# FUNCTIONAL MAGNETIC RESONANCE IMAGING OF EMOTIONAL REACTIVITY AND WISDOM ASSESSMENT OF MEDITATORS AND NON-MEDITATORS

By

MARC F. KURTZMAN

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To my parents: thank you for continuing to believe in me

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# FUNCTIONAL MAGNETIC RESONANCE IMAGING OF EMOTIONAL REACTIVITY AND WISDOM ASSESSMENT OF MEDITATORS AND NON-MEDITATORS

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Marc F. Kurtzman

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Chair: Shaya Isenberg
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The growing interest in meditation has opened the door for new and innovative research to understand both the psychological and physiological effects of this ancient practice. Research in the area of meditation is normally interdisciplinary in nature. Meditation research encompasses many fields of research from religious studies to psychology to neuroscience. The following study was an interdisciplinary venture that brought together researchers from the fields of religious studies, psychology, sociology, and neuroscience.

The first portion of the study explored the psychological impact of meditation. Using Monika Ardelt's Three-Dimensional Wisdom Scale (3D-WS), 42 subjects of meditators and non-meditators completed the 3D-WS and scores were computed among the various dimensions that comprise the 3D-WS. Various groupings and statistical analysis were performed in evaluating the possible differences. The results demonstrated significant differences in overall wisdom. Among the three dimensions that comprise

overall wisdom, significant differences were found in the reflective dimension but most significant in the affective domain.

In the second portion of the study, we utilized the technology of functional magnetic resonance imaging (fMRI) in a pilot study to explore possible differences in brain activation between meditators and non-meditators in the presence of emotional stimuli from the International Affective Picture System (IAPS). Six subjects (3 meditators, 3 non-meditators) underwent an fMRI and a descriptive volume analysis was used in exploring global and regions of interest differences between the two groups. Global asymmetries were found in the time-locked all affect based deconvolution. The occipital region showed asymmetries for all affect based deconvolution. Frontal region activity showed asymmetries for the time-locked negative affect only deconvolution.

The study shed light on areas of exploration that should be further explored. The low number of subjects in the fMRI portion of the study inhibited statistically significant differences from being demonstrated. The implications of the study shed further light on the many changes that are possible in both mind and brain with the practicing of meditation.

# CHAPTER 1
# INTRODUCTION

There is a widespread interest in the benefits/effects of meditation on the whole person. The practice of sitting in silence is no longer confined to the realms of "new age" hocus pocus but have entered the spheres of medicine and mental health. From its roots in contemplative religious practices, meditation has been transformed and made secular for those seeking the benefits without the beliefs. The effects of meditation have been studied from the level of microbiology to the macro level of cognitive neuroscience. Along the dimensions from micro to macro, there is a general consensus of positive effects. Technological advances in neuroimaging have enabled a new generation of studies that are better equipped to image the spatial dynamics of meditation versus the temporal dynamics of meditation. Recent studies as late as 2003, have suggested that meditation research should utilize technology that provides greater neuroanatomical information of brain function, i.e., functional magnetic resonance imaging (Davidson, Kabat-Zinn *et al*., 2003). The latest generation of meditation research has focused less on the changes during meditation and more on the permanent/enduring changes that a consistent practice brings to the practitioner.

## An Integralist Approach

The conceptualization of my research rests upon the Integral System formulated by Ken Wilber. In his four-quadrant system (discussed below), the left half has correlates

in the right half. In other words the mental has correlates in the physical. These physical correlates take the form of the body and its underlying systems. As stated by Ken Wilber, "feelings, mental ideas, and spiritual illuminations all have physical correlates that can be measured by various scientific means, from EEG machines to blood chemistry to PET scans to galvanic skin response" (Wilber, 2000a, p 75). However, Wilber was not the first to correlate the inner landscape of the mind to its physical embodiment.

William James's classic, *The Varieties of Religious Experience*, is the text of his Gifford Lectures on Natural Religion delivered at Edinburgh in 1901-02. An early lecture in the series was titled, "Religion and Neurology." A passage from the lecture discusses on the issue of brain and mind in the context of religious experiences:

> To plead the organic causation of a religious state of mind, then, in refutation of its claim to possess superior spiritual value, is quite illogical and arbitrary, unless one has already worked out in advance some psycho-physical theory connecting spiritual values in general with determinate sorts of physiological change. Otherwise none of our thoughts and feelings, not even our scientific doctrines, not even our disbeliefs, could retain any value as revelations of the truth, for every one of them without exception flows from the state of their possessor's body at the time…It has no physiological theory of the production of these its favorite states, by which it may accredit them; and its attempt to discredit the states which it dislikes, by vaguely associating them with nerves and liver, and connecting them with names connoting bodily affliction, is altogether illogical and inconsistent. (James, 1986, p. 33)

This project does not have the task of assigning origin[1] to either the body or mind; rather the focus of the research is on the dynamic relationship between the two domains.

[1] This unanswered question is of particular importance in all fields of neurological studies. The question is whether the mind or body comes first or is a dynamic relationship? If our moment-to-moment experience is the sum of our neurological activity then what does that say about our existence on the other hand if mind precedes experience then of what realm does the mind exist in? This is a troubling question that myself and my fellow colleagues that work within neurological studies have many hours of discussion over; the issue of the origination of consciousness is perhaps a problem in the question. It might be that the question of origination in brain or mind is limited in its scope.

This is contrast to some previous research that have provided an unapologetic bias by claiming that all experiences are brain-based without considering the dynamic relationship between these two fields (Saver & Rabin, 1997).

The mutual relationship between the mind and body or in other words the physical and non-physical is the focus of Integral theory. Ken Wilber's Integral Philosophy fits into a four quadrant domain. Below is a map of the four quadrant system.

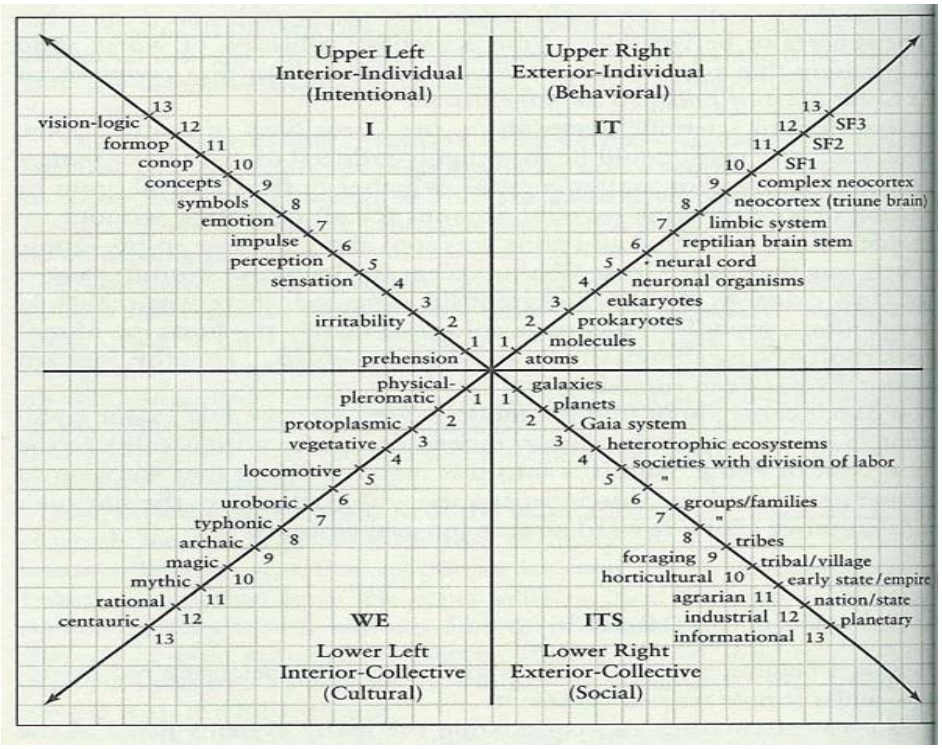


Figure 1. Four quadrant map of Ken Wilber's Integral theory (Wilber, 2000b, p. 1).

To interpret this elaborate map, it is crucial to understand that Wilber's system is a construction on the continuum from simple to complex. In this pattern, he states that in life there are divisions of singular-plural, interior-exterior, and mind-body or spirit-matter. In referring to the Four Quadrant map I will use the abbreviations UR (upper right), UL (upper left), LR (lower right), and LL (lower left). The UR on the map says

"IT", the "it" of this map is all matter ranging from atoms to complex SF3[2] humans. The LR says "ITS" and the "its" is the collective matter or habitat in which the "its" subsist in. The UL says "I" and this quadrant deals with the interior "I" or mind. The LL is the "We" and this quadrant deals with the collective interior "we" or simply put the individual's worldview.

When viewing the map, it is helpful to divide the system before explaining the it as a whole. The right side deals with the exterior or matter and the left side deals with the interior or mind. A further division is that the top half of the system deals with the singular and the bottom half deals with the plural. Starting with UR and then proceeding clockwise one can correlate all quadrants. Starting from level six appears the term neural cord in UR, in LR we see that level six corresponds to societies with divisions of labor, in UL six corresponds to perception, and in LL one corresponds to locomotive. So, a living creature having a neural cord has a habitat within a society with divisions of labor, this creature's interior singular is perception meaning its nervous system has the ability to perceive the universe, and its worldview is locomotive.

The purpose of this study is to investigate the interactive relationship between the left and right halves of the integral system. The assessment of the wisdom of an individual evaluates the UL and LL. The wisdom of an individual pertains to both the UL and LL because the 3D-WS assesses both the individual's psyche as well as worldview. The assessment of the neurological reactivity of subjects to affective pictures assesses the UR. The practice of meditation is widely understood as a transformational

[2] Terms like SF3 humans or other terms that will be mentioned are terms that Wilber has defined in part with his Integral System. Rather than spend lots of time on explaining all of the various levels it is important to grasp from this short explanation that there are various levels and these levels have names given by Wilber.

process. This study aims to evaluate these transformations of both dimensions of an individual. Meditation involves the concentration of both body and mind which has guided this study. Meditation, for the purpose of this study, is sedentary and a stillness of the body must be maintained. These points of concentration are hypothesized to have changes on both physical and nonphysical dimensions.

## Meditation: A Definition

What exactly is meditation? Some have argued that meditation is a kind of altered state of consciousness (Tart, 1969). Various definitions of meditation arise because of the various forms of meditation. Epstein and Lieff[3] in their article in *Transformations of Consciousness* defined meditation more clinically:

> Meditation may be conceptualized as a process of attentional restructuring wherein the mind can be trained both in concentration, the ability to rest undisturbed on a single object, and in mindfulness, the ability to observe its own moment-to-moment nature, to pay attention undistractedly to a series of changing objects. This perceptual retraining allows a finely honed investigation of the rapidly changing self-concepts that perpetuate the sense of self. (Epstein & Lieff, 1986: 58)

Researchers have shown that "retraining" or development of mindfulness via the practice of meditation has been shown by researchers to change the body, psyche, and even society (Davidson, Kabat-Zinn et al, 2003; Kabat-Zinn, Miller et al, 1995; Gilliani, Smith et al, 2001; ). Benson et al, 1990; Hagelin et al, 1999).

From a researcher's perspective a specific research protocol to define meditation is difficult to establish. Researchers, including Jon Kabat-Zinn, have formulated a secularized version of meditation that is taught under the name of "mindfulness" (Kabat-Zinn, 1990). Recent literature attempts to establish criteria for the classification of

[3] The background and personal practice of these two physicians is in Vipassana which is evident in their definition of meditation. Although I feel their definition highlights the common themes of meditation, the vipassana tradition tends to focus on bare insight and awareness without the usage of visualizations or chanting just simply being and breathing.

meditation in research (Cardoso, Souza et al, 2004). Cardoso and Souza developed a five-point criterion for defining meditation in health research. They include a specified technique, body relaxation, "logic relaxation", self-induction, and a employment of a self-focus skill (Cardoso, Souza et al, 2004). By Cardoso's own admission this operational definition will be unable to capture all of the intricacies of various practices of meditation. The current study's interdisciplinary staff is an asset to properly understand and classify various forms of meditation in the sample population. The researchers for previous meditation studies have not had an interdisciplinary group of researchers to aid in the evaluation of meditation as a practice. Thus previous studies on meditation lacked expertise on various meditative traditions. The assemblage of the project staff for this research study draws upon the fields of sociology, religious studies, and neuroscience. This multidisciplinary staff will benefit the research in identifying possible latent variables such as the nature of the individuals practice or theory behind the practice. These seemingly trivial aspects are crucial in isolating and understanding the subject's practice.

## Previous Research in Meditation

The popularity of meditation and Eastern religions has been steadily increasing in Western culture. Eastern philosophy and practices, from yoga to meditation, have migrated to the West. Initially the benefits of meditation were known anecdotally. From the ability to levitate to a life with reduced stress, the claims of meditation have attracted a large population. Today, however, the benefits of meditation have science to support them. Scientific research on meditation has been published in popular media such as *Time* magazines profile of "The Science of Meditation: New Age mumbo jumbo? Not for millions of Americans who meditate for health and well-being. Here's how it works"

(Stein, 2004). The benefit of meditation concluded in scientific research has made its practice more widespread. No longer relegated to the spheres of religious/spiritual practices, meditation is now broadly taught in the field of medicine.

One of the earliest research studies on meditation came from Japan. It was an electroencephalographic study of Zen meditators (Kasamatsu & Hirai, 1966). Since that time many researchers have made careers from meditation research most notably Richard Davidson Ph.D., Jon Kabat-Zinn Ph.D., and Herbert Benson M.D. An article from *Science* on Benson characterized him aptly as the "mind-body maverick" (Roush, 1997). Benson is most famous for his best-selling work on the relaxation response. The relaxation response an original term coined by Benson that describes physiological alterations during a state of relaxation (Roush, 1997). As a result of his research, Benson has come to advocate meditation practice. In one of his studies on meditation he examined Tibetan Buddhist monks, regarded as advanced meditators, and found that they were able to alter their metabolism and more specifically decrease it (Benson et al, 1990). This study and the majority of previous studies of meditation utilize electroencephalogram[4] (EEG). In this EEG study, Benson found the alteration in metabolism was not one-way. Benson found metabolism could be raised 61% from baseline and lowered to 64% from baseline depending upon the particular meditation employed (Benson et al, 1990). To differentiate normal relaxation versus meditation, Solberg studied hemodynamic changes during long meditations in contrast to non-meditators resting in a seated position for the same length of time (Solberg et al, 2004). They found that during the first hour heart-rate declined more in meditators than non-

[4] It should be stated that many advancements have occurred in EEG and are utilized widely in current neuroscience research.

meditators/controls and during the second hour HR declined even further in meditators (Solberg et al, 2004). This study provided evidence that simply sitting in a rested position with lack of focus i.e. relaxing does not produce the same hemodynamic changes as seen in meditation.

Davidson and Kabat-Zinn recently concluded that "mindfulness meditation" produced demonstrable effects on brain and immune function (Davidson, Kabat-Zinn et al., 2003). Mindfulness meditation is a form of meditation that is secular in nature that was developed by Kabat-Zinn. In this same study Davidson and Kabat-Zinn also discovered, via usage of EEG and Electrooculography (EOG) that increases in left-side anterior activation followed the practice of mindfulness. Left-side anterior activation is a pattern associated with positive affect. Mindfulness meditation is a technique that combines yoga, breathing, imagery, progressive muscle relaxation, and Zen psychology (Gillani & Smith, 2001). In another study, Kabat-Zinn and his research team performed a 3 year follow-up on 22 patients who all had a DSM (Diagnostic and Statistical Manual of Mental Disorders) diagnosed anxiety disorder and who were all taught the mindfulness program (Kabat-Zinn, Miller, & Fletcher, 1995). Kabat-Zinn found that the continuing practice led to a decrease in anxiety[5] (Kabat-Zinn, Miller, & Fletcher, 1995). The highlight of this article is the authors' description of the transformational mindset that this meditation supports. "They encourage the practitioner to adopt a more dispassionate, witness-like observing and self-reporting of the moment by moment unfolding of one's experience" (Kabat-Zinn, Miller, & Fletcher, 1995, p. 197). The idea of a detachment from the reactivity to life is a reinforcing attitude within the practice of many forms of

[5] Gilliani and Smith came to an identical conclusion regarding a substantial decrease in anxiety levels but the form of meditation utilized was purely based on the Zen Buddhist tradition (Gillani & Smith, 2001)

meditation. Detachment in the previous context is not a form of uncompassionate withdrawal but a type of compassionate awareness. Goleman supports this idea when he states, "meditators were able to roll with life's punches, handling daily stresses well and suffering fewer consequences from them" (Goleman, 1988 p. 163).

A recent meta-analysis was performed to evaluate mindfulness-based stress reduction (MBSR) in clinical treatment (Grossman *et al.*, 2004). Grossman discussed the characteristics of mindfulness which entail dispassionate, non-evaluative and sustained moment-to-moment awareness (Grossman *et al.*, 2004). The meta-analysis performed was limited by the number of investigations to date which evaluate MBSR. The studies they investigated utilized MBSR for a wide array of ailments such as Fibromyalgia, cancer, depression, chronic pain, and a host of other physical and psychological pathologies. Both controlled and observational studies provided a statistically significant conclusion ($p < .0001$) that MBSR helps a wide population to manage a host of clinical and non-clinical problems (Grossman *et al.*, 2004).

From physiological/neurological changes to clinical applications, meditation spans the spectrum of research. Studies of physiological effects of meditation have tended to focus upon the changes either during or post meditation (Lutz et al., 2004; Davidson, Kabat-Zinn et al., 2003; Solberg et al., 2004; Takahashi et al., 2004). Few studies have studied the enduring changes in moment-to-moment awareness of affective stimuli of long term meditators.

## Wisdom

In the article "Meditation: Royal Road to the Transpersonal", Walsh and Vaughan discuss various qualities cultivated by the "technology of transcendence" i.e. meditation (Walsh & Vaughan, 1993, p. 51). One such quality is wisdom: "Whereas knowledge is

something we have, wisdom is something we become. Developing it requires self-transformation" (Walsh & Vaughan, 1993, p. 51). From a religious point of view, Sant Rajinder Singh discusses the cultivation of wisdom and the difference between what he designates as the "soul's wisdom" from knowledge, "the mind analyzes through the subjective eyes of the ego, while the soul views everything through the clear glass of truth" (Singh, 1999, p. 19). Sant Rajinder Singh discusses the difference within the context of elaborating on the qualities attained through the practice of meditation. The terms wisdom and meditation are coupled together often but the question arises, how does one perform research to assess wisdom?

Monika Ardelt, Ph.D., has constructed assessment surveys and specific definitions for defining what constitutes wisdom. She defines wisdom as a combination of cognitive, affective, and reflective dimensions (3D-WS, Ardelt, 2003). For Ardelt, wisdom is a experiential rather than intellectual knowledge (Ardelt, 2004). Intellectual and wisdom-related knowledge share a common theme of the search for truth (Ardelt, 2000). The opposition of quantitative and qualitative underscores the major differences between intellectual and wisdom-related knowledge (Ardelt, 2000). Not only do these two forms of knowledge differ in their goals but they are brought about by different methods. Intellectual knowledge is obtained from scientific, theoretical, abstract or detached approaches but while wisdom-related knowledge is inherently spiritual in nature (Ardelt, 2000). The underlying themes to these two approaches are objectivity and subjectivity which are not the same as impersonal vs. personal. Intellectual knowledge is impersonal whereas wisdom-related knowledge is deeply personal (Ardelt, 2000). The

personal nature of wisdom-related knowledge is consistent with Ardelt's earlier argument that wisdom is experientially based.

Earlier I noted that Ardelt defines wisdom along three dimensions. The cognitive dimension pertains to an individual's ability to understand the significance and deeper meaning of life's events (Ardelt, 2003). Ardelt considers the reflective dimension a prerequisite for the development of the cognitive dimension (Ardelt, 2003), for an individual must have a reality free from distortions in order to come to a deeper understanding of phenomena (Ardelt, 2003). For Ardelt, the reflective component takes into consideration the many perspectives of life's events. The idea of a multi-perspectival viewpoint is akin to Wilber's notion of 'aperspectival' (Wilber, 2000a). The affective dimension is characterized by a sense of sympathy or acts of kindness towards others (Ardelt, 2003). In measuring wisdom, Ardelt has developed a three-dimensional wisdom scale (3D-WS) that assesses wisdom along the aforementioned dimensions. The 3D-WS has been utilized and tested for reliability and validity.

## Functional Magnetic Resonance Imaging

In Keith White's talk titled "MR Physics in 20 Minutes: A talk from Hell" he stated, "In the MRI scanner a very large coil cooled with liquid helium has a very strong electric current flowing continuously. This makes the strong (3 Tesla) unchanging magnetic field called $B_0$. Protons in this strong field: (a) become more magnetic, and (b) become lined up with $B_0$". Dr. White was referring to the protons in the hydrogen atoms which is found throughout the body since each water molecule is composed of 2 hydrogen atoms and 1 oxygen atom. Since water is the most abundant substrate in tissues its signal is dominant in the information content of images (Ogawa et al., 1990). Once these hydrogen nuclei (protons) align with the magnetic field of the scanner a RF (radio

frequency) coil sends a pulse of energy to knock the molecules out of alignment, to a "flip angle" with respect to $B_0$. The protons, return back to alignment by releasing energy, sending radio waves to the transceiver. The RF coil in the scanner is what is known as a transceiver since it is both able to transmit a signal (i.e. the pulse that knocks the protons to their flip angle) and to receive the signal of the protons returning back to alignment with $B_0$. The basic four steps that occur while the subject is in the scanner are to (1) transmit radio waves into a subject, (2) to turn off radio wave transmitter, (3) to receive radio waves re-transmitted by subject, and (4) to store measured radio wave data (Cox, 2003).

Functional MRI operates under the same physics as previously explained. Brain activity is measured by the principal of blood oxygenation level-dependent (BOLD) contrast (Ogawa et al., 1990). There is a three-step relationship to the BOLD sequence. An increase in neural activity descreases blood oxygen in the site of neural activity. A change in magnetization occurs when blood exchanges oxygen with neural tissue and oxyhemoglobin becomes deoxyhemoglobin. The ration of deoxyhemoglobin to oxyhemoglobin alters the signal from water molecules surrounding a blood vessel, resulting in blood oxygenation level-dependent contrast. The genius of BOLD contrast is its dependency on blood oxygenation which is in turn dependent upon physiological events that change the oxy/deoxyhemoglobin ratio (Ogawa et al., 1990).

## Neuroimaging Emotion

Emotion itself is a non-physical entity that is unable to be captured but the correlates of neural activity to various emotional states have been extensively studied and isolated. The founder of Neuropsychology, Paul Broca, was the first to identify a region of the brain that was later theorized by James Papez to be the cortical structures for

emotion known as the limbic lobe (Iverson et al., 2000). The limbic lobe is ring-like in shape and consists of phylogenetically primitive cortex, in relation to the neocortex, around the brain stem (Iverson et al., 2000).

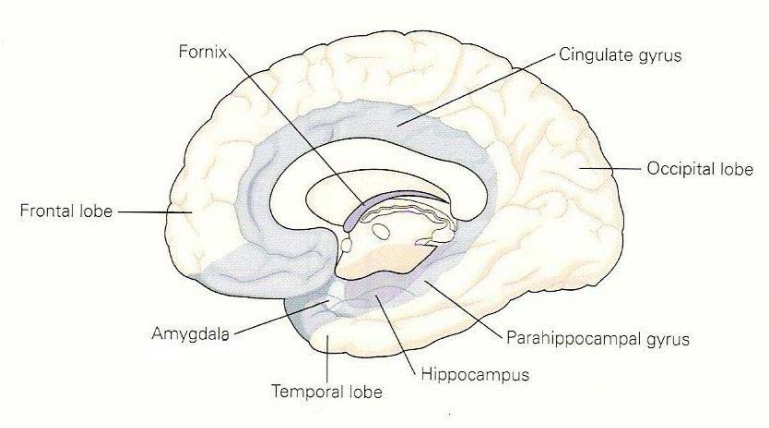


Figure 2: Medial view of brain with limbic lobe and prefrontal limbic cortex (Iverson et al., 2000, p. 987).

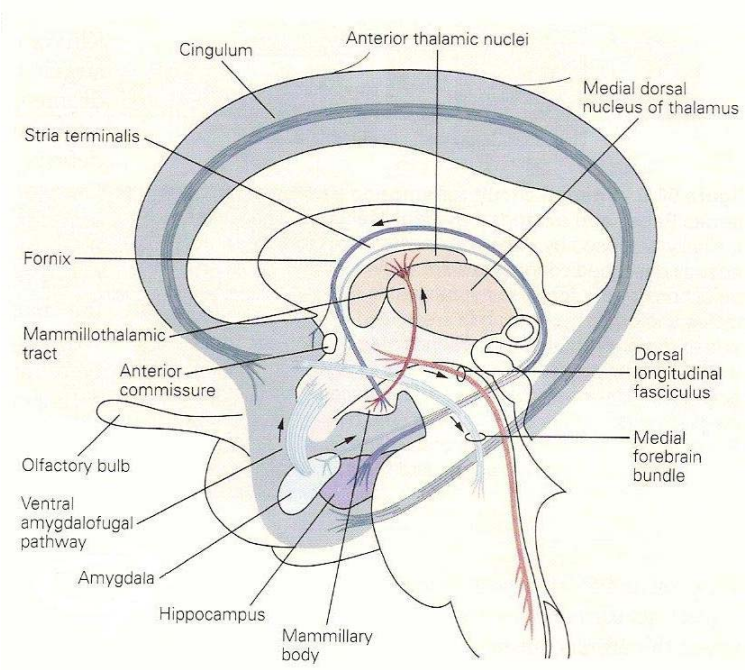


Figure 3: Limbic system showing interconnectedness of the structures and arrows indicating the predominant direction of neural activity (Iverson et al., 2000, p. 987).

The limbic lobe is comprised of the cingulate gyrus, parahippocampal gyrus, and the hippocampal formation (Iverson et al., 2000). Later, Paul MacLean developed the concept of the limbic system which added the structures of the hypothalamus, septal area, nucleus accumbens, neocortical regions such as the orbitofrontal cortex, and the most popular structure to examine, the amygdala (Iverson et al., 2000). In neuroimaging the anatomy of emotion, further areas of interest include areas common to neuroimaging studies include the anterior cingulate, supplementary motor cortex, medial prefrontal cortex, mid- and posterior cingulate, temporal cortex (including hippocampus), parietal and occipital lobes, insular cortex, basal forebrain, amygdala, and brainstem (Wager et al., 2003). Studies utilizing functional magnetic resonance imaging tend to focus on global activation rather than focusing on various regions of interest (ROI's), e.g. the amygdala. The rationale for focusing solely upon the amygdala and foregoing other areas of the limbic system is the difficulty of imaging the amygdala (Chen et al., 2003). T2*-weighted gradient-echo echo-planar imaging (EPI) sequences are commonly used in fMRI studies because of the inherent sensitivity to BOLD contrast (Chen et al., 2003). A problem arises with the location of the amygdala. T2*-weighted imaging is sensitive to the static field gradient formed by the tissue-air susceptibility difference (Chen et al., 2003). With this stated, the amygdala is in a region of the brain that has a field of inhomogeneity (Chen et al., 2003). The problems arising with the location of the amygdala force many researchers to image only a portion of the brain rather than a whole-brain acquisition for optimal sensitivity.

Neuroimaging studies of emotion vary from the technology utilized (i.e. PET, fMRI, etc) to tasks and/or stimuli utilized to induce emotion in subjects. Various long-

standing theories underlie many emotion studies. One of the oldest theories is that emotion has overall right-hemisphere dominance (Wager et al., 2003). More recent theories of emotion posit that both hemispheres are involved in emotional processing but each hemisphere has dominance over particular types of emotion (Lee et al., 2004). Other theories postulate that lateralization and anatomy of emotion is contingent upon gender (Wager et al., 2003).

As previously mentioned, studies of emotion occasionally employ tasks that present a stimulus or instruct subjects to be passive during stimulation (Shapira et al., 2003; Lang & Bradley et al., 1998; Klein et al., 2003; Sabatinelli et al., 2004; Lee et al., 2004). Emotional stimuli tend to vary across populations and therefore for accurate classification of valence and arousal of stimuli databases of emotional stimuli have been tested and made available to researchers. Valence and arousal are two of three dimensions that the International Affective Picture System (IAPS) measures the stimuli. Affective valence ranges from pleasant to unpleasant and measurement of its arousal that ranges from calm to excited (CSEA-NIMH, 1999). One very popular database is the International Affective Picture System[6] (IAPS) (CSEA-NIMH, 1999). IAPS was developed to provide a database of normative emotional stimuli for experimentation (Lang, Bradley, Cuthbert, 2001).

[6] The NIMH Center for the Study of Emotion and Attention have developed other normative sets of stimuli for non-visual research such as the International Affective Digitized Sounds (IADS) and Affective Lexicon of English Words (ANEW).

## Hypothesis

### Wisdom

Meditation is known as a transformational process and with Wilber's Integral System such transformations should be able to be captured by technology or by internal inventory like the 3D-WS. With the behavioral analysis meditators should show significant differences in affective and reflective dimensions of the 3D-WS. The cognitive dimension is more difficult to predict. Since the cognitive dimension is evaluating a quest for deeper understanding of the phenomena of life, the subjects chosen for this study may show insignificant differences in this dimension due to the spiritually liberal nature of the groups chosen for this study. Overall wisdom should be higher in meditators than non-meditators. Meditation is often a lifetime practice and therefore the consistent practice of meditation should produce significant differences in the purpose in life dimension. Since most meditators recruited for this study belong to a group the shared spiritual/religious activities assessment should be higher than non-meditators. Mastery should be higher in meditators. The therapeutic nature of meditation should aid in meditators having less psychological ills and therefore meditators should score lower on the depressive symptoms.

### Functional Imaging

The lack of understanding of neurological reactions in meditators as opposed to the same reactions in a non-meditator has not been studied and therefore specific regions of difference are difficult to hypothesize. Overall it is expected that meditators should have a lower volume activity on a global level and perhaps asymmetries both globally and in regions of interest, in response to emotionally charged visual stimuli. Perhaps

meditation allows for the right hemisphere dominance of emotion to be less defined and a mutual sharing of emotion among the hemispheres could be the result.

# CHAPTER 2
# METHODS

## Materials and Methods for Wisdom Assessment

### Participants

Forty-two (18 men, 24 women) volunteers participated (age 19-78 years, M = 46.4 years, SD = 15.66 years; education 10-21 years, M = 16.74 years, SD = 2.43 years). Nineteen meditation subjects were recruited from two different local religious groups and 8 non-meditation subjects were gathered from a local religious group. Mediation groups were recruited from those familiar with the project staff and non-meditation groups were chosen from two local liberal natured groups. I chose non-fundamentalist groups for the study so as to minimize the possible effect of comparing groups that are philosophically opposite in their cultural open-mindedness. The remaining participants were recruited acquaintances of the project staff. The group-based versus non-group based subjects were recruited to discriminate the variable of group effect. Potential subjects were excluded from the study if they reported a history of neurological disease, major psychiatric disturbance, or substance abuse. Two subjects requested not to be included in the final pool of subjects selected to undergo the fMRI portion of the study. Potential risks were explained at each phase of the study, and informed consent was obtained from participants according to institutional guidelines established by the Health Science Center Institutional Review Board at the University of Florida.

**Survey Instruments**

Meditation and non-meditation subjects both completed a survey comprised of 119 questions. Responses were coded as a numerical value e.g. 1-5. Wisdom was measured by the Three-Dimensional Wisdom Scale (Ardelt, 2003). In the 3D-WS, wisdom is treated as a latent variable comprised of cognitive, reflective, and affective dimensions (Ardelt, 2003). The cognitive dimension is evaluated by items that assess an understanding of life or the desire to know the truth (3D-WS, Ardelt, 2003). An example of the cognitive component is the following: "It is better not to know too much about things that cannot be changed" with answers ranging from 1 (strongly agree) to 5 (strongly disagree). The reflective dimension assesses an individual's capability to view events from various perspectives and to avoid layering such events with subjectivity and projections. A sample item from the reflective dimension is the following: "When I look back on what has happened to me, I can't help feeling resentful" with answers ranging from 1 (definitely true of myself) to 5 (not true of myself). The third dimension of wisdom is the affective component, it assesses altruistic emotions and behavior along with the absence of its opposite emotions and behaviors towards other sentient beings. A sample item from this dimension is: "Sometimes I feel a real compassion for everyone" with answers ranging from 1 (definitely true of myself) to 5 (not true of myself). The wisdom score was derived by averaging the means of the cognitive, affective, and reflective dimensions. Internal consistency of the items measuring the cognitive, reflective, and affective dimensions of the 3D-WS were measured using Cronbach's alpha. The cognitive, reflective, and affective dimensions had respective alpha levels of .72, .74, and .77; with overall wisdom having an alpha level of .76.

Along with wisdom and its components, other areas were evaluated. Mastery was assessed by Pearlin and Schooler's (1978) Mastery Scale (Ardelt, 2003). The Mastery Scale consists of seven statements such as "Sometimes I feel that I'm being pushed around in life" with answers ranging from 1 (strongly agree) to 5 (strongly disagree). Cronbach's alpha for the Mastery Scale was .56. Depression was another measurement taken and was assessed by the CES-D (Radloff 1977). The depression scale evaluated a list of emotions possibly felt in the past week of taking the survey such as "I did not feel like eating; my appetite was poor" with answers ranging from 1 (less than 1 day) to 4 (5-7 days). Cronbach's alpha for the CES-D was .86. Purpose in life was measured by Crumbaugh and Maholick's (1964) Purpose in Life Test. The PIL assesses an individuals positive and negative emotions towards life e.g. "My personal existence often seems meaningless and without purpose" with answers ranging from 1 (definitely true of myself) to 5 (not true of myself). Cronbach's alpha for PIL was .76. Subjective health was measured by adapted of items from the OARS Multidimensional Functional Assessment Questionnaire (Center for the Study of Aging and Human Development 1975), the National Survey of the Aged (Shanas 1962, 1982), and the Americans' Changing Lives Questionnaire, Wave I (House 1994). A sample question from the subjective health section is "How would you rate your overall health at the present time?" with answers ranging from 1 (excellent) to 5 (very bad). Cronbach's alpha for the subjective health questions was .61. Gender was surveyed with an allowable range of either 1 (female) or 2 (male). Age was measured by having subjects list their date of birth. Race was assessed with a range of 1 (white/European) to 6 (other). Religious/spiritual activities was assessed by how often the subject participated in

spiritual/religious activities with at least one other person in the past month; subjects had a range of 1 (more than 15 times) to 5 (0 times).

Meditation experience and practice was assessed by several questions. The first question inquired about the frequency of meditation in a typical week ranging from 1 (never) to 6 (once a day or more). If this question was answered "never" then respondents did not proceed to further questions. The second question inquired about the length of time the person has been practicing meditation with 1 (less than 1 year) to 4 (more than 10 years). The third question asked about the length of time the person spends on a single meditation session from 1 (less than fifteen minutes) to 4 (more than an hour). The question was phrased "meditating in one sitting" assuming that the individual practiced a sedentary form of meditation. This was important in order to distinguish meditation from yoga or other forms of meditation-in-motion. Meditation-in-motion or yoga might cloud the results because it would be difficult to assess whether the act of meditation or physical activity is the primary factor. The final open-ended questions asked the subject to name and describe the type of meditation they practice. Again, this was very useful information in distinguishing meditation from forms of relaxation.

**Analysis**

All statistical analysis performed used SPSS 12.0 for Windows. Correlation analyses and t-tests were performed to assess differences in wisdom and other variables between those who meditate against those who do not, those who meditate in a group against those who meditate alone and non-meditators, and those who meditated at least 60-90 minutes per week against non-meditators and those who meditate less than 60 minutes a week.

## Materials and Methods for Functional Magnetic Resonance Imaging

### Participants

Six subjects (3 men, 3 women) were chosen to participate in the fMRI portion of the study. Three meditators and three non-meditators were selected (Meditators: 2 women, 1 man, ages 25-50, M = 40.7, SD = 13.7; education 17-18 years, M = 17.7, SD = .58) (Non-meditators: 2 women, 1 man, ages 20-68, M = 36.3, SD = 27.4; education 14-16 years, M = 15.3, SD = 1.15). The six participants were not matched in education due to the insignificance of education on affective perception. Potential risks and a second informed consent as well as a full MRI safety screening were conducted according to the institutional guidelines established by the Health Center Institutional Review Board at the University of Florida.

### Experimental Stimuli

Experimental stimuli consisted of 75 pictures from the International Affective Picture System were presented across five runs (CSEA-NIMH, 1999). Twenty-five pictures from each affective domain were presented in an affective block design; negative (valence: 1-3) M = 2.41, positive (valence: 7-9) M = 7.72, and neutral (valence 4-6) M = 5.03.

### Experimental Design

During each of five functional imaging runs, three different affective blocks from each affective domain (see below for design of an affective block) were presented with inter-stimulus-intervals (ISI) of 28.9, 34, and 39.1 sec. were distributed within runs (see below for layout of a single run) in a pseudorandomized order. Inter-stimulus-intervals were presentations of a white blank screen. Participants were instructed to view the stimuli presented on the screen passively.

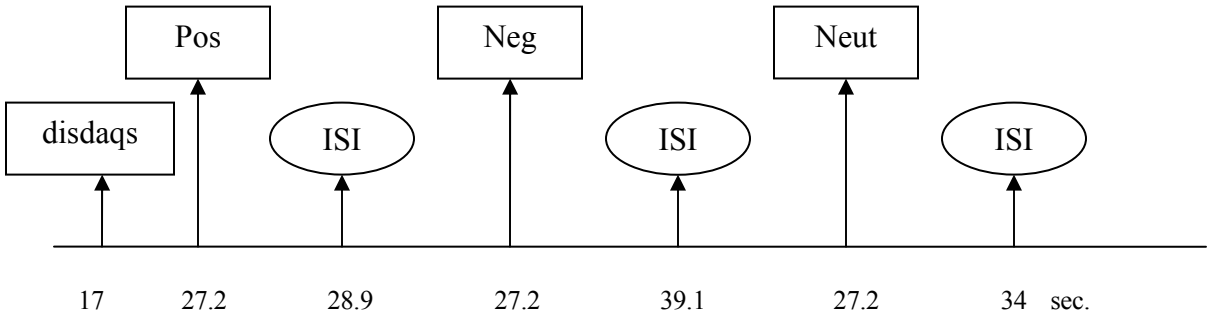


Figure 4: The schematic above is an example of a single run. The total run length was 200.6 sec.

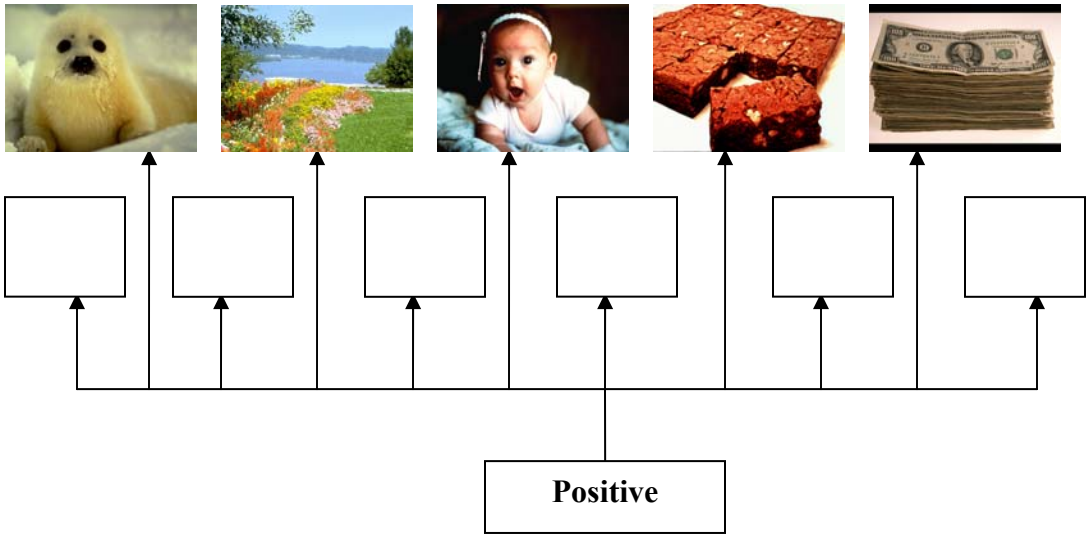


Figure 5: Above is an example of an affective stimulus block (positive) consisting of five interchanging pictures from the International Affective Picture System shown for a duration of 3.4 sec. and with white blank images shown between for 1.7 sec. for a total block time of 27.2 seconds.

**Image Acquisition**

Each experimental run consisted of three 27.2-sec affective blocks during which 16 images were collected. The inter-stimulus-interval baseline state was a blank white screen. The ISI varied in lengths of 28.9, 34, or 39.1 sec (corresponding to 17, 20, and 23 images respectively). To allow for a homogenous magnetic field a 17 sec period was

placed at the beginning of each functional run in which 8 images were collected and subsequently discarded. The length of the baseline periods, i.e. ISI, was varied pseudorandomly to mitigate low-frequency periodic and quasiperiodic physiological artifacts. Each length of the ISI was used once during each run. For each functional imaging run, there were three blocks consisting of five pictures totaling fifteen IAPS pictures per run. Thus, for each functional imaging run, there were 8 disdaq[1] images, 3 affective blocks of 16 images each, and three baseline cycles consisting of 17, 20, and 23 images for a total of 118 images collected per functional run. By randomizing and having unequal lengths of the baseline condition, the onsets of the affective blocks were aperiodic. The length of each affective block did not vary so that a single hemodynamic response could be modeled for each block using the deconvolution technique.

Whole brain imaging was performed on a 3.0-T Siemens Allegra scanner. The head was aligned such that the interhemispheric fissure was within $1^{o}$ of vertical. Before functional image acquisition, structural images were acquired for 124 1.3 mm thick sagittal slices, using a T1-weighted volume acquisition (TE = 2000 msec, FA = $8^{o}$, NEX = 1, FOV = 240 mm, matrix size = 256 x 192. For functional imaging sequences, 32 slices (4.5 mm) were acquired in a sagittal orientation (matrix size = 64x64). Images were obtained using a gradient-echo EPI (echo-planar imaging) sequence using the following parameters: TE = 25 msec, TR = 1700 msec, FA = $70^{o}$, FOV = 240 mm.

**Image Analysis**

Functional images were analyzed and overlaid onto anatomic images with Analysis of Functional Neuroimages (AFNI) software (Cox, 1996). To lessen the effects

[1] Disdaq images are those images removed/discarded prior to full processing of functional datasets.

of head motion, the time series were spatially registered in 3-D space to the coordinates of the first functional run which immediately followed the anatomical scan. Images were visually inspected for artifacts. For each dataset, the mean slice signal intensities were normalized to the grand mean of slice intensity across all functional runs. Voxels where the standard deviation of the signal change exceeded 8% of the mean signal were set to zero to decrease large vessel effects and residual motion artifact.

The first eight images were dropped from each functional run to allow for a homogenous magnetic field. Dropping the eight images from each run brought a total of 112 images per run with five functional runs. The runs were concatenated in chronological order into a single time series of 560 images for each of the 32 functional image slices. After concatenation of the time series, the time series was deconvolved from the 560-image time series on a voxel-by-voxel basis. Each hemodynamic response (HDR) was modeled using a maxlag of 25 TR periods following the onset of the first picture in an affective block. The long maxlag of 25 TR was used in order to capture the entire HDR from its onset to its return to baseline. For each voxel, a single HDR was deconvolved for all affective blocks and separately for positive, negative, and neutral blocks.

Anatomic and functional images were interpolated to volumes with 1-$mm^3$ voxels, coregistered, and converted to the stereotaxic coordinate space of Talairach and Tournoux (Talairach & Tournoux, 1988) using AFNI. In order to discriminate between baseline and affective stimulus a separate deconvolution was performed following the onset of baseline periods. Five deconvolutions were carried out for each subject's fMRI data: (1) time locked to positive affect blocks only, (2) time-locked to negative affect

blocks only, (3) time-locked to neutral affect blocks only, (4) time-locked to all affect blocks, and (5) time-locked to baseline. Following the baseline-deconvolution an $R^2$ voxel-wise distribution dump file was created for time-locked to negative affect blocks only, time-locked all affect block and time-locked to baseline deconvolution datasets. The $R^2$ distributions for each subject were compared using the Kolmogorov-Smirnoff test to detect significant differences between time-locked negative affect blocks only to time-locked to baseline as well as time-locked all affect blocks to time-locked baseline. Further KS tests of the negative or neutral time-locked datasets to the time-locked baseline condition were not performed due to lack of significant activity in either deconvolution datasets. Following the KS test, a whole-brain cluster analyses was performed on each subject for all affective blocks as well as positive, negative, and neutral deconvolution datasets. Cluster reports had thresholds of 0.16 $R^2$ and volume threshold of 100 µl. The low number of subjects prohibited an ANOVA based testing. Clusters were localized and a descriptive ROI analysis was performed on group data. Groups were contrasted between meditators and non-meditators. ROI t-tests were performed on a few regions.

# CHAPTER 3
# RESULTS

## Wisdom Surveys

### Meditators versus Non-Meditators

T-tests were performed to detect significant differences between meditators and non-meditators with regard to wisdom, mastery, purpose in life, depression, subjective health, education, age, and religious activities. In testing differences between meditators and non-meditators, no threshold for the amount of time an individual practices was applied. Therefore meditators were classified according to those who answered "about once a week" to the question "in a typical week, how often do you practice meditation?" From all the participants who took the survey, 13 were classified as non-meditators and 29 meditators according to their response to this question. No significant differences in age, gender or education were found.

Meditators had a significantly higher score than non-meditators on wisdom ($t = -2.932$; $p = .006$). In analyzing the components of the wisdom survey, the two groups did not significantly differ in the cognitive dimension but did differ in the reflective domain ($t = -2.619$; $p = .0012$). An even greater difference was discovered in the affective domain ($t = -3.898$; $p = .000$), and insignificant differences were found in the cognitive dimension ($t = -0.610$; $p = .546$). In both the reflective and affective domains, the meditators had a higher mean score than non-meditators. No significant differences were found in self-mastery ($t = -1.628$; $p = 0.111$) but meditators also had a significantly

higher purpose in life score (t = -5.038; p = .000), a higher subjective health rating (t = -2.029; p = .049), and fewer depressive symptoms (t = 1.81; p = .08). Meditators scored higher in the religious activities component (t = -1.915; p = .063). The meditators and non-meditators were found to have no significant difference in the demographic statistics of education (t = 0.876; p = 0.386), gender (t = 0.447; p = 0.347), age (t = 0.772; p = 0.225), and race (t = 0.090; p = 0.426).

Table 1: Group statistics of meditators and non-meditators in the various portions of the survey.

| Group Statistics Meditators vs Non-Meditators | | | | | |
|---|---|---|---|---|---|
| | meditate | N | Mean | Std. Deviation | Std. Error Mean |
| Cognitive | No | 13 | 3.9835 | 0.47573 | 0.13194 |
| | Yes | 29 | 4.0665 | 0.37503 | 0.06964 |
| Reflective | No | 13 | 3.8654 | 0.43105 | 0.11955 |
| | Yes | 29 | 4.2040 | 0.36704 | 0.06816 |
| Affective | No | 13 | 3.4320 | 0.47371 | 0.13138 |
| | Yes | 29 | 3.9708 | 0.38594 | 0.07167 |
| Wisdom | No | 13 | 3.7603 | 0.39987 | 0.11090 |
| | Yes | 29 | 4.0804 | 0.29040 | 0.05393 |
| Mastery | No | 13 | 3.7473 | 0.62312 | 0.17282 |
| | Yes | 29 | 4.0296 | 0.46820 | 0.08694 |
| Purpose in Life | No | 13 | 3.6667 | 0.83887 | 0.23266 |
| | Yes | 29 | 4.6322 | 0.41159 | 0.07643 |
| Depression | No | 13 | 1.4692 | 0.45210 | 0.12539 |
| | Yes | 29 | 1.2569 | 0.29813 | 0.05536 |
| Subj Health | No | 13 | 3.7308 | 0.69568 | 0.19295 |
| | Yes | 29 | 4.2931 | 0.88153 | 0.16370 |
| Education | No | 13 | 17.2308 | 2.65059 | 0.73514 |
| | Yes | 29 | 16.5172 | 2.34324 | 0.43513 |
| Gender | No | 13 | 0.4615 | 0.51887 | 0.14391 |
| | Yes | 29 | 0.6207 | 0.49380 | 0.09170 |
| Age | No | 13 | 50.8462 | 16.43597 | 4.55852 |
| | Yes | 29 | 44.4483 | 15.17184 | 2.81734 |
| Race | No | 13 | 0.9231 | 0.27735 | 0.07692 |
| | Yes | 29 | 0.8276 | 0.38443 | 0.07139 |
| Religious Activities | No | 13 | 2.3846 | 0.76795 | 0.21299 |
| | Yes | 29 | 3.0000 | 1.03510 | 0.19221 |

**Group Based Meditators versus Non-group Based Meditators and Non-Meditators**

The group based analysis was performed to analyze a possible greater significant difference between those who meditate in groups versus non-group based meditators and non-meditators. The rationale was that perhaps the changes brought about via meditation practice could be attributed to a group phenomenon rather than to a phenomenon of meditation practice. If significant differences in domains not previously found to be different are discovered then the results could demonstrate that being a member of a spiritual group might be a factor to consider in addition to meditation. There were 24 group-based meditators and 18 respondents who either did not belong to a specific group or were non-meditators.

Group based subjects had a significantly higher wisdom score ($t = -2.020$; $p = 0.050$). Group meditators were found to have a higher scores in the reflective and affective dimensions, with significant differences in the reflective ($t = -1.905$; $p = .064$) and affective ($t = -2.56$; $p = 0.014$) dimensions of wisdom. Again no significant differences were found in the cognitive dimension ($t = -0.397$; $p = 0.694$). Mastery was again not found to be significant ($t = -0.392$; $p = 0.697$). Group meditators had significantly higher score in the components of purpose in life ($t = -3.579$; $p = 0.001$) and subjective health ($t = -2.129$; $p = 0.039$). Non-group meditators were found to have a significant higher score in the depression scale ($t = 2.007$; $p = 0.052$). Group meditators were found to have a greater participation in religious activities ($t = -3.359$; $p = 0.002$). Again none of the demographic statistics were found to be significantly different between the two measured groups (age: $p = 0.871$, education: $p = 0.552$, gender: $p = 0.861$, and race: $p = 0.711$).

Table 2: Group statistics of group based meditators and non-meditators/non-group based meditators in the various portions of the survey.

| Group Statistics of Group Based Meditators vs. Non-Group Based Meditators and Non-Meditators | | | | | |
|---|---|---|---|---|---|
| | Meditation group | N | Mean | Std. Deviation | Std. Error Mean |
| Cognitive | no | 18 | 4.0119 | 0.44049 | 0.10382 |
| | yes | 24 | 4.0625 | 0.38397 | 0.07838 |
| Reflective | no | 18 | 3.9630 | 0.41146 | 0.09698 |
| | yes | 24 | 4.2014 | 0.39388 | 0.08040 |
| Affective | no | 18 | 3.5983 | 0.52342 | 0.12337 |
| | yes | 24 | 3.9583 | 0.38893 | 0.07939 |
| Wisdom | no | 18 | 3.8577 | 0.39295 | 0.09262 |
| | yes | 24 | 4.0741 | 0.30171 | 0.06159 |
| Mastery | no | 18 | 3.9048 | 0.61592 | 0.14517 |
| | yes | 24 | 3.9702 | 0.46716 | 0.09536 |
| Purpose In Life | no | 18 | 3.9259 | 0.86739 | 0.20445 |
| | yes | 24 | 4.6389 | 0.39215 | 0.08005 |
| Depression | no | 18 | 1.4472 | 0.42650 | 0.10053 |
| | yes | 24 | 1.2292 | 0.27699 | 0.05654 |
| Subj Health | no | 18 | 3.8056 | 0.68897 | 0.16239 |
| | yes | 24 | 4.3542 | 0.91461 | 0.18669 |
| Education | no | 18 | 17.0000 | 2.52050 | 0.59409 |
| | yes | 24 | 16.5417 | 2.39980 | 0.48986 |
| Gender | no | 18 | 0.5556 | 0.51131 | 0.12052 |
| | yes | 24 | 0.5833 | 0.50361 | 0.10280 |
| Age | no | 18 | 46.8889 | 18.69850 | 4.40728 |
| | yes | 24 | 46.0833 | 13.35768 | 2.72662 |
| Race | no | 18 | 0.8333 | 0.38348 | 0.09039 |
| | yes | 24 | 0.8750 | 0.33783 | 0.06896 |
| Religious Activities | no | 18 | 2.2778 | 0.75190 | 0.17723 |
| | yes | 24 | 3.2083 | 0.97709 | 0.19945 |

## Threshold Meditators

When applying the threshold of 60-90 minutes a week to qualify as a meditator in the final analyses, there were 24 meditators and 18 “non-meditators”. Twenty-three of the 24 group-based meditators indicated that they meditated at least 60-90 minutes a week, whereas only one of the non-group meditators reported to mediate for at least 60-90 minutes a week.

Threshold meditators scored higher in the dimensions of reflective ($t = -1.696$; $p = 0.098$) and affective ($t = -2.377$; $p = 0.022$) but no significant differences were discovered

in the cognitive dimension (t = -0.782; p = 0.439). Wisdom was significantly higher in threshold meditators (t = -2.207; p = 0.049). Threshold meditators had a significantly higher purpose in life (t = -3.579; p =0.001) and subjective health rating (t = -2.129 ; p =0.039). No differences were found in self-mastery but non-threshold meditators had a higher depression rating (t =2.207; p =0.033). Threshold meditators participate more in religious activities (t =-2.527; p = 0.016). No significant differences were found in the two groups demographic statistics (age: p =0.615, education: p =0.733, race: p =0.711, and gender: p =0.430).

Table 3: Group statistics of threshold meditators and non-meditators/non-threshold meditators in the various portions of the survey.

| Group Statistics Meditation Threshold vs Non-Threshold Meditators and Non-Meditators | | | | | |
|---|---|---|---|---|---|
| | Meditation threshold | N | Mean | Std. Deviation | Std. Error Mean |
| Cognitive | No | 18 | 3.9841 | 0.43796 | 0.10323 |
| | Yes | 24 | 4.0833 | 0.38186 | 0.07795 |
| Reflective | No | 18 | 3.9769 | 0.42280 | 0.09966 |
| | Yes | 24 | 4.1910 | 0.39124 | 0.07986 |
| Affective | No | 18 | 3.6111 | 0.53650 | 0.12645 |
| | Yes | 24 | 3.9487 | 0.38473 | 0.07853 |
| Wisdom | No | 18 | 3.8574 | 0.39267 | 0.09255 |
| | Yes | 24 | 4.0743 | 0.30178 | 0.06160 |
| Mastery | No | 18 | 3.8968 | 0.60372 | 0.14230 |
| | Yes | 24 | 3.9762 | 0.47784 | 0.09754 |
| Purpose In Life | No | 18 | 3.9259 | 0.86739 | 0.20445 |
| | Yes | 24 | 4.6389 | 0.39215 | 0.08005 |
| Depression | No | 18 | 1.4583 | 0.42087 | 0.09920 |
| | Yes | 24 | 1.2208 | 0.27620 | 0.05638 |
| Subj Health | No | 18 | 3.8056 | 0.68897 | 0.16239 |
| | Yes | 24 | 4.3542 | 0.91461 | 0.18669 |
| Education | No | 18 | 16.8889 | 2.56421 | 0.60439 |
| | Yes | 24 | 16.6250 | 2.37857 | 0.48552 |
| Gender | No | 18 | 0.5000 | 0.51450 | 0.12127 |
| | Yes | 24 | 0.6250 | 0.49454 | 0.10095 |
| Age | No | 18 | 45.0000 | 19.52977 | 4.60321 |
| | Yes | 24 | 47.5000 | 12.34645 | 2.52021 |
| Race | No | 18 | 0.8333 | 0.38348 | 0.09039 |
| | Yes | 24 | 0.8750 | 0.33783 | 0.06896 |
| Religious Activities | No | 18 | 2.3889 | 0.84984 | 0.20031 |
| | Yes | 24 | 3.1250 | 0.99181 | 0.20245 |

**Functional Imaging Results**

After performing deconvolution on the time-locked baseline and time-locked all and negative affect blocks I performed a Kolmogorov-Smirnoff test. All p-values for the KS test were $p < .0001$ therefore a descriptive based analysis was performed. Rejecting the null hypothesis in the KS test demonstrates that the deconvolved HDR's fit the data differently in the different cases of deconvolution.

**All Affect Based Deconvolution T-Tests**

After localizing the various clusters, various t-tests were performed to ascertain any significant differences in possible global asymmetries between meditators and non-meditators. Significant differences could not be demonstrated because of the low n of subjects scanned in addition to the presence of individual differences in the subject's datasets. After t-tests of designated regions of interest (ROI) were performed an attempt was made to perform non-parametric statistical tests (i.e. Mann-Whitney test). The non-parametric tests failed to demonstrate significant differences. A decision was made to forego statistical tests of difference and move into a descriptive analysis.

**All Affect Based Deconvolution Descriptive Analysis**

In analyzing the cluster reports, the data was aggregated into meditators and non-meditators. After localizing all clusters, clusters were grouped into various ROI's e.g. BA 6 Middle Frontal Gyrus and BA 9 Superior Frontal Gyrus were grouped into the Frontal lobe region in their respective hemisphere. In looking at hemispheric asymmetries on a whole-brain level some interesting findings were discovered (see pie charts below).

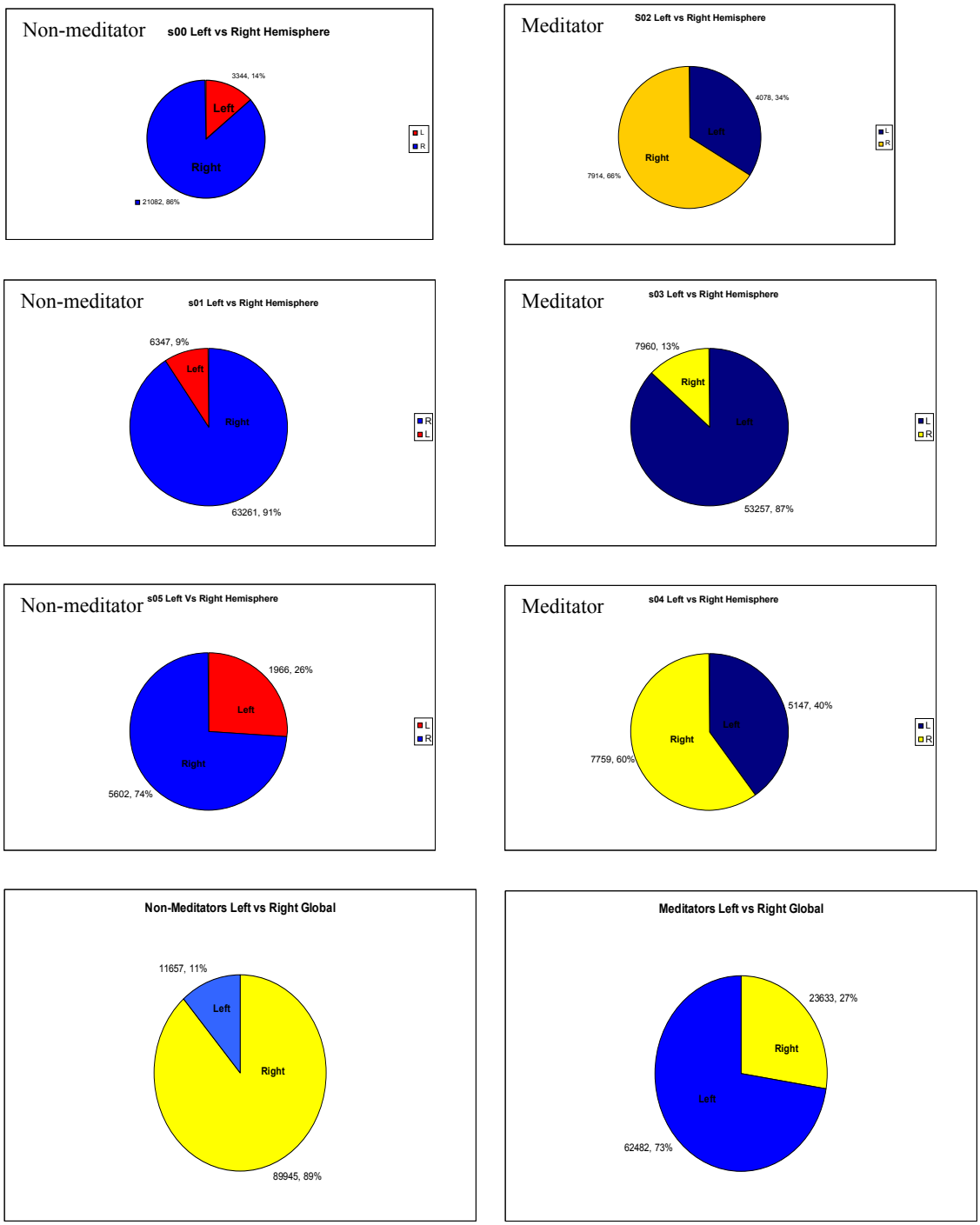


Figure 6: Aggregated data of meditators and non-meditators depicting hemispheric activity according to volume size. The red and blue pie charts above the aggregated non-meditators give the breakdown of each individual non-meditator subject. The blue and yellow pie charts above the aggregated meditator data is the breakdown of each individual meditator subject.

The aggregated cluster data show that in the all based level 89% of the non-meditator group data were isolated to the right hemisphere with a total volume size of 89945 µl compared to only 27% of the meditator group with a total volume size of 23633 µl. The aggregated cluster data for the frontal region showed slight differences hemispheric activity. Non-meditators right frontal region accounted for 47% of all frontal activity with a volume size of 3694 µl while meditators right frontal region accounted for 54% of all frontal activity with a volume size of 4505 µl.

Table 4: Individual subject data of volume of left and right frontal activity (µl).

| Non-meditator | Right | Left |
|---|---|---|
| S00 | 269 | 1068 |
| S01 | 2995 | 3043 |
| S05 | 430 | 0 |
| Meditator | | |
| S02 | 689 | 1921 |
| S03 | 3346 | 1844 |
| S04 | 470 | 137 |

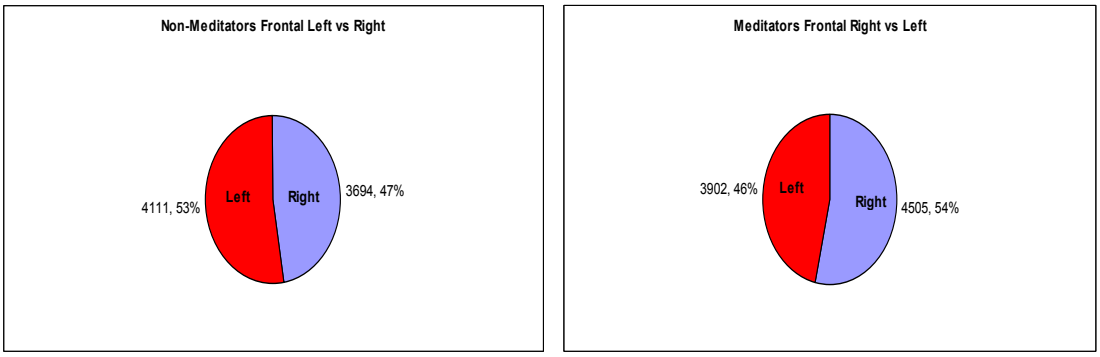


Figure 7: Aggregated data of meditators and non-meditators depicting frontal lobe hemispheric activity according to volume size.

In assessing limbic activity, limbic system structures were aggregated in their proper hemispheric location and then total activity was summed in accordance with the

two groups. Limbic activity in meditators had a total volume of 5626 µl and non-meditators had a total volume of 4212 µl. In non-meditators 73% of limbic activity was isolated to the right hemisphere as opposed to meditators whose right hemisphere limbic activity was only 40%.

Table 5: Individual subject data of volume of left and right limbic activity (µl).

| Non-meditator | Right | Left |
|---|---|---|
| S00 | 1351 | 208 |
| S01 | 1292 | 931 |
| S05 | 430 | 0 |
| Meditator | | |
| S02 | 1639 | 1261 |
| S03 | 117 | 1718 |
| S04 | 470 | 421 |

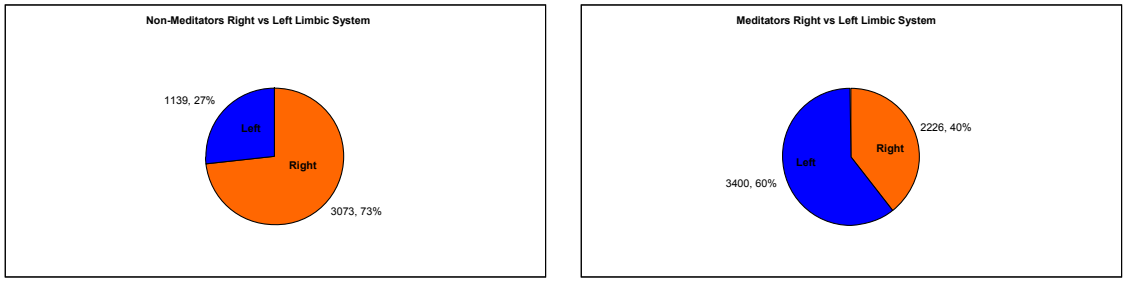


Figure 8: Aggregated data of meditators and non-meditators depicting limbic system hemispheric activity according to volume size.

The occipital region between the two groups showed differences with right hemisphere dominant in non-meditators and the left hemisphere dominant in meditators. Non-meditators right occipital region accounted for 91% of total occipital volume as opposed to only 35% of total occipital activity in meditators.

Table 7: Individual subject data of volume of left and right occipital activity (µl).

| Non-meditator | Right | Left |
|---|---|---|
| S00 | 19017 | 844 |
| S01 | 0 | 460 |
| S05 | 2989 | 953 |
| Meditator | | |
| S02 | 1311 | 301 |
| S03 | 228 | 3944 |
| S04 | 1654 | 1712 |

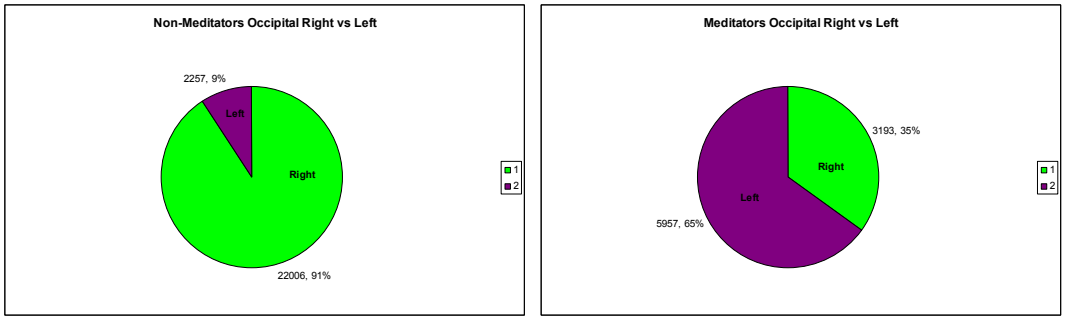


Figure 9: Aggregated data of meditators and non-meditators depicting occipital lobe hemispheric activity according to volume size.

**Affect Based Deconvolution**

Affect based deconvolution produced significantly lower $R^2$ values which in turn affect cluster reports. In creating the cluster reports a threshold of an $R^2$ 0.16 and a volume size of 100 µl was implemented. This threshold caused many cluster reports of affect based datasets to be absent of clusters that met the threshold criteria. Not surprisingly all subjects' negative based datasets had sufficient activity to produce clusters that met the cluster report criteria. Therefore in evaluating affect based datasets only negative based datasets were assessed since all subjects were included in the analysis.

Non-meditators total right hemisphere volume activity accounted for 24% of total activity with a volume of 5638 µl and meditators right hemisphere activity accounted for 38% of total activity with a volume of 6188 µl.

Table 6: Individual subject data of volume of left and right activity (µl).

| Non-meditator | Right | Left |
|---|---|---|
| S00 | 3202 | 1412 |
| S01 | 664 | 1713 |
| S05 | 1772 | 14544 |
| Meditator | | |
| S02 | 616 | 0 |
| S03 | 4399 | 9063 |
| S04 | 1173 | 930 |

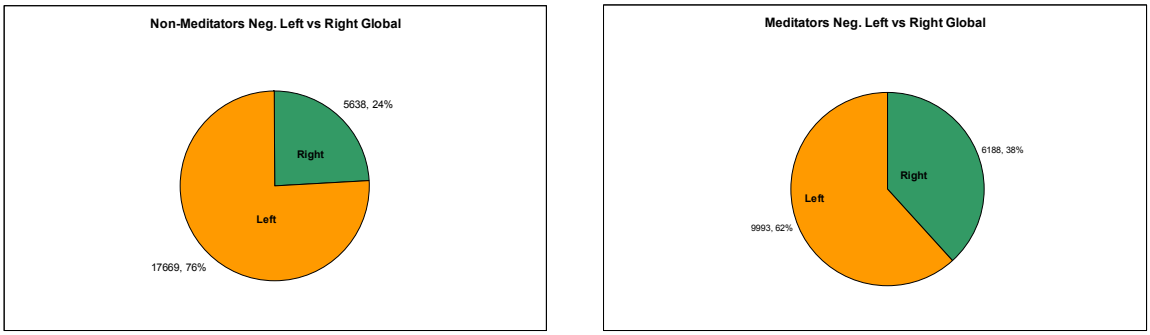


Figure 9: Aggregated data of meditators and non-meditators depicting hemispheric activity according to volume size during presentation of negative affective stimuli.

In assessing frontal lobe activity non-meditators right frontal activity accounted for 41% of total frontal activity with a volume 4633 µl of while meditators right frontal activity accounted for 59% of total activity with a volume of 932 µl. More interesting than the ratio of activity to hemispheres is the total frontal region activity. Non-meditators total frontal region activity volume was 11172 µl while meditators total volume was 1573 µl.

Table 7: Individual subject data of volume of left and right frontal activity (µl).

| Non-meditator | Right | Left |
|---|---|---|
| S00 | 3202 | 1412 |
| S01 | 0 | 1713 |
| S05 | 1431 | 3414 |
| Meditator | | |
| S02 | 0 | 0 |
| S03 | 932 | 641 |
| S04 | 0 | 0 |

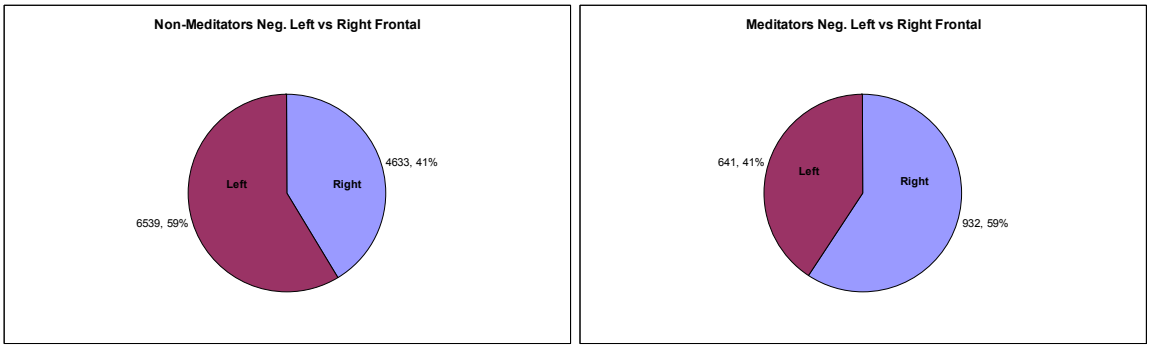


Figure 10: Aggregated data of meditators and non-meditators depicting frontal lobe hemispheric activity according to volume size during presentation of negative affective stimuli.

Non-meditators right occipital activity accounted for 43% of total occipital activity as opposed to meditators whose right hemisphere occipital activity accounted for 65% of total occipital volume.

Table 8: Individual subject data of volume of left and right occipital activity (µl).

| Non-meditator | Right | Left |
|---|---|---|
| S00 | 430 | 296 |
| S01 | 519 | 0 |
| S05 | 0 | 972 |
| Meditator | | |
| S02 | 616 | 0 |
| S03 | 1260 | 934 |
| S04 | 133 | 125 |

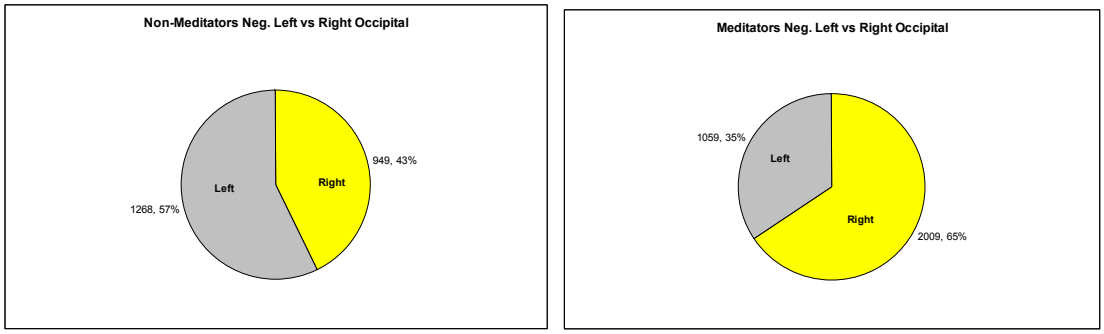


Figure 11: Aggregated data of meditators and non-meditators depicting occipital lobe hemispheric activity according to volume size during presentation of negative affective stimuli.

Not enough limbic activity was present in the datasets to make a reasonable comparison.

# CHAPTER 4
# DISCUSSION

## Wisdom Surveys

One of the groups to participate in this study was the Science of Spirituality which is a non-profit, non-denominational organization that is headed by Sant Rajinder Singh. In Sant Rajinder Singh's book on meditation, he captures the transformational process that is the motivational factor behind many practitioners quest to begin and maintain a meditative practice, "Through meditation, a whole new world opens up for us. By learning meditation, we can gain entry through a doorway that leads us to worlds of bliss, light, and love within" (Singh, 1999, p. 132). From another point-of-view, the heart of a meditation practice is the cultivation of awareness. As stated by a popular Buddhist psychiatrist, Mark Epstein M.D., "Breaking identification through the power of awareness is the great contribution of the meditative approach, and it is inevitably therapeutic" (Epstein, 1995, p. 125).

The results from the 3D-WS show an interesting pattern of significance. In looking at the components of wisdom (cognitive, affective, and reflective dimensions) only two of the components are significantly different between the groups tested. In each case tested meditators scored higher in reflective and affective domains with affective being slightly more significant in each case. If meditation is synonymous with only one word, that word would be "awareness". Ardelt states about the reflective domain, "one

needs to engage in reflective thinking by looking at phenomena and events from many different perspectives to develop self-awareness and self-insight" (Ardelt, 2003, p.278). The practice of meditation is a process of developing self-awareness and insight. If the meditator is engaging in self-awareness then the affective domains greater significant difference suggests that engaging in self-awareness might produce altruistic emotions. In discussing the improvement of affective emotions, Ardelt states that the improvement would likely be brought about by a diminished self-centeredness (Ardelt, 2003). Self-centeredness hinges upon the presence of a wholly intact ego that takes a position of subjectivity in the flow of life. Writing on the developmental process of humanity, Ken Wilber writes, "far from being some sort of narcissistic withdrawal or inward isolation, meditation is a simple and natural continuation of the evolutionary process, where every going within is also a going beyond to a wider embrace" (Wilber, 2000b, p. 263). The widening of awareness naturally brings about a previously discussed notion of aperspectival awareness. With this awareness a less and less subjective experience would arise which would lead one towards empathy and compassion brought about via the ability to be a witness for all sentient beings.

In all three cases, the cognitive domain failed to provide significant differences. Previously it was mentioned that the cognitive component is comprised of items that assess an understanding of life or the pursuit of truth. The relatively high level of education among the participants explain the lack of cognitive significant difference. Even though Ardelt (2003) didn't find a strong correlation between education and wisdom she later mentions that those in pursuit of wisdom would likely seek advanced degrees. In a correlation analysis of wisdom with the three cases the strongest correlation

with wisdom wasn't the length of time one spends per week in individual or group meditation ($r = 0.305$; $p = 0.049$) or group meditative practice ($r = 0.304$; $p = 0.05$) but whether an individual meditates at all ($r = 0.421$; $p = 0.006$). Perhaps the willingness to engage in a practice that facilitates transformation is a strong indicator of wisdom.

Ardelt (2003) discussed the differences between wisdoms of different cultures. Meditation has a long history in Eastern culture particularly in the religious traditions of Buddhism. The enhancement of wisdom among meditators may reveal what Ardelt (2003) stated, "Eastern wisdom traditions tend to integrate the cognitive, reflective, and affective elements of wisdom. In the Eastern wisdom traditions, wisdom is characterized by flexibility, honesty, sensitivity, understanding, compassion, altruism, and a balanced state of mind that is able to perceive and accept the reality of the present moment" (Ardelt, 2003, p. 283). In *Path to Bliss* the Dalai Lama comments on the two types of wisdom, "the wisdom examining the ultimate natures of phenomena, and then wisdom examining the conventional or relative nature of phenomena" (Lama, 1991, p. 192). The 3D-WS examines both types of wisdom in the three dimensions.

The lack of significant difference in all cases in the area of mastery is not a surprise. The items that comprise the mastery scale tend to revolve around the issue of helplessness. I would hypothesize that individuals with the level of education present in the participants would tend to reveal a sense of mastery via their higher educational pursuits. Revisiting the therapeutic nature of meditation, I find it very plausible that purpose in life and subjective health are higher in meditators than non-meditators. Meditators, group meditators, and threshold meditators all show significantly higher purpose in life (all groups $p < .01$) and subjective health (all groups $p < .05$) scores. The

significant difference between meditators and non-meditators on the depression scale further supports the claim of meditation as a therapeutic practice. Non-meditators scored significantly higher on the depression scale which evaluates the psychological state of an individual over the past week. This finding supports previous research and suggests meditation is a therapy practice like Kabat-Zinn's Mindfulness based therapy.

Education had no significant correlation with any dimension indicating that the survey accurately detects a type of knowledge not found within the educational system. A wise individual is sometimes depicted as an elder individual perhaps with gray or white hair but the correlation analysis showed a negative correlation between age and wisdom ($r = -0.341$; $p = .027$). No further demographic statistics were found to be significant with any area of the survey except that gender correlated positively with the affective domain ($r = 0.336$; $p = 0.029$). Gender was coded 1 for females therefore female participants were shown to be significantly different than their male counterparts in the affective domain.

**Functional Imaging**

The functional imaging data provided no statistically significant data. The low n of each group was sufficient for the task of a pilot study investigating possible differences in brain activation between meditators and non-meditators. In the time-locked to all affect based deconvolution analysis, the interesting finding of a more pronounced right hemisphere dominance in non-meditators than in meditators provides an interesting framework for launching future studies. According to Lee (2004) the asymmetries of emotion have found general right hemisphere dominance in the perception of emotion. This asymmetry was clearly present for non-meditators but less so (or even reversed) for meditators, in data aggragated over the hemispheres or in data restricted to limbic

structures. Hemispheric asymmetry was less consistent for frontal or occipital regions of interest. In the negative affect dataset asymmetry does not show a consistent difference between non-meditators and meditators. Lang & Bradley (1998) found that using affective stimulation right hemisphere activation was greater than left.

## Future Research

The possible underlying mechanisms for this neurological shift are not widely understood since repeat scans of meditators viewing affective stimuli have not been conducted. This study was a pilot to assess possible avenues for future research to explore differences between meditators and non-meditators in the neuroimaging of emotion. With the data collected from this study I would propose a study that analyzes non-meditators who undergo meditation training. The same design of affective picture stimuli could be implemented to analyze possible volumetric and laterality differences over the course of meditation training. This study should utilize information derived from the 3D-WS. It is important that future studies have control over their sample population in order to isolate possible variables that could account for the variation in data. Whether fMRI or some other form of non-invasive technology is utilized in examining meditation, it should always be used in conjunction with behavioral assessment in order to properly document all of the possible changes brought about through the practice of meditation. The transformations of meditation practice are not widely understood so future studies should develop protocols that assess many areas of the subject.

## Conclusion

This study has confirmed that Wilber's theory of the right half and left half of the four-quadrant system is an ongoing reciprocal relationship that can be shown through the

experimentation process. Thus the interdisciplinary nature of the study helped to demonstrate the integral nature of meditation and that meditation is an ancient practice that can be studied today via modern technology and methods. Its introduction to Western culture on a mass level during the 1960's has transformed meditation from a counter-culture practice to common practice as well as a therapy utilized in medicine. If this study adds to the body of literature supporting the idea that meditation does indeed provide a transformation within the body and mind of individuals then I feel I have accomplished what I set forth to do.

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## BIOGRAPHICAL SKETCH

Marc Franklin Kurtzman was born in Tampa, Florida, on October 17, 1981. He graduated from Sickles High School in 2000 and received his Bachelor of Arts degree in religious studies from the University of Florida, Gainesville, Florida, in May 2004. During Marc's junior year he was accepted into the combined Bachelor's/Maste'rs program in the Department of Religious Studies. From August 2003 to July 2005, Marc Kurtzman was employed as a neuroimaging research assistant in the Crosson Neuroimaging Lab and a part of the neuroimaging core at the Malcom Randall V.A. Medical Center's Brain Rehabilitation Research Center. Marc's interests are in the role of religious activities and their possible effects upon the psyche and brain.