ISSUES, POSSIBILITIES AND THE ROLE OF NEURAL NOISE IN MEDITATION RESEARCH

J. ShashiKiran Reddy[1*]
Sisir Roy [2*]

Abstract
In recent years, a surge of interest came up with studies in terms of the influence of different types of meditation on the brain and body. Lacking the basic understanding as to why ancient cultures conceived this practice primarily in its various facets, most of these studies mainly focus on delineating the underlying mechanisms of influence in terms of wellbeing and the cognitive enhancement. Thus, they not only involve various definitional and taxonomical issues, but also methodological issues. In this concern, here, we share a new perspective and also emphasize on few issues which are fundamental to meditation research that should be addressed in future studies.

Keywords: Meditation; Awareness; Buddha-hood; Neural Noise; Sleep

Introduction

For more than thousands of years, meditation has been practiced by various ancient cultures of the Orient primarily for higher spiritual attainment (WOODS, 1927/2003; RUKMANI, 2001; RAO, 2011; AWASTHI, 2013; NASH; NEWBERG, 2013; SCHMIDT; WALACH, 2014) and subsequently as a means of cultivating the state of well-being (BRABOSZCZ et al., 2010, 2017; RAO, 2011). They used meditation as a tool to realize one's true nature or to attain the state of Samadhi/Buddha-hood; which is close to a thoughtless state of mind (WOODS, 1927/2003; RUKMANI, 2001; REDDY; ROY, 2018). Oblivious to this, almost all modern scientific studies on different types and modalities of meditation mainly focused on delineating the underlying mechanisms of influence, and hence they not only involve definitional and taxonomical issues, but also various methodological concerns (BRABOSZCZ et al., 2010; RAO, 2011; AWASTHI, 2013; NASH; NEWBERG, 2013; SCHMIDT, 2014; SCHMIDT;WALACH, 2014; TOMASINO et al., 2014; TOMASINO; FABBRO, 2015; TANG

[1*] Research Scholar, Bangalore, India. Email Address: jumpalreddy@live.com, jumpal_shashi@yahoo.com
[2*] National Institute of Advanced Studies, Indian Institute of Science (IISc) Campus, Bangalore, India. Email Address: sisir.sisirroy@gmail.com

et al., 2015). In this context, to capture the phenomenon of meditation in its totality, we not only need more methodologically rigorous studies (TANG et al., 2015), but also a different approach to discernment (RAO, 2011; AWASTHI, 2013; NASH; NEWBERG, 2013; SCHMIDT, 2014). Addressing this; in the following, we share some possibilities in meditation research with a new perspective, and also emphasize on few issues that are fundamental to any type of meditation which should be critically discussed for scientific considerations.

The Role of Neural Noise and Possibilities in Meditation Research

- On reviewing the literature on meditation across various cultures and traditions, it appears that awareness is central to any type of meditation (BRABOSZCZ et al., 2010; TRAVIS, 2011; SCHMIDT, 2014). Currently, we are not clear as to what brain pattern corresponds to the presence of awareness. Though few studies consider awareness to be associated with gamma oscillations in the brain (LLINAS; RIBARY, 2006), and report the neural mechanisms underlying such conscious awareness to be related to gamma synchronization (in the range of 30-100 Hz: VARELA et al., 2001; FRIES, 2005); as indicated in Braboszcz et al. (2017) - '*there is as of yet no clear understanding of the functional role of EEG gamma activity in the literature'*.

We now have several studies indicating the dominance of the presence of other oscillations such as delta, theta, alpha and beta in meditation (LEE et al., 2018). The dominance of a specific brain wave oscillation in different regions of the brain depends on a particular type of meditation and the cognitive modality involved. As indicated in Lee et al. (2018), we have distinct differences in neural oscillatory activity among different practices of meditation. Thus, gamma alone cannot be considered as the sign post of awareness. This is because, what essentially under lies all other types of meditation is awareness itself, just that in some practices it is directed towards external aspects and in others, on the ongoing mental content without a response or reaction. To solve such an ambiguity, there is a need to distinguish the mechanisms associated with internal and external awareness and see, how it applies to different practices and stages of progress in meditation.

In this regard, an interesting perspective may emerge from lateral and longitudinal studies of wakeful state, REM-sleep and non-REM (deep) sleep states over meditation(in line with studies such as –Llinas and Ribary (2006), Cvetkovic and Cosic (2011), Travis (2011), Ferrarelli

et al. (2013), Wind and Noreika (2011); Dissanayaka et al. (2015)). Anticipating a deeper connection between sleep and meditation; both being different states associated with the presence of internal awareness, some ancient cultures have already devised methods to transform a normal sleep state into a deeper meditative state called Yoga Nidra (SHARMA, 2004; SARASWATI, 2008). During this, an advanced practitioner is believed to enter into a state of awareness where one remains alert even in different sleep phases (just as in the case of lucid dreaming). In this context, studying the phenomenon of lucid dreaming may not only give deeper insights into the nature of consciousness in general (VOSS et al., 2009, 2013; WINDT et al., 2016; WIND; NOREIKA, 2011), but would also have important implications to understanding the meditative states of consciousness.

Even in light of the above-mentioned studies that suggest connection between awareness and gamma oscillations, understanding lucid dreaming seems to be important. Because, in a recent study (VOSS et al., 2014), the component of self-awareness is induced in dreams through frontal low current stimulation of gamma activity in the brain (which is not the characteristic activity associated with different sleep phases). There also exists another possibility where one can understand the degree of awareness in different sleep phases via meditation research. This is because, during sleep, we don't have a subject giving constant feedback as in other meditation interventions.

- Research shows that during sleep the intercellular spaces in the brain may increase up to 60% and this expansion drive the clearance of waste, allowing it to flush out toxic metabolites that accumulate during the waking period (XU et al., 2014; KRUENGER et al., 2016).The presence of these toxic materials may disrupt the normal functioning and thus, generate more noise, and sleep is necessary for reducing the noise. This cleansing is done by the glymphatic system that controls the flow of cerebrospinal fluid (CSF), and hence, various neurodegenerative disorders can be connected to the functioning of this system. Since meditation has beneficial effects on different phases of sleep qualitatively through various physiological mechanisms (WINBUSH et al., 2007; NAGENDRA et al., 2012; FERRARELLI et al., 2013), it is bound to influence the activity of the glymphatic system. But, it is surprising to see that there are no studies in this connection and hence we propose a new implication where meditation as a practice is helpful in removing toxic noise, and subsequently has a positive impact on neural disorders.

- With the discovery of stochastic resonance in biological systems, the functional role of noise gives rise to new perspective in understanding the living organism (MCDONNELL, 2011; ROY; LLINÁS, 2012; DINSTEIN et al., 2015). In some instances, it is known to play a constructive role by inducing synchronization for an array of random oscillators. Since each neuron at an individual level can act as a chaotic oscillator (ROY; LLINÁS, 2012); the study of coherence of noise in the brain may shed new insights. It is found that spike-timing of individual neuron exhibit significant irregularities even when an identical stimulus is repeatedly applied under exactly identical experimental conditions. In this regard, an important question has been raised by Stein et al. (2005) - '*Is this variation an unavoidable effect of generating spikes by sensory or synaptic processes ('neural noise') or is it an important part of the 'signal' that is transmitted to other neurons?*'Further, recent observations clearly demonstrate that such noise or variability plays an important role in understanding various aspects of brain function (MCDONNELL, 2011; ROY; LLINÁS, 2012; DINSTEIN et al., 2015) and cognitive activities (including decision making: Roy, 2016); hence its role in meditation can be anticipated. In this context, it is interesting to see how noise and meditation are related. But, the question here would be, how do we define noise in the context of meditation and how is it connected to the neural noise discussed above?

For defining the noise in relation to meditation, we referred to Patanjali Yoga Sutras (WOODS, 1927/2003; RUKMANI, 2001), which is considered to be the repository of knowledge of various stages of a yogic meditation. Here, yogic meditation is treated as '*YogahChittaVrittiNirodhah'*.It means that yoga is the process which blocks fluctuations or perturbations (*Vritti*) of *Chitta*. The word *Chitta* is derived from the word *Chit* (it means to experience and in general translated to consciousness). In the present context, *Chitta*refer to impressions of the experiences happened in the past; so, it can be regarded as the storage of experienced memories or past impressions, which translates to the functions of mind. It is quite impossible to remove fluctuations of the mind because, as from the above view, one can see that it is fundamental nature of the mind. But, Patanjaliin Yoga Sutras suggest a step-wise practice in the form of yoga and meditation as a method of quieting the mind. Here, the perturbation/fluctuation is nothing but 'scattered thoughts' or more precisely 'unwanted variation

of thoughts'. This is nothing but noise in the sense of 'unwanted variation', though this very much depends on the context.

In modern neuroscience, the mind and its elemental functions (thoughts) are related to and associated with the neuronal activities in the brain. If this is the case, the next question would be what is the source of noise at the neuronal level? Here, noise can be classified as 'external noise' and 'internal noise' depending on the source. For example, if noise is generated because of the external activity or influence it is called external noise, and the noise associated with neurons themselves is called internal noise. Noise may arise from the random opening and closing of the gates of the ion channels as well. Inclusive of all, the sources of noise can be broadly classified as follows: Basic Physics noise, Stimulus noise, Ionic channel noise, Ionic channel noise, Cellular contractile and secretory noise, Macroscopic behavioral execution noise etc. (for more details on each of these noise types, we suggest referring to Royand Llinás, 2012).

Considering various sources of noise, we anticipate that each different type of meditation involving a particular cognitive modality, may help to subdue or reduce noise generation by acting on the underlying cognitive processes involved. Since it has been found that the degree of coherence increases during deep meditative states (TRAVIS et al., 2010; DISSANAYAKA et al., 2015; BRABOSZCZ et al., 2017), there exist two possible cases; either noise makes synchronized oscillation like noise induced oscillation, or the noise level is reduced during the process of meditation (REDDY; ROY, 2018). Accordingly, there is a possibility that these noise levels are directly linked to one's progress in the practice of meditation (thus varies from a novice to an experienced practitioner). To validate this, we need more research studies investigating the role of noise in the context of meditation. Such an approach may open up new vistas in meditation research.

Issues in Meditation Research

In meditation research, a baseline is usually estimated for different practitioners in comparison to a noviceand this is generally determined either considering the resting state or by spontaneous/instructed mind wandering techniques (TOMASINO et al., 2014; DISSANAYAKA et al., 2015). In the following, we will discuss other additional aspects which are usually

neglected in studies concerned with meditation either while comparing subjects or in setting up a base-line.

I. In the practice of meditation, even the body postures (used for meditation) seem to play a role. As indicated in Braboszcz et al. (2017) '*a key principle of meditation is that stillness of the mind requires stillness of the body*'. During the recording sessions, though an advanced practitioner would perfectly remain immobile needing minimal posture adjustment, a novice or a control subject may not always be comfortable in meditation postures, and thus would generate more muscular activity (via external stimuli) due to discomfort and posture adjustments (BRABOSZCZ et al., 2017).Also, different sitting postures would subsequently generate different neural readings. In this context, it will be interesting to study to what extent such postures would influence the neuroscientific studies on meditation.

II. Along with this, other important aspect which is in general ignored is a breathing technique. Since, we now have enough evidence showing how changes in one's breathing pattern influences EEG recordings (ARAMBULA et al., 2001; VIALATTE et al., 2009; PARK; PARK, 2012; KAUR; SINGH, 2015); one should take this into consideration while conducting studies on meditation. This is because, some meditation practices may involve specific breathing patterns and this may significantly contribute to the final output. Hence, it is reasonable to compare subjects following similar breathing techniques while dealing with specific meditation practices and techniques.

When we look at different practices of meditation associated with various cultures and traditions, each one adopts different sitting postures and unique techniques (AWASTHI, 2013; BRABOSZCZ et al., 2017). Hence, there is a need to thoroughly investigate roles played by different postures and breathing patterns associated with the oscillations of neurons in the brain in meditation research.

III. While estimating a baseline, in addition, the neurophysiological studies on meditation seem to neglect the possible role of neural plasticity of the brain. Studies indicate that the brain's natural capacity to adapt to life style changes (i.e., plasticity of the brain) depends on age factor; consequently, this capacity is high during the early phases of life (GOH;

PARK, 2009; PARK; BISCHOF, 2013). So, in order to estimate a baseline for comparing different practitioners of meditation, subjects are to be selected not only according to the years of practice and level of experience, but also based on the time of inception of meditation practice in one's life. That is, knowing from what age an individual started practicing meditation is also a key to understand the neurophysiological influence of meditation. For example, though, both the subjects to be compared may have similar years of practice and experience, more plastic changes (due to long-term meditation practices) will be observed in an individual who began practice at an early age. So, comparing subjects just with same age groups or with individuals having similar years of practice is not the best way to estimate a baseline in meditation research.

These are some of the aspects which are neglected in many recent studies on meditation that can possibly have important implications to large-scale statistical studies. In addition to these, various other factors like genetic predisposition, brain structure, life experiences, environmental factors and the individual differences in personality may also affect how an individual would respond and benefit from meditation (TANG et al., 2015, 2016). To overcome this, we recently emphasized in Reddy and Roy (2018), the need to recognize the presence of a 'universal baseline' or Buddha-hood in every individual (which is the primary purpose of meditation: RUKMANI, 2001; RAO, 2011). During the process of one's evolution, the influence of various factors discussed above may appear as different noise levels. Meditation is essentially a process to reduce this noise level (BÆRENTSEN, 2015; REDDY; ROY, 2018), or the noise itself may produce synchronized oscillations in the brain and hence the coherence. The most challenging issue for future studies on meditation is to define this universal baseline from the operational point of view.

Conclusion

Meditation practices are introduced by different traditions with an intention to reach and experience higher levels of consciousness by transcending normal (day-to-day) states of experiences. They also indicate that this is possible by subduing the fluctuations (noises) of mind and reaching a state of mental silence (or a noise-free state). Though, there has been a lot of

research on different practices of meditation in terms of the areas they influence in the brain for cognitive enhancement and wellbeing, not much is studied on the possibility of reaching a state of mental silence and implications it can have on one's functional consciousness. In this regard, referring to the traditional source of knowledge on yoga and meditation, we propose a connection between neural noise and meditation. One would need more studies to explore the nature of this connection and the role noise can play in meditation.

These are some of the issues and possibilities related to meditation research. Though from time to time a few studies have detailed and discussed one or the other issues (RAO, 2011; AWASTHI, 2013; NASH; NEWBERG, 2013; SCHMIDT, 2014; SCHMIDT; WALACH, 2014; KAUR; SINGH, 2015; REDDY; ROY, 2018), we still have numerous studies coming up that simply report and analyze the data, lacking the fundamental purpose and methodology. In this context, we want to emphasize that, to make a worthwhile contribution to literature and capture meditation in its true extent, these issues are to be addressed in future research studies.

References

ARAMBULA, P. et al. The physiological correlates of Kundalini yoga meditation: a study of a yoga master. *Applied Psychophysiology and Biofeedback*, v. 26, p. 147-153, 2001.

AWASTHI, B. Issues and perspectives in meditation research: in search for a definition. *Frontiers in Psychology*, v. 3, p. 613, 2013. doi: 10.3389/fpsyg.2012.00613.

BÆRENTSEN, K. B. Patanjali and neuroscientific research on meditation. *Frontiers in Psychology*, v. 6, p. 915, 2015.

BRABOSZCZ, C. et al. Meditation and neuroscience: from basic research to clinical practice. In: CARLSTEDT, R. (Ed.). *Integrative clinical psychology, psychiatry and behavioral medicine*: perspectives, practices and research. New York: Springer Publishing, 2010. chap. 27, p. 1910-1929.

BRABOSZCZ, C. et al. Increased gamma brain wave amplitude compared to control in three different meditation traditions. *PLoS One*, v. 12, n. 1, p. 1-27, 2017.

CVETKOVIC, D.; COSIC, I. (Ed.). *States of consciousness*: experimental insights into meditation, waking, sleep and dreams. New York: Springer, 2011.

DISSANAYAKA, C. et al. Comparison between human awake, meditation and drowsiness EEG activities based on directed transfer function and MVDR coherence methods. *Medical & Biological Engineering & Computing*, v. 53, p. 599-607, 2015.

DINSTEIN, I. Neural variability: friend or foe? *Trends in Cognitive Sciences*, v. 19, p. 322-328, 2015.

FERRARELLI, F. et al. Experienced mindfulness meditators exhibit higher parietal-occipital eeg gamma activity during NREM Sleep. *PLoS One*, v. 8, n. 8, p. e73417, 2013. doi: 10.1371/journal.pone.0073417.

FRIES, P. A mechanism for cognitive dynamics: neuronal communication through neuronal coherence. *Trends in Cognitive Sciences*, v. 9, n. 10, p. 474-480, 2005. doi: 10.1016/j.tics.2005.08.011.

GOH, J. O.; PARK, D. C. Neuroplasticity and cognitive aging: the scaffolding theory of aging and cognition. *Restorative Neurology Neuroscience*, v. 27, n. 5, p. 391-403, 2009. doi: 10.3233/RNN-2009-0493.

KAUR, C.; SINGH, P. EEG derived neuronal dynamics during meditation: progress and challenges. *Advances in Preventive Medicine*, v. 2015, p. 1-10, 2015. doi: http://doi.org/10.1155/2015/614723.

KRUEGER, J. M. et al. Sleep function: toward elucidating an enigma. *Sleep Medicine Reviews*, v. 28, p. 46-54, 2016. doi: https://doi.org/10.1016/j.smrv.2015.08.005.

LEE, D. J. et al. Review of the neural oscillations underlying meditation. *Frontiers in Neuroscience*, v. 12, p. 178, 2018.doi: 10.3389/fnins.2018.00178.

LLINAS, R. R.; RIBARY, U. Consciousness and the brain: the thalamocortical dialogue in health and disease. *Annals of the New York Academy of Sciences*, v. 929, n. 1, p. 166-175, 2006. doi: 10.1111/j.1749-6632.2001.tb05715.x.

MCDONNELL, M. D. The benefits of noise in neural systems: bridging theory and experiment. *Nature Reviews Neuroscience*, v. 12, n. 7, p. 415-426, 2011.

NAGENDRA, R. P.; MARUTHAI, N.; KUTTY, B. M. Meditation and its regulatory role on sleep. *Frontiers in Neuroscience*, v. 3, p. 54, 2012. doi: 10.3389/fneur.2012.00054.

NASH, J. D.; NEWBERG, A. Toward a unifying taxonomy and definition for meditation. *Frontiers in Psychology*, v. 4, p. 806, 2013.

PARK, Y. J.; PARK, Y. B. Clinical utility of paced breathing as a concentration meditation practice. *Complementary Therapies in Medicine*, v. 20, n. 6, p. 393-399, 2012. doi: 10.1016/j.ctim.2012.07.008.

PARK, D. C.; BISCHOF, G. N. The aging mind: neuroplasticity in response to cognitive training. *Dialogues in Clinical Neuroscience*, v. 15, n. 1, p. 109-119, 2013.

RAO, K. R. Applied yoga psychology: studies of neurophysiology of meditation. *Journal of Consciousness Studies: Controversies in Science & The Humanities*, v. 18, p. 161-198, 2011.

REDDY, J. S. K.; ROY, S. Commentary: patanjali and neuroscientific research on meditation. *Frontiers in Psychology*, v. 9, p. 248, 2018. doi: 10.3389/fpsyg.2018.00248.

ROY, S.; LLINÁS, R. Role of noise in brain function. In: BERTRAND, Z. et al. (Ed.). *Science*: image in action. Singapore: World Scientific Publishers, 2012. p. 34-44.

ROY, S. *Decision making and modeling in cognitive science*. Índia: Springer, 2016.

RUKMANI, T. S. *Yoga sutras of patanjali*: with the commentary of vyasa. Montreal: Chair in Hindu Studies, Concordia University, 2001.

SARASWATI, S. S. *Yoga Nidra*. Munger: Yoga Publications Trust, 2008.

SCHMIDT, S. Opening up meditation for science: the development of a meditation classification system. In: SCHMIDT, S.; WALACH, H. (Ed.). *Meditation*: neuroscientific approaches and philosophical implications. Cham Switzerland: Springer International Publishing Switzerland, 2014. p. 137-152.

SCHMIDT, S.; WALACH, H. (Ed.). *Meditation*: neuroscientific approaches and philosophical implications. Cham Switzerland: Springer International Publishing Switzerland, 2014.

SHARMA, A. *Sleep as a state of consciousness in Advaita Vedånta*. New York: State University of New York, 2004.

STEIN, R. B.; GOSSEN, E. R.; KELVIN, E. J. Neuronal variability: noise or part of the signal? *Nature Reviews Neuroscience*, v. 6, p. 389-397, 2005. doi:10.1038/nrn1668

TANG, Y. Y.; HÖLZEL, B. K.; POSNER, M. I. The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience*, v. 16, p. 213-225, 2015.

TANG, Y. Y.; HÖLZEL, B. K.; POSNER, M. I. Traits and states in mindfulness meditation. *Nature Reviews Neuroscience*, v. 17, p. 59, 2016.

TOMASINO, B.; CHIESA, A.; FABBRO, F. Disentangling neural mechanisms involved in Hinduism- and Buddhism-related meditations. *Brain and Cognition*, v. 90, p. 32-40, 2014.

TOMASINO, B.; FABBRO, F. Editorial: neuroimaging and neuropsychology of meditation states. *Frontiers in Psychology*, v. 6, p. 1757, 2015. doi: 10.3389/fpsyg.2015.01757.

TRAVIS, F. et al. A selfreferential default brain state: patterns of coherence, power, and e LORETA sources during eyes closed rest and transcendental meditation practice. *Cognitive Processing*, v. 11, n. 1, p. 21-30, 2010.

TRAVIS, F. States of consciousness beyond waking, dreaming and sleeping: perspectives from research on meditation experiences. In: CVETKOVIC, D.; COSIC, I. (Ed.). *States of consciousness*: experimental insights into meditation, waking, sleep and dreams. New York: Springer, 2011. p. 257-272.

VARELA, F. et al. The brain web: phase synchronization and large-scale integration. *Nature Reviews Neuroscience*, v. 2, n. 4, p. 229-239, 2001. doi: 10.1038/35067550.

VIALATTE, F. B. et al. EEG paroxysmal gamma waves during bhramari pranayama: a yoga breathing technique. *Consciousness and Cognition*, v. 18, n. 4, p. 977-988, 2009. doi: 10.1016/j.concog.2008.01.004.

VOSS, U. et al. Lucid dreaming: a state of consciousness with features of both waking and non-lucid dreaming. *Sleep*, v. 32, p. 1191-1200, 2009.

VOSS, U. et al. Measuring consciousness in dreams: the lucidity and consciousness in dreams scale. *Consciousness and Cognition*, v. 22, n. 1, p. 8-21, 2013.

VOSS, U. et al. Induction of self-awareness in dreams through frontal low current stimulation of gamma activity. *Nature Neuroscience*, v. 17, p. 810-812, 2014. doi:10.1038/nn.3719.

WINBUSH, N. Y.; GROSS, C. R.; KREITZER, M. J. The effects of mindfulness-based stress reduction on sleep disturbance: a systematic review. *Explore*, v. 3, n. 6, p. 585-591, 2007.

WINDT, J. M.; NOREIKA, V. How to integrate dreaming into a general theory of consciousness - a critical review of existing positions and suggestions for future research. *Consciousness and Cognition*, v. 20, n. 4, p. 1091-1107, 2011.

WINDT, J. M.; NIELSEN, T.; THOMPSON, E. Does consciousness disappear in dreamless sleep? *Trends in Cognitive Sciences*, v. 20, n. 12, p. 871-882, 2016.

WOODS, J. H. *The yoga-sutra of patanjali*. New York: Dover, 1927/2003.

XU, L. et al. Sleep drives metabolite clearance from the adult brain. *Science*, v. 342, p. 373-377, 2014.

Acknowledgements:

One of the authors (Sisir Roy) is indebted to HomiBhabha Trust, Mumbai for financial assistance to perform this work as Senior HomiBhabha Fellow.