Meditation and the Brain:

How Neuroscience Can Help Meditators with Their Practice

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In the opening lines of the *Yoga Sutras*, Patañjali writes: "Yogaś citta-vritti-nirodhaḥ," which has been variously translated: "Yoga is the restraint of mental modifications"; “Yoga is the cessation of the turnings of thought”; “Yoga is the ability to direct the mind exclusively toward an object and sustain that direction without any distractions”; “Yoga is the neutralisation of the alternating waves in consciousness”; and “Yoga is the settling of the mind into silence.”[1].

A neuroscientist might translate Patañjali’s words, “Yoga is the conscious reshaping of one’s brain waves and brain structure.”

Advances in neuroimaging and brain wave monitoring technology have enabled important discoveries about meditation. Studies have proven that meditators of all levels show altered brain wave activity. Changes in the grey matter of the brain can be detected after only eight weeks of practice and are profound in lifelong meditators. This paper summarizes some of the recent research on meditation, relates it to Patañjali’s categories of meditation in the *Yoga Sutras*, and inquires how meditators can make practical use of scientific discoveries about how their practice changes the brain. By examining how various types of meditation affect the brain differently, we can choose practices that will be most likely to help us conquer destructive patterns of thought or behavior or cultivate states of mind that increase our ability to perceive clearly.

[1] Rama Prasada, Barbara Stoler Miller, T.K.V. Desikachar, Paramahansa Yogananda, Alistair Shearer.

Categories of Meditation

Brain scientists Fred Travis and Jonathan Shear have proposed three categories of meditation based on how they affect the brain. They developed these three categories by monitoring the EEG patterns of experienced meditators as they practiced a variety of traditional forms of meditation and analyzing data from other similar studies. Future research may broaden or change this outline, however it is illuminating to consider it as it stands.

The first meditation category*, focused attention,* is characterized by increased beta/gamma brainwave activity in the cortex. Gamma waves are the highest Hz frequency of brain waves (30-100 Hz) and represent the simultaneous firing of different populations of neurons for the purpose of carrying out a certain cognitive or motor function. Gamma waves form whenever we are involved in tasks that require our concentration.

Focused object meditations include many traditional Eastern meditation techniques as well as commonly taught relaxation methods. All require the meditator to exercise cognitive control to focus on a specific object. For example, there are forty canonical objects of meditation in Theraveda Buddhism, ranging from elements and colors, to rotting corpses, virtues, and formless states.[2] In other focused object meditations, one follows the breath; stares at a candle flame or god image; focuses on a particular chakra (often the Ājña or third eye chakra) or on a state of mind such as compassion or loving-kindness.

What is key to focused attention meditation is that the meditator actively returns his or her attention to the chosen object whenever the mind wanders. Meditators with 10,000-50,000 hours of experience in this type of meditation were compared with student volunteers and demonstrated much more powerful gamma wave

[2] Wikipedia, “Kammatthana”

activity during focused attention meditation.[3] Areas of increased gamma activity were correlated with increased brain blood flow in Qiqong meditators.[4] A 59-year old Tibetan lama practiced a variety of focused attention meditations during which increased gamma activity was noted in the areas of his brain associated with whatever he was focusing on, i.e., visual (during visualizations), verbal (during mantra recitation), or frontal cortex (while concentrating on an abstract idea such as dissolution of the self in boundless unity).[5]

Unique brain states associated with focused attention on compassion and loving-kindness have been extensively documented by Richard Davidson and his team at the University of Wisconsin-Madison. With the cooperation of the Dalai Lama and several Tibetan Buddhist monks, Davidson was able to capture startling EEG data. The monks' gamma signals showed "extremely large increases of the sort that have never been reported before in neuroscience literature," according to Davidson. "It's like a continuous *aha!* moment."[6] The monks' gamma waves remained heightened even when they were not meditating, evidence of an enduring brain change. There was significantly greater activation in the brain areas called the caudate and right insula, which are linked to empathy and maternal love.[7] The monks also showed activity in the parts of the brains which plan movement, as if they were ready to act to assist others, and in the left prefrontal cortex area associated with happiness.

The second meditation category, *open monitoring*, is characterized by increased theta brainwave activity, and includes a variety of Buddhist, Chinese and Vedic

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[3] Lutz, A., Greischar, L. L., Rawlings, N. B., Ricard, M., & Davidson, R. J. (2004). Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *Proceedings of the National Academy of Science*, 101(46), 16369–16373.

[4] Litscher, G., Wenzel, G., Niederwieser, G., & Schwarz, G. (2001). Effects of qigong on brain function. *Neurological Research*, 23(5), 501–505.

[5] Lehmann, D., Faber, P. L., Achermann, P., Jeanmonod, D., Gianotti, L. R., & Pizzagalli, D. (2001). Brain sources of EEG gamma frequency during volitionally meditation-induced, altered states of consciousness, and experience of the self. *Psychiatry Research*, 108(2), 111–121.

[6] Begley, Sharon (2007). *Train Your Mind, Change Your Brain,* New York: Ballantine, p.235. See Lutz, A., Greischar, L.L., Rawlings, N.B., Ricard, M., Davidson, R.J.. (Nov. 16, 2004). Long-Term Meditators Self-Induce High Amplitude Gamma Synchrony During Mental Practice, *Proceedings of the National Academy of Sciences*, 101; 16369-73).

[7] Ibid., p.237.

practices. Theta brain waves are relatively slow (4-7 Hz) and are seen normally in young children and during relaxed, reflective or creative states. Open monitoring meditation involves non-reactive and non-judgmental awareness of experience, moment-by-moment, without high levels of manipulation or control of the contents of experience. It involves the meta-awareness that, "Mental processes are happening" and it can enable one to become more self-aware of one's characteristic patterns of thought and emotion. An example of open monitoring practice is Vipassanā meditation (or vipaśyanā which means "insight into the nature of reality") and mindfulness meditation as taught by Thich Nhat Hanh or Jon Kabat Zinn. One study established that among 16 individuals who had practiced Vipassana for an average of 20 years, theta activity increased in frontal regions of the brain. [8] Another study compared EEG findings recorded in groups of Zen monks with extensive and moderate meditation experience and a non-meditating control group. Only the long-term Zen meditators showed increased frontal theta activity during meditation. The more experienced the meditators, the more theta activity was seen.[9] A study of Sahaja meditation, a Vedic tradition involving "thoughtless awareness" or "mental silence" free of unnecessary mental activity showed that long-term Sahaja meditators had significantly higher theta activity in the frontal areas.[10]

Open monitoring meditation practices can also alter brain structure. After only eight-weeks of training in mindfulness based stress reduction practices, brain scans showed decreased gray matter density in the amygdalas of subjects who

[8] Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, 132(2), 180–211.

[9] Murata, T., Koshino, Y., & Ormari, M. (1994). Quantitative EEG study on Zen meditation (zazen). *Japanese Journal of Psychiatry and Neurology*, 48, 881–890.

[10] Aftanas, L. I., & Golocheikine, S. A. (2001). Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: High-resolution EEG investigation of meditation. *Neuroscience Letters,* 310(1), 57–60.

reported less stress.[11] The amygdala is the part of the brain associated with stress, anxiety and fight-or-flight reactions.

The third meditation category is *automatic self-transcending*, which is characterized by increased alpha1 activity. Alpha1 waves range from 8-12 Hz and are associated with eyes-closed states, relaxation, and comas. Mental exertion or eye-opening generally causes alpha1 to attenuate. Automatic self-transcending techniques include those designed to go beyond their own activity, in which there is no distinction between the meditator, the act of meditation and the object of meditation. From an EEG standpoint, self-transcending involves minimal cognitive control or manipulation while meditating, i.e., it is effortless. Meditators describe "an absence of time, space and body sense."[12]

A study of 19 practitioners of Transcendental Meditation, as taught by Maharishi Mahesh Yogi, showed increased alpha1 activity and lower beta1 and gamma power (the latter are associated with cognitive tasks and thinking). Although TM involves the use of mantra, students are instructed to "use the mantra to lose it." In other words, the object of attention is not sustained in awareness, but allowed to fade away as awareness itself becomes primary.[13] One study of a Qiqong practitioner of 45 years reported that his alpha1 power increased immediately during practice and remained high even during daily life, indicating enduring brain change.[14] It is possible that transcending the steps of other meditation techniques (including focused attention techniques) can lead to automatic self-transcending, once the procedures are so natural to the meditator that they no

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[11] Hölzel BK, Carmody J, Evans KC, Hoge EA, Dusek JA, Morgan L, Pitman RK, Lazar SW. (2010). Stress reduction correlates with structural changes in the amygdala. *Social Cognitive and Affective Neuroscience.*.5(1):11-7.

[12] Travis, F., & Pearson, C. (2000). Pure consciousness: Distinct phenomenological and physiological correlates of ‘‘consciousness itself". *International Journal of Neuroscience*, 100, 77–89.

[13] Travis, F., Haaga, D., Hagelin, J., Arenander, A., Tanner, M., & Schneider, R. (2010). Self-referential awareness: Coherence, power, and eloreta patterns during eyes-closed rest, Transcendental Meditation and TM-sidhi practice. *Journal of Cognitive Processing*, 11(1), 21–30.

[14] Qin, Z., Jin, Y., Lin, S., & Hermanowicz, N. S. (2009). A forty-five year follow-up EEG study of qigong practice*. International Journal of Neuroscience*, 119(4), 538–552.

longer require controlled processing. In other words, what appears to be a focused object meditation may in fact be an open monitoring or automatic self-transcending meditation from an EEG standpoint.

The Three Meditation Categories in Patañjali's Samyama System

Patañjali outlines samyama, the combined practice of three forms of meditation, in the Yoga Sutras as follows:

> 3.1 deśabandhaścittasya dhāraṇā .
>
> Fixing the consciousness on one point or region is concentration (dhāraṇā).
>
> 3.2 tatra pratyayaikatānatā dhyānam .
>
> A steady, continuous flow of attention directed towards the same point or region is meditation (dhyāna).
>
> 3.3 tadḥ evārthamātranirbhāsaṃ svarūpaśūnyamḥ iva samādhiḥ
>
> When the object of meditation engulfs the meditator, appearing as the subject, self-awareness is lost. This is samādhi.
>
> 3.4 trayamḥ ekatra saṃyamaḥ.
>
> These three together [dhāraṇā, dhyāna and samādhi] constitute integration or saṃyama.[15]

Samyama ("constraint" or "perfect discipline") is a system in which concentration, meditation, and ecstasy make up a phased and multilayered spectrum leading to unification of consciousness.[16]

Patañjali's three categories of samyama practice remind us of Travis and Shear's three categories of meditative brain activity: focused attention, open monitoring and automatic self-transcending. Open monitoring or mindfulness meditation is

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[15] Iyengar, B.K.S. (1993). *Light on the Yoga Sutras of Patañjali*. Hammersmith, London, UK: Thorstons (an imprint of HarperCollinsPublishers). pp. 178–183.

[16]Translations from George Feuerstein, (1989), *Yoga: The Technology of Ecstasy*, New York: St. Martins, p. 192-195.

not explicitly described in the *Yoga Sutras*, but aspects of dhyāna and samprajaña samādhi will be explored which pertain to it.

Dhāraṇā and dhyāna represent two phases of focused attention meditation. In dhāraṇā (from the root dhri, "to hold"), the object of meditation is held in awareness while it and the meditator remain separate. For this reason, some researchers dub focused attention meditation "dual" meditation.[17] In this practice, awareness of the object of attention generally wavers and returns. It represents a concentration task, especially for novices who find their minds rebellious, and can require a good deal of effort. For the advanced meditator, dhāraṇā can eventually mean "holding the mind in a motionless state."[18]

Dhyāna occurs as the meditator becomes more adept at this process and the brain requires less cognitive control to sustain focus. This may be the point at which "busy" gamma waves are replaced with slower theta waves. Some brain scientists speak of open monitoring meditation as "nondual" meditation, because it seems to be characterized by the ability to process external phenomena while maintaining self-reflexive awareness.[19] Wakefulness intensifies and ideations arise, but constellate non-judgmentally around phenomena. Dualities such as meditator vs. object, self vs. other and internal vs. external grow less concrete. Charlotte Bell writes of dhyāna:

> As the steadiness of dharana widens into the flow of dhyana, our minds become more impartial. As we witness sensations, thoughts, and mental states simply as they are, we begin to see that no judgment is required. The evaluations we layer over experience simply serve to obscure what is true…. At these times of dwelling in the settled mind, my thoughts are not at all enticing. They arise, they pass and they leave no mark… As our practice matures, we begin to understand the insubstantiality of the phenomena projected onto the screen of awareness. We are able to meet pleasant and unpleasant thoughts

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[17] Jospovic, Z., (2010). Duality and nonduality in meditation research, *Consciousness and Cognition*, April 10. [Epub ahead of print].

[18] Feuerstein, p. 192.

[19] Jospovic, (2010) and Storrs, Carina (2009). Contemplating Oneness: The Neuroscience of Meditation, *Scienceline*, New York University, August 13. http://www.scienceline.org/2009/08/13/storrs-neuroscience-meditation-fmri-brain/

> and mental states with equanimity. This witnessing consciousness expands into our daily life practice as well. The practice of dhyana develops clear, unbiased seeing.[20]

This description of dhyāna by Bell, a Vipassana meditator for twenty years, tracks closely with Travis and Shear's description of open monitoring practices as studied in laboratories with Vipassana practitioners, who display increased theta activity in the cortex. Although these meditators sometimes steady the mind by paying attention to the breath, dhāraṇā and dhyāna combine seamlessly as the flow of consciousness opens into a wider channel and absorption in the moment-to-moment stream of experience becomes more effortless and uncontrolled. The fact that this wakeful, expansive consciousness can remain with the meditator in daily life is an indicator of enduring brain change, possibly connected with the ability to process external and internal phenomena simultaneously.[21]

In the first book of the *Yoga Sutras*, Patañjali delineates two types of samādhi: samprajaña or savikalpa and asamprajaña or nirvikalpa.

The former corresponds to the Pali term sampajañña, which appears in The *Satipatthana Sutta* of the Pali Canon, one of the first Buddhist canons to be captured in textual form. It was transmitted orally and written down in the 1st century BCE, three hundred years after the death of Siddhārtha Gautama, the Buddha. Sampajañña is the seventh aspect of the Buddha's eightfold path

Thich Nhat Hanh, whose teachings are partly inspired by the *Satipatthana Sutta*, translates sampajañña as "full awareness" or "mindfulness." Although this type of meditation retains objects of attention, be they changing sense perceptions, everyday acts, or metaphysical inquiries, sampajañña in this sense is akin to open monitoring because it involves an alert, non-judging response to shifting phenomena. Sampajañña is not a form of undiluted samādhi or ecstasy although it can lead to it. Discussing sampajañña, Thich Nhat Hanh writes:

> This is the fundamental practice of the monk. When I was first ordained as a novice forty-eight years ago, the first book my master gave me to learn by heart was a book of gathas

[20] Bell, Charlotte (2007), *Mindful Yoga, Mindful Life*, Berkeley: Rodmell, pp.156-158.
[21] Storrs, (2010).

> [verses] to be practiced while washing your hands, brushing your teeth, washing your face, putting on your clothes, sweeping the courtyard, relieving yourself, having a bath, and so on.
>
> ... If a novice applies himself to the practice of [this] ... exercise, he will see that his everyday actions become harmonious, graceful, and measured. Mindfulness becomes visible in his actions and speech. When any action is placed in the light of mindfulness, the body and mind become relaxed, peaceful, and joyful. [22]

As explained in the *Satipatthana Sutta*, sampajañña involves calm, non-judging awareness of the body, feelings, thoughts, and consciousness itself. Interestingly, the ordering of these categories from the gross to the subtle parallels Patanjali's vitarka (cogitation), vicara (reflection or existential pondering, i.e., "Who am I?"), ananda (bliss) and asmita (I-am-ness) (1.17).[23] As Karel Werner writes, "Patañjali 's system is unthinkable without Buddhism. As far as its terminology goes there is much in the *Yoga Sutras* that reminds us of Buddhist formulations from the Pāli Canon…"[24] What is the relationship between Gautama Buddha's sampajañña, or mindfulness, and Patanjali's samprajaña samādhi, or conscious ecstasy?[25]

In Patanjali's samprajaña, the meditator becomes ecstatically aware of the ultimate unity of consciousness yet, in some subtle sense, remains a separate subject in relationship with objects. Duality, or the "seed" of ego remains. "You are not completely free, the ideas in the mind are not completely roasted. They could still germinate again."[26] Sampajañña as taught by Thich Nhat Hanh does not depend on attaining samādhi but on full presence and attention. Therefore it seems that the terms sampajañña and samprajaña began to diverge slightly at some point.

The final type of samādhi, asamprajaña or nirvikalpa, corresponds to automatic self-transcending. In this nirbija or "seedless state," the meditator has gone

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[22] Nhat Hanh, Thich (trans. Annabel Laity) (1990). *Transformation and Healing: the Sutra on the Four Establishments of Mindfulness.* Berkeley, CA: Parallax Press, pp.50-1

[23] George Feuerstein, (2000), *The Shambhala Encyclopedia of Yoga*. Boston: Shambhala, pps., 333, 325,

[24] Karel Werner (1994). *The Yogi and the Mystic.* New York: Routledge, p. 27.

[25] Feuerstein, p. 196.

[26] Swami Satchidananda (1990), *The Yoga Sutras of Patanjali*. Yogaville: Integral Yoga Publications, p.176.

beyond the kernel of ego and objects of attention into a state of nonduality. Cognitive manipulations cease and an effortless unity with consciousness itself takes over, which may even be sustained in daily life:

> In the most advanced state [of samadhi], nirvikalpa samadhi, the soul realizes itself and Spirit as one. The ego consciousness, the soul consciousness, and the ocean of Spirit are seen all existing together. It is the state of simultaneously watching the ocean of Spirit and the waves of creation. The individual no longer sees himself as a 'John Smith' related to a particular environment; he realizes that the ocean of Spirit has become not only the wave of John Smith but also the waves of all other lives. In nirvikalpa the soul is simultaneously conscious of Spirit within and creation without. The divine man in the nirvikalpa state may even engage in performance of his material duties with no loss of inner God-union.[27]

Adyashanti, who teaches a type of nondual meditation in which minimal cognitive control is exercised, writes:

> In true meditation, the emphasis in on being awareness: not on being aware of objects, but on resting as primordial awareness itself. Primordial awareness (consciousness) is the source in which all objects arise and subside. As you gently relax into awareness, into listening, the mind's compulsive contraction around objects will fade. Silence of being will come more clearly into consciousness as a welcoming to rest and abide…. Silence is itself the eternal witness without form or attributes.[28]

It would be interesting to monitor the brains of novice and intermediate students of Adyashanti to determine what type of activity their brains show. Traditionally, beginning meditators are encouraged to practice focused attention meditations, which require objects of focus, however Adyashanti encourages meditators to cease this type of effort and seek rest in primordial awareness itself.

Edward Conze translates the Buddhist term nirvikalpa-jñāna as "undifferentiated cognition." He attempts to describe it, but points out that it can only be validated through direct experience:

> The "undiscriminate cognition" knows first the unreality of all objects, then realizes that without them also the knowledge itself falls to the ground, and finally directly intuits the supreme reality. Great efforts are made to maintain the paradoxical nature of this gnosis. Though without concepts, judgments and discrimination, it is nevertheless not just mere thoughtlessness. It is neither a cognition nor a non-cognition; its basis is neither thought

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[27] Yogananda, Paramahamsa, *God Talks with Arjuna: The Bhagavad Gita*, Los Angeles: Self Realization Fellowship, p.97.

[28] Adyashanti (2006). *True Meditation*, Boulder: Sounds True, p.ix-x.

> nor non-thought.... There is here no duality of subject and object. The cognition is not different from that which is cognized, but completely identical with it.[29]

Asamprajaña samādhi appears to correspond with Travis and Shear's automatic self-transcending category. It is possible that certain stages or permutations of samprajaña samādhi in which cogitation and reflection cease also reflect automatic self-transcending activity. As research on meditative brain states continues in the future, additional discoveries may be made in this regard.

How Meditators Can Benefit from Neuroscience

We live in a unique era, when science has begun to illuminate some of the mysteries of what takes place in the brain during meditation. The Dalai Lama has shown intense interest in this topic through his involvement with the Mind and Life Institute, whose aim is to use science to understand how humanity can cultivate increased compassion and wisdom.[30] How might meditators choose practices that will assist them in overcoming negative patterns of thought and behavior and develop virtuous qualities and clarity of mind?

Focused attention practices can be beneficial to meditators seeking to strengthen gamma activity in specific cognitive portions of the brain. In other words, these meditations can help to increase the attention span, ward off the decreased mental acuity of aging, or cultivate specific states of mind such as compassion or gratitude.[31] Objects of attention should be chosen carefully. Some traditional Buddhist objects of meditation, such as visualizations of decaying corpses, are helpful reminders of impermanence but may provoke anxiety in some.

Focusing attention on virtuous states such as loving kindness can strengthen activity in areas of the brain associated with these positive qualities and can bring permanent change to the meditator's personality. Novice meditators with

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[29] Conze, Edward (1962). *Buddhist Thought In India*, George Allen & Unwin Ltd, p. 253, footnote.

[30] http://www.mindandlife.org

[31] Xiong GL, Doraiswamy P.M. (2009). Does meditation enhance cognition and brain plasticity? *Annals of the New York Academy of Science*, August;; 1172: pp. 63-9.

tendencies toward perfectionism or obsessive activity in daily life should guard against focused attention meditation becoming an area of perceived failure or an exhausting mental task.

Open monitoring practices are being used with increasing frequency in Western psychological and medical contexts to treat stress, anxiety, depression, trauma, and addiction. These practices may be especially useful to individuals seeking to relax their perception that life is fast-paced or hectic; observe emotional states and thought patterns in order to choose more positive behaviors; become more in-tune with their surroundings; and strengthen awareness and discernment in general.

Automatic self-transcending cannot be achieved by the novice through effort, but comes unbidden to almost everyone at moments. It appears that advanced practitioners of focused attention and open monitoring meditation may achieve automatic self-transcendence once meditation procedures become second nature and begin to "fall away." Scientific studies of alpha wave activity are still in their infancy and will hopefully reveal more about the intriguing states described by highly advanced meditators. However, we need not trouble ourselves with setting automatic self-transcendence as a goal (in fact, effortful activity makes the possibility of attaining it more distant). The beginning meditator can reap great benefits through the simplest of focused attention and open monitoring practices.

Regardless of what meditation activity we choose to pursue, science has now conclusively established that meditation can and does alter our brains for the better. It is perhaps only a matter of time until meditation is considered indispensable for emotional and mental well being, just as exercise is for physical health.