

Neurological Research on Meditation

Knowledge of the neurophysiology of meditation, including mindfulness, is changing rapidly. Recent advances in medical imaging, such as rCBF (regional Cerebral Blood Flow), real time MRI (Magnetic Resonance Imaging), MEG (magnetoencephalography), and improved EEG (electroencephalography) allow detailed studies that are reshaping our understanding of the effects of meditation on neural behavior. Already there are several basic effects that have been documented which demonstrate the profound influence meditation has on neurophysiology. For example, in reviews of the literature on meditation research, published in 2006, and more specifically on mindfulness research published in 2009, the writers concluded that the three substantiated neurological effects of meditation at this time are 1) an increase in Alpha and Theta brainwave activity, 2) changes in both the prefrontal cortex (PFC) and the anterior cingulate cortex (ACC) and 3) changes in cerebral areas related to attention. Chiesa A, Serretti A (2009). "[A systematic review of neurobiological and clinical features of mindfulness meditations.](#)" *Psychol Med* 40(8): 1239-52. Epub 2009 Nov 27.

Research has been conducted on a variety of meditation techniques. Since most techniques have some aspects in common with mindfulness practice, reports of research on other practices are included below. When possible the specific type of meditation is identified.

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Dr. Newberg found that the front part of the brain, which is usually involved in focusing attention and concentration, is more active during meditation, but there was greatly decreased activity in the parietal lobe. See his research results, see the article "[The Effect of Meditation on the Brain activity in Tibetan Meditators](#)" on Dr. Newberg's website. (Unfortunately the specific type of meditation is not identified.)

The parietal area of the brain is responsible for giving us a sense of our orientation in space and time. He hypothesized that blocking all sensory and cognitive input into this area during meditation results in the sense of no space and no time. When this part of the brain, which weaves sensory data into a feeling of where the self ends, is deprived of sensory input through the mediator's focus on inward concentration, it cannot do its job of finding the border between the self and the world. Dr. Newberg described how this affects consciousness:

"The brain had no choice. It perceived the self to be endless, as one with all of creation. And this felt utterly real. The absorption of the self into something larger [is] not the result of emotional fabrication or wishful thinking. It springs from neurological events, as when the orientation area goes dark." [Why God Won't Go Away : Brain Science and the Biology of Belief](#) by Andrew Newberg M.D.

The Youtube video at this [link](#) offers an introduction to this topic by Dr. Newberg, describing the similar neurological research results across spiritual traditions, the difference in the brains of experienced practitioners and those who don't practice, as well as the "chicken vs the egg" issue this difference raises.

Neuroimaging has been used to study meditation from other angles, including the comparison of the impact of different forms of meditation on the activation of particular brain regions, neurophysiological differences between novice and experienced meditators, and the relationship between particular subjective meditative states and neuroanatomy, and the effects of long-term meditation practice on brain size. One study used fMRI to study the Japanese monks doing two somewhat similar meditation practices: reciting a mantra and reciting a Buddhist sutra. These two practices both cause increased activation in the cerebral cortex though in different folds of the cerebral brain matter. The mantra activated areas associated with concentration and visuo-spatial attention while sutra recitation affected only regions known to be involved in visuo-spatial attention, albeit different such regions than were activated by mantra practice. (Shimomura T, Fujiki M, Akiyoshi J, Yoshida T, Tabata M, Kabasawa H, Kobayashi H (2008) [Functional brain mapping during recitation of Buddhist scriptures and repetition of the Namu Amida Butsu: A study in experienced Japanese monks.](#) *Turk Neurosurg* 18(2): 134-41.)

Using fMRI to study the impact of concentration forms of meditation practice, where the intent of the practice is to train the mind to stay focused on a single object of attention, on brain activity, activation of a network of brain areas typically involved in attention was increased for meditators with an average of 19,000 hours practice as compared with novices. However more experienced meditators, averaging 44,000 hours practice showed less activation of the same region. The researchers suggest that this can be understood as moderately experienced group having better skill at the effort required to establish and sustain attention than the control groups while the most experienced meditators had so mastered the concentration skills involved that very little effort was required. (Brefczynski-Lewis JA, Lutz A, Schaefer HS, Levinson DB, Davidson RJ. (2007). [Neural correlates of attentional expertise in long-term meditation practitioners.](#) *Proc Natl Acad Sci U S A* 104(27): 11483-8. Epub 2007 Jun 27.)

Neuroimaging (MRI) has identified a particular set of brain regions, the default network, that activate when we rest wakefully but then shut down when we resume activity. These regions have been associated with the 'stream of consciousness' thinking that tends to arise when we are in a waking resting state. Zen practice is known to be a waking restful state, which however for experienced practitioners involves less 'stream of consciousness' thinking. Neuroimaging research on Zen practitioners showed a shorter duration of response in the default network. The researchers propose that "that meditative training may foster the ability to control the

automatic cascade of semantic associations triggered by a stimulus and, by extension, to voluntarily regulate the flow of spontaneous mentation.” (Pagnoni G, Cekic M, Guo Y (2008). [Thinking about not-thinking: neural correlates of conceptual processing during Zen meditation](#). *PLoS One* 3(9): e3083.

Noting that meditative states are subjectively reported to be different from ordinary human consciousness in significant ways, including “timelessness, boundarylessness, and a lack of a sense-of-self,” Neumann and Frasch undertook a survey of the neuroimaging literature on meditation to look for correlating brain states. They conclude that the research through 2006 suggests that the prefrontal cortex and the cingulate areas of the brain are the most likely cerebral regions to be involved. They caution that research is still in the early stages. (Neumann NU, Frasch K (2006) [The neurobiological dimension of meditation--results from neuroimaging studies](#). *Psychother Psychosom Med Psychol* 56(12): 488-92. For the results of neuroimaging research on the impact of mindfulness practice on the volume of brain matter in different parts of the brain, see the following article: Hölzel BK, Ott U, Gard T, Hempel H, Weygandt M, Morgen K, Vaitl D (2008) [Investigation of mindfulness meditation practitioners with voxel-based morphometry](#). *Soc Cogn Affect Neurosci* 3(1): 55-61. Epub 2007 Dec 3.

Neurochemical Effects

Studies have looked at the neurochemistry of meditation. In one such study, transcendental meditation has been shown to increase serotonin production. Serotonin is an important neurotransmitter and neuropeptide that influences mood and behavior in many ways. Its importance is demonstrated by the recent explosion in use of fluvoxamine, a “selective serotonin re-uptake inhibitor” like Prozac, Paxil, and Zoloft, for treating depression-related emotional disorders. Low levels of serotonin have been linked to a variety of disorders. For example, conditions associated with low serotonin levels include: depression, obesity, insomnia, narcolepsy, sleep apnea, migraine headaches, premenstrual syndrome, and fibromyalgia. (Bujatti M, Riederer P (1976) [Serotonin, noradrenaline, dopamine metabolites in transcendental meditation-technique](#). *J Neural Transm* 39(3): 257-67.

In a Scandinavian research project, Acem Meditation, which the researchers describe as being similar to Transcendental Meditation in that it involves the repetition of a sound or mantra, has also been associated with increased melatonin availability. Melatonin is also an important neurotransmitter and neuropeptide that influences mood and behavior. It is derived from serotonin. Melatonin has been linked to regulation of sleep. Solberg EE, Holen A, Ekeberg Ø, Østerud B, Halvorsen R, Sandvik L (2004). [The effects of long meditation on plasma melatonin and blood serotonin](#). *Med Sci Monit*. 2004 Mar;10(3):CR96-101

Neuroelectrical Effects

As mentioned above scientific studies using electroencephalography (EEG) have demonstrated that meditation has predictable effects on brain wave patterns, and differences in brain wave patterns between meditators and non-meditators. In summary, meditation has been shown to increase Alpha (8-13 Hz or cycles per second) production increase Theta (4-7 Hz) production Alpha patterns are associated with calm and focused attention; Theta patterns are associated with reverie, imagery, and creativity. A study of Zen practitioners of varying degrees of expertise showed a correlation between the degree of alpha and theta increase with the degree of expertise. Zen meditation practice could protect from cognitive decline usually associated with age and enhance antioxidant activity. From a clinical point of view, Zen meditation was found to reduce stress and blood pressure, and be efficacious for a variety of conditions. (Chiesa A (2009). [Zen meditation: an integration of current evidence](#). *J Altern Complement Med*. 15(5): 585-92.)

Working with long-term qigong meditators vs. a control group, Tei, et al., studied EEG profiles during a resting state. The differences between the two groups led them to conclude that:

“In the meditators, (in contrast to the control group) appraisal systems were inhibited, while brain areas involved in the detection and integration of internal and external sensory information showed increased activation. This suggests that neuroplasticity effects of long-term meditation practice, subjectively described as increased awareness and greater detachment, are carried over into non-meditating states.” Tei S, Faber PL, Lehmann D, Tsujiuchi T, Kumano H, Pascual-Marqui RD, Gianotti LR, Kochi K (2009). [Meditators and non-meditators: EEG source imaging during resting](#). *Brain Topogr* 22(3): 158-65. Epub 2009 Aug 4.

EEG studies have also been used to compare different kinds of meditation. Working with mindfulness vs. concentration techniques, Dunn et al. conclude that these two different approaches to meditation produce distinctly different EEG profiles. (Dunn BR, Hartigan JA, Mikulas WL (1999). [Concentration and mindfulness meditations: unique forms of consciousness?](#) *Appl Psychophysiol Biofeedback* 24(3): 147-65. For an as yet unpublished working paper on the EEG readings for a meditator experiencing deeply absorbed states of concentration described by the Buddha (the jhanas), see Hagerty MR, Isaacs J, Brasington L, Shupe L, Fetz EE (2008). [EEG Power and Coherence Analysis of an Expert Meditator in the Eight Jhanas](#). Brasington, the subject of the study, discusses his participation in the following video.

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Then watch the next video to test your own attentional blink.

Clinical Implications

Two reviews of the literature explore clinical implications. The Rubia review summarizes that,

“Physiological evidence shows a reduction with meditation of stress-related autonomic and endocrine measures, while neuroimaging studies demonstrate the functional up-regulation of brain regions of affect regulation and attention control. Clinical studies show some evidence for the effectiveness of meditation in disorders of affect, anxiety and attention.”
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In another survey article, the authors reviewed neurochemical, neuroelectrical, and neuroimaging research results suggesting, with guarded optimism, that meditation may promote both brain health and longevity of brain function. (Doraiswamy PM, Xiong GL (2007). [Does Meditation Enhance Cognition and Brain Longevity?](#) *Ann N Y Acad Sci* Sep 28.

Conclusion

The neurological study of meditation is still very much in its infancy. While its promise is great, there are many challenging issues to address to harness these findings. In their survey of the research relative to the impact of meditation on cognition and brain plasticity, Xiong and Doraiswamy offer the following assessment of the tasks that lay ahead:

“The enthusiasm [for the positive results of neurological research on meditation to date] must be balanced by the inconsistency and preliminary nature of existing studies as well as the fact that meditation comprises a heterogeneous group of practices. Key future challenges include the isolation of a potential common elements in the different meditation modalities, replication of existing findings in larger randomized trials, determining the correct "dose," studying whether findings from expert practitioners are generalizable to a wider population, and better control of the confounding genetic, dietary and lifestyle influences.” Xiong GL, Doraiswamy PM (2009). “[Does meditation enhance cognition and brain plasticity?](#)” *Ann N Y Acad Sci* 1172: 63-9.

As such, an important next step relative to mindfulness is to specifically research the neurophysiology of this kind of meditation practice.

For an engaging overview of the promise and perils of the neuroscience explosion, including research on meditation, for the field of psychotherapy, see Rick Hansen, PhD's engaging 2010 article “[The Brain: So What? The Benefits and Perils of Applying Neuroscience to Psychotherapy](#)” *Wise Brain Bulletin* 4:2 (online).

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