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Inside the Meditator's Mind: Insight Through Neuroscience

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Abstract

This paper presents a review of research on the neuroscience behind meditation. The brain areas of the prefrontal gyrus, anterior cingulate cortex, inferior frontal gyrus, right thalamus, right middle temporal gyrus, and right precuneus are discussed. Emotional regulation and enhanced attentional skill are both suggested to be positively correlated with time spent meditating. The meditative state is described as relaxed attentiveness, signified by increased frontal theta activity and posterior alpha activity. Neuroimaging techniques like fMRI and EEG's are used to monitor brain activity. A variety of meditative techniques are examined to increase reliability and validity of this review including: Zen, Vipassana, loving-kindness, focused-attention, acem and yogic meditation. Lastly, cognitive effects of meditation are discussed.

Key words: *neuroscience, meditation, neuroimaging, emotional regulation, attention,*

brain waves

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Meditation and other mindfulness practices have become popular topics within psychological research. In fact, the rate of research articles being published on topics of meditation and mindfulness has increased exponentially since the 1990's (Williams & Kabat-Zinn, 2011). Although the practice of meditation is hundreds of years old, we have known little about the intricate process happening within the brain while a person is in a meditative state. While there are many kinds of meditation techniques, they share common fundamental concepts like mindful awareness, focused attention, and alert relaxation. Mindful awareness can be described as a state of alertness and openness to present experience devoid of judgments or expectations (Siegel, 2012). Dan Siegel (2012) states that several studies have concluded that person's with mindful awareness display increased emotional flexibility, balanced emotional regulation, confidence in approaching challenging events, increased empathy, enhanced immune function, resilience to chronic pain, and healthier relationships. Meditation may seem like the miracle solution to life's challenges, but as I will discuss further, research shows that the neurological benefits from mindfulness achieved through meditation can take years of practice and dedication.

In this research paper, I explore how the field of neuroscience is helping to shine light on the internal processes of the mind within the meditative state by examining the existing research thus far. Mediation is hard to study because of the internal nature of the practice. However, neuroscience is shedding new light into the experience of meditation by using neuroimaging tools such as an electroencephalogram (EEG) or functional magnetic resonance imaging (fMRI) to

monitor which areas of the brain are activated during the practice. This has provided scientific support to validate the positive health and affect benefits of meditation.

In this paper I review the present research that has been conducted on meditation through the lens of neuroscience. Lee et al. (2012) conducted a study comparing two different types of meditation and used fMRI technology to track differences between groups. Their findings implicated the emotional regulation areas of the brain and correlated emotional control with meditation. This led me to explore the relationship between meditation and emotions further; Gootjes et al. (2011) examined the effects of meditation on one's capacity to emotionally regulate, and found significant changes in areas of the brain involved with attention and emotional regulation. Furthermore, neuroimaging technology has revealed new insights into brain wave changes during meditation, as examined by Lagopoulos et al. (2009) which focused mostly on theta and alpha waves. Study of the traits related to theta and alpha waves led me into a discussion of the cognitive effects of the meditative state and their affective implications.

This led my research to branch off into two directions, the cognitive effects of meditation and the neurophysiological changes that occur through meditation. It is important to note that there is a plethora of meditative techniques, and to increase the reliability and validity of this paper I evaluated research articles which used a variety of meditative techniques: yogic, acem, loving-kindness, focused-attention, and Vipassana.

Brain Activation during Meditation

Siegel (2012) compiled research from several studies and found that the parts of the brain that were routinely activated in mindfulness practices were located in the middle prefrontal

cortex, composed of the anterior and posterior cingulate, the orbitofrontal cortex, and both medial and ventral aspects of the prefrontal region - including the insula and limbic hippocampus. These parts of the frontal cortex are associated with body regulation, attuned communication, emotional balance, fear and modulation, flexibility of response, insight, empathy, morality and intuition (Siegel, 2012, p.6-4). I deduce that, since meditation is a form of mindfulness practice, meditators would similarly show increased cerebral activity in those areas. From this information I can also infer that the self-reflective nature of meditation creates an attunement of the individual with his/her self in the present moment, increasing awareness of the observer that he/she is, and an innate gage of right/wrong behavior towards the self and others.

Lee and colleagues (2012) examined the effects of focus-attention meditation (FAM) and loving-kindness meditation (LKM) on neural activity of two groups, novice and expert (3 or more years of practice) meditators, in both cognitive and affective domains. Using fMRI technology to observe BOLD signals in brain areas, such as the left superior frontal gyrus (SFG), anterior cingulate cortex (ACC), and medial prefrontal cortex (MPC), during a cognitive performance test (CPT) the researchers were able to comparatively analyze brain waves from. Lee et al. (2012) predicted that there would be dissociable effects on neural activity associated with attentional control and emotional processing between long-term LKM and FAM meditators.

While viewing happy pictures in the CPT, expert meditators practicing LKM exhibited greater activation in the left ventral ACC, which plays a role in processing the emotional value of stimuli and producing the corresponding affective state (Lee et al., 2012, p.9). These findings

evidenced that LKM practice is associated with activity in the emotional processing areas of the brain, from which they deduced a significant impact on emotional regulation and subsequent production of positive emotions (Lee et al., 2012). This led researchers to hypothesize that the "cultivation of loving-kindness may allow experts to be more capable of sharing the positive emotions of others by feeling the happiness of others as their own and further wishing for others' happiness" (Phillips et al., 2003).

Similar results were found in FAM, which showed higher activity in the ventral neural system. The ventral neural system is associated with processing of emotional stimuli (Phillips et al., 2003 as cited by Lee et al., 2010). In comparison to novices, FAM experts showed variance in activity in the right thalamus, right middle temporal gyrus (MTG), and right precuneus. The lower thalamic activity in experts was indicative to researchers that practice of FAM could bring about clarity and increased attentional stability with reduced task effort. This was supported by previous research which suggested that the lower activity in the right thalamus was associated with a subjective feeling of needing less mental load to complete attention related tasks. The conclusion that FAM could enhance attention-related brain areas was further supported by stronger signals in the right MTG, which is associated with maintaining attention and controlling bottom-up, stimulus-driven attention (Karnath, Ferber, & Himmelbach, 2001 as cited by Lee et al., 2012).

Differences in activation of the right inferior frontal gyrus (IFG) during meditation were found to be greater in experts vs. novices. The IFG in the dorsal affective processing system of the brain is associated with regulating emotional responses (Phillips et al., 2003 as cited by Lee

et al., 2012). Lee et al. (2012) suggested that the different findings in neural activity between novice and expert meditators when performing an Evoked Potential Test (EPT) suggested there was a difference in neural mechanisms for processing affective stimuli. The link between meditation and processing affective stimuli is further discussed in the following research.

Meditation and Increased Emotional Regulation

Meditation has recently gained scientific notoriety as an effective tool for emotional regulation. Gootjes et al. (2011) examined whether meditative practice is associated with emotional regulation by studying neurophysiological correlates of cognitive reappraisal in practitioners of yogic meditation vs. a control group. Rapid processing of emotional stimuli was studied using Late Positive Potential (LPP), which was correlated with emotional response. Their results suggested that practitioners of yogic meditation were able to sustain emotional responses for longer periods of time subsequent to emotional regulation.

The affective system is thought to be capable of growth or neuroplasticity through the practice of meditative techniques (Davidson, Jackson, & Kalin, 2000 as cited by Gootjes et al., 2011). Neuroplasticity refers to the way in which the brain changes structurally via synaptic connections or pruning, across the lifespan (Siegel, 2012). Neuroimaging studies on emotion regulation point at involvement of the dorsolateral prefrontal cortex (PFC) and the anterior cingulate cortex (ACC) in cognitive reappraisal (Goldin et al, 2008; Ochsner et al., 2002; Oschner & Gross, 2005 as cited by Gootjes et al., 2000, p.92). The PFC integrates social, somatic, brainstem, limbic and cortical systems all into one functioning whole (Siegel, 2012, p. 3-4). The ACC coordinates the focus of attention, the linkage of thinking with feeling, the

awareness of bodily states (i.e., pain) (Siegel, 2012, p.A1-4). These areas of the brain initiate willful, sustained attention, which is also required for meditation.

Gootjes et al. (2011) concluded that changes within the PFC and ACC, brain regions involved in attention and emotion might be at the basis of state and trait effects of meditative practices (p.92). They supported their findings with a meta-analysis of neuroimaging techniques such as EEG and ERP reports which show changes in similar areas of the brain during meditation (Cahn & Polich, 2006 as cited by Gootjes et al., 2011). Ultimately Gootjes et al. (2011) found that yogic meditative practitioners showed sustained neurophysiological signs of successful cognitive appraisal in which the strength of the neurophysiological response related to experience. Cognitive reappraisal is elemental in self-regulation as it creates reduced reactivity to negative emotional states (i.e., anxiety) and the possibility of forming new neural pathways through new actions in response to stimuli.

Brain Waves and Meditation

Lagopoulos et al. (2009) examined EEG changes during acem meditation to investigate the neural mechanisms behind meditation. Acem meditation is non-religious and non-directive. The research was designed using the same group in two conditions: in the first condition, they were asked to do 20 minutes of acem meditation and in the second, to sit quietly in relaxation. Their results showed significant increase in theta waves in the meditative condition, specifically in the frontal and temporal regions. There were also significant increases in alpha waves in the posterior region of the brain. From these results, Lagopoulos et al. (2009) deduced that non-directive meditation increases theta and alpha waves significantly more than regular sitting

relaxation. Theta activity is associated with alert, attentive, and relaxed states. Theta activity has also been correlated with orienting, working memory, and affective processing (Aftantans & Golochelkrine, 2001 as cited by Lagopoulos, 2009) which helps Lagopoulos et al. (2009) infer that increased theta activity may mean increased cognitive processing and awareness. Previous studies have concluded that meditators have higher alpha and theta activity (Afantans & Golochelkrine, 2001).

In exploration of further evidence of meditation increasing alpha and theta waves I refer to a study by Murata et al., (1994) that compared 20 monks, half with extensive experience and half with moderate experience, prior to and during Zen meditation. They found that alpha waves appeared in all of the meditators but there was a significant difference in theta waves of the extensive experience group. This implies that increase theta activity is correlated with time spent meditating.

Frontal brain theta waves are associated with attention and working memory systems in the prefrontal neural circuitry, including the anterior cingulate cortex (Kurbota et al., 2001). Kurbota et al. (2001) found increased sympathetic and parasympathetic systems in correlation with increased frontal theta activity of meditators, suggesting a relationship between cardiac autonomic functioning and activity of the medial frontal neural circuitry. Interestingly, increased theta activity is suggested by Lagopoulos et al. (2009) to be meditation specific and reflective of increased awareness and attention in meditators, along with cognitive and affective processes. Suggested neural processing of theta power could point to the anterior cingulate cortex, and limbic areas. Alpha waves were found more often in posterior regions of the brain and were

postulated to be in connection with increased relaxation and decreased sensory awareness (due to posterior vs. temporal location).

Cognitive Effects

A State of Relaxed Awareness

From the previously discussed research findings in regards to alpha and theta waves, I came to understand that the meditative state can be described as relaxed attentiveness. The increased in relaxation and decrease in sensory awareness of meditators discussed in the previous research can be further explained in terms of a particular quality of mindful attention. Newberg et al. (2001) found that experienced meditators show less activation in the frontal lobes and more activation in the parietal lobes, which implies a shift from outer to inner attention. Inferior regions of the right parietal lobe become activated even when we observe others in stillness; this may help explain certain kinds of meditation which focus on still objects (i.e., a Buddha) in order to embody a similar feeling of stillness or centeredness (Cozolino, 2010). The parietal lobe is involved in observing the quality of one's inner experiences through integration of working visual memory, attentional capacities and bodily awareness (Cozolino, 2010). It is also key in producing mental imagery, which is related to theta brain waves. Increased parietal activity in meditators is viewed as indicative of internal attentiveness which is a key element of the essence of meditation: the development of insight into the nature of the mind.

Chambers, Lo, and Allen (2007) studied attentional control, cognitive style and affect in relation to Vipassana meditation, or Insight meditation, which develops mindful awareness of present moment psychological responses. They proposed that Vipassana meditation aids in the

development of two facets of higher cognition: sustained attention, and attention switching, or the ability to volitionally switch the attentional focus between stimuli. This results in an increased range and flexibility of actions, termed *cognitive flexibility* (Roemer & Orsillo, 2003 as cited by Chambers, Lo & Allen, 2007). They found that the benefits of Vipassana meditation were reflected in significantly enhanced self-reported levels of mindfulness, reduced self-reported depressive symptoms, reflective rumination, and negative affect.

Conclusion

Although a person in meditation may be sitting in stillness, there is nothing stagnant about the meditation process. Current research paints a picture of the complex inner-workings of the meditative state. For instance, EEG technology found increased theta activity which is thought to be meditation specific.

As we mature and learn through experience, our brains are capable of making new changes through neuroplasticity. Experience with mindfulness practices like meditation is positively correlated with increased brain activity and strength of brain signals coming from areas involved with executive functioning: emotional regulation and attention (Murata et al., 1994; Lee et al., 2012; Gootjes et al., 2011; Kurbota et al., 2001). Activation in the prefrontal gyrus, anterior cingulate cortex, inferior frontal gyrus, right thalamus, right middle temporal gyrus, and right precuneus were all found to be significantly activated during meditation practice (Lee et al., 2012; Gootjes et al., 2011; Lagopoulos et al, 2009).

Through doing a literature review of meditation and neuroscience I gained a new breadth of insight into the practice of meditation and what effects it has on the brain and

subsequently on behavior. Neuroscience has given scientific validation to the positive effects of meditation which was previously only experiential or qualitative.

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