-------2-------3--------4--------5--------10--------15-------20-------30------40 or more

If you currently consume alcohol, when did you have your last drink?

List Date and Time_____

The last time you consumed alcohol, how many drinks did you consume (to estimate this, please treat the following items as 1 drink: 12 oz beer, 1 glass wine, 1 shot whiskey, 1 shot other alcohol (e.g., gin, vodka).

Number of drinks on the most recent occasion.
0-------1-------2-------3--------4--------5--------10--------15-------20 or more

CAFFEINE USE
Which of the following best describes you?
a. Lifetime Abstainer
b. Occasional Coffee Drinker (e.g., one to three cups a month)
c. Former Coffee Drinker.   (e.g., you have not consumed alcohol in 6 months or more)

d. Trying to Quit (e.g., you have significantly reduced coffee for more 1 week or more).

e. Regular Coffee Drinker (consume coffee on regular basis)

If you have ever consumed caffeine, please answer the following questions.

How long have you been drinking coffee (months / years)? _____

Please estimate the number of each item you CURRENTLY use PER WEEK.

Standard Cup of Coffee (12 oz)
0-------1-------2-------3--------4--------5--------10--------15------20-------30------40 or more
Espresso Drinks (in number of shots)
0-------1-------2-------3--------4--------5--------10--------15------20-------30------40 or more
Caffeinated Tea (in number of bags)
0-------1-------2-------3--------4--------5--------10--------15------20-------30------40 or more
Caffeinated Soda (in number of 12 oz servings)
0-------1-------2-------3--------4--------5--------10--------15------20-------30------40 or more
Other Caffeinated Beverages
0-------1-------2-------3--------4--------5--------6--------7--------8--------9-------10

If you consume caffeine, when did you have your last caffeinated beverage?
List Date and Time_____

Number of caffeine units on the most recent occasion (e.g., a 12 oz cup, 1 shot of espresso, and a 12 oz soda each count as a "unit").
0-------1-------2-------3--------4--------5--------6--------7-------8-------9------10 or more

How would you rate your current desire to have coffee / caffeine at this moment?
1--------------------2--------------------3--------------------4--------------------5

| Satisfied / | Low Desire / | Moderate | Definite Craving | Strong Desire/ |
| No desire | Take it or leave it | Desire | But not too bad | Will have a cigarette right away when you leave. |

RECREATIONAL DRUGS
Which of the following best describes you?
a. Lifetime Abstainer from Drugs
b. Occasional Recreational Drug Use (e.g., one to three uses a month)
c. Formerly Used Recreational Drugs. (e.g., you have not consumed a drug in 6 months or more)
d. Trying to Quit (e.g., you have significantly reduced drug intake for more 1 week or more).
e. Regular Recreational Drug User (consume recreational drugs on semi-regular basis)

If you consume drugs, when did you consume your most recent drug?
List Date and Time and type of drug_____

Number of drug units on the most recent occasion (e.g., a joint, a bowl, etc)
0-------1-------2-------3--------4--------5--------6--------7-------8-------9------10 or more

How would you rate your current desire to have a drug at this moment?
1--------------------2--------------------3--------------------4--------------------5
Satisfied /   Low Desire /   Moderate   Definite Craving   Strong Desire/
No desire   Take it or leave it Desire   But not too bad

PHYSICAL ACTIVITY
Please estimate the typical number of MINUTES PER WEEK you currently spend in the following activities.

Overall cardiovascular / aerobic activity (e.g, fitness machines, running, bicycling, swimming, exercise class, basketball, football, Frisbee, etc). (IN HOURS PER WEEK)
0------1-----2-----3-----4-----5-----6----7----8-----9----10----12----14----16----18----20----22

Please Circle the type of exercise you do and estimate WEEKLY AMOUNT IN MINUTES, where relevant. If your activity is not listed, list at the end.

Cardiovascular Fitness Machine (e.g., stairmaster, treadmill, stationary bike, etc)_____
Running (outside a gym) _____
Bicycling (outside a gym) _____
Swimming (in minutes) _____
Exercise Class Not Using Machine (e.g., pilates, aeorobics) _____
Sports (football, basketball, tennis, racquetball, etc) _____
Other type of Exercise Not Listed_____

Overall Strength Training Per Week (e.g., free weights, machines) in HOURS
0------1-----2-----3-----4-----5-----6----7----8-----9----10----12----14----16----18----20----22

Overall Flexibility Training Per Week (stretching, yoga)
0------1-----2-----3-----4-----5-----6----7----8-----9----10----12----14----16----18----20----22

If you do YOGA, please list the type:
1.hatha yoga   2. bikram /iyengar/other version 3.sun salutation

If you EXERCISE, when was the LAST TIME you exercised?
List Date and Time_____
What Activity did you perform? _____

Duration of activity in minutes
0------10-----20-----30-----40-----50-----60-----70-----80-----90----100----110----120 More

Regardless of whether you currently exercise, how would you rate your current

cardiovascular fitness?

1	2	3	4	5
Very Unfit	Somewhat Unfit	Average Fitness	Above Average	Very Fit

MEDITATION PRACTICE
Which of the following best describes your experience with meditation?
a. Never tried meditation
b. Infrequent or intermittent meditation (e.g., a couple times a year)
c. Former Meditator.   (e.g., you haven't meditated regularly in over three months)
d. Meditator who has Slipped (you usually meditate, but haven't in several weeks)
e. Novice meditator (you just started in recent weeks)
f. Regular Meditator (meditate several times a week)
g. Devout Meditator (meditate several times a day)

If you have meditated, please answer the following questions:

Frequency of Meditation
In total in your life, what span of time have you have meditated, regardless of whether this time is consecutive (in months and years)? _____

How many TIMES have you meditated? (please estimate)
0-----10-----20----30----40----50----100----200----300-----400----500----1000----2000
If more than 2000, please estimate _____

In a typical recent session (in the last month), for how many minutes do you meditate?
0------10-----20-----30-----40-----50-----60-----70-----80-----90----100----110----120 More

In a typical week, how many times do you meditate?
0------1-----2-----3-----4-----5-----6-----7-----8-----9----10----11----12----13----14----15
If more than 15, please specify _____

The Feel of the Meditative Experience and Type of Practice

In general, how would you characterize the depth of your typical meditation experience?

1	2	3	4	5
Relaxation	Passed into a deep state a few times	Intermittently Pass into a deep state	Often Pass into a deep state	Always Pass into deep state

In general, how "skilled" do you think you are as a meditator?

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

| Novice | Modest Experience, Feel myself Improving | Experienced and effective | Experienced and highly effective | Unusual Level of Mastery |

During your meditation practice, to what extent do you do each of the following:

Try to remain focused on a mantra, idea, or thought to the exclusion of all other thoughts

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

| Never | Rarely | Sometimes | Often | Always |

Try to focus on your breathing

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

| Never | Rarely | Sometimes | Often | Always |

Try to clear your mind of any thought, idea, or image whatsoever, including breathing.

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

| Never | Rarely | Sometimes | Often | Always |

Try to develop a complex personal vision, and keep this in mind consistently

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

| Never | Rarely | Sometimes | Often | Always |

What type of meditation do you perform? _____

If you are willing, can you describe your practice?

_____

_____

_____

The Effect of Meditation

In general, how do you think meditation influences your ability to concentrate throughout the day, compared to when you don't meditate?

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

| No effect | Modest Benefit in Focus, | Noticeable Benefit in focus | Feel More focused than others | Promotes a profound and unusual focus |

Which of the following best describes your reason for meditating (please rank order)?

1. I lead a very busy, hectic, and demanding life, and meditating helps me to stay mentally focused and on top of things (it helps you concentrate). _____

2. I have trouble sleeping, and meditation helps me become calm and sleep. _____

3. I simply enjoy the heightened state of alertness and consciousness it brings to life___
4. I am seeking spiritual enlightenment and religious experience. _____
5. Meditation helps ease anxieties and depression, and keeps me even. _____
6. Meditation helps to reduce my stress level. _____
7. Other reason to meditate: _____

Your Most Recent Meditative Experience
When was your most recent Meditation Experience (date, time) _____
How long did you meditate during this recent experience: _____

How deep was your most recent meditation experience?
1--------------------2------------------------3-----------------------4------------------5
Relaxation   Moderately deep   Very Deep

Your Meditation Background
How many meditation books do you own?   _____
How many meditation retreats have you attended? _____
What is the longest Meditation retreat you attended? _____
Have you studied meditation in classes or with a mentor? If so, please describe your training (i.e., how many classes, how long a relationship with mentor, and who was the mentor).
Do you read regularly about meditation (in articles, magazines)?

SLEEP
1. Please rate how much you agree or disagree with the following statement: " I am a morning person. I feel awake, alert, and energetic early in the morning."

Strongly Disagree	Disagree Somewhat	Neutral	Agree Somewhat	Strongly Agree
0	1	2	3	4

2. Please rate how much you agree or disagree with the following statement: " I am a night person. I feel awake, alert, and energetic in the late evening or late at night."

Strongly Disagree	Disagree Somewhat	Neutral	Agree Somewhat	Strongly Agree
0	1	2	3	4

3. On a typical weekday, what time do you get up and out of bed?
        6am or earlier   7   8   9   10   11   Noon   1pm or later

4. On a typical weekday, what time do you go to sleep?
8pm or earlier 9   10   11   Midnight   1   2   3   4am or later.

5. Please rate how much you agree or disagree with the following statement: " In a typical night, my sleep is restful and undisturbed."

Strongly Disagree	Disagree Somewhat	Neutral	Agree Somewhat	Strongly Agree
0	1	2	3	4

6. On a typical night, how many hours of sleep do you think you need to feel adequately rested?

| 2hrs or less | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 or more. |

7. Last night, how many hours of sleep did you get (estimate as accurately as possible).

| 2hrs or less | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 or more. |

8. Please rate how much you agree or disagree with the following statement: " I felt awake and alert when I began this experiment."

Strongly Disagree	Disagree Somewhat	Neutral	Agree Somewhat	Strongly Agree
0	1	2	3	4

APPENDIX C

EEG SESSION INSTRUCTION

This session will be subdivided into 5 parts: 1) A base-line rest period of 2 minutes, 2) 10 minutes of mental focus, 3) another 2 minute rest period, 4) 10 more minutes of mental focus, and 5) a final 2 minute rest period. We will tell you when each part starts. You will keep your eyes closed, your body still throughout the rest and mental focus periods.

During the task we will need you to remain as still as possible and to minimized all movements. This includes facial tension and movement. We will also ask you to not move your eyes around while they are closed during the rest or mental focus periods. The reason why it is important that you keep your body and eyes still is that body movements or eye movements can decrease the data quality.

When you hear me say "We're starting the Rest session now, you can close your eyes and just rest" we will record your resting for 2 minutes.

When you hear me say "We're starting the Mental Focus session now", we will record for 10 minutes.

During the mental focus task, with your eyes still closed, you will begin to focus on your breath, while silently repeating, inside your head, the syllable "Om" or "Um" on the in-breath and the out-breath. Your goal is to keep your mind focused on the syllable, as you breathe in and out.

However, if your mind begins to wander, and you think of anything else, as soon as you notice that your mind has become engaged in another thought, you will press the Button 1 on the Left with your index finger. You will then immediately return your attentional focus to the syllable OM or UM on the in-breath and out-breath. Also, if you begin to go to sleep, as soon as you notice it, you will press the Button 4 on the Right with the same index finger, and again, bring your mind back to the repetition of OM with the breath. If you are staying on your Mental Focus task then you should not press any button but simply continue doing the Mental Focus task.

Sometimes during the mental focus tasks you will hear a bell. At that time you should press one of the two buttons to indicate if you are having Thoughts or Sleepy. If you were staying on your Mental Focus task then you should not press any button but simply continue.

Participants sometimes ask what constitutes a thought. Simple awareness of sensations or sounds don't count as a thought. A thought is a mental stream of words or images that comes into mind. If you just begin to notice a thought come up, and immediately let it go, before it really expresses itself, that would not be counted as a thought.

Do you have any questions about the task what you will be doing?

Please then tell me what the basic rest and mental focus tasks involve.

Let's try a short practice session now, with 20 seconds of rest, and 1 minute of mental focus. So I will say: "We're starting the practice rest session now, you can close your eyes and rest" (wait 20 sec). "We're starting the practice mental focus session now." (Wait 1 minute). You can open your eyes now and rest.

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