HEALTHY BRAIN: COGNITIVE TRANSFORMATIONS AND ASSOCIATED NEURAL DYNAMICS OF VIPASSANA MEDITATION

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ABSTRACT

Meditation is a complex neurocognitive process inducing changes in Brain and Behavior. Long term meditative practice is reported to alter cortical activity of the brain and further influencing cognitive behaviors. Studies have reported changes in two facets of cognition - sustained attention (ability to focus attentional resources on specific stimuli for a sustained length of time) and attention switching (ability to intentionally switch attentional focus between stimuli). These changes facilitate brain's regulatory processes fostering heightened awareness, cognitive control, flexibility and emotional balance. Nuances of brainwave patterns associated with these cognitive transformations are yet to be identified. To understand Vipassana meditation induced cognitive transformations, we carried out electro-encephalographic (EEG) studies in three groups of Vipassana meditators (practitioners trained in the tradition of Sayagyi U Ba Khin as taught by Acharya S.N. Goenka) who differed in terms of their meditation experience both in duration and quality (novices, senior practitioners and teachers). EEG data was acquired using sophisticated technology (Geodesic EEG System 300 with 128 channel Hydrocel Sensor Nets and Net Station software version 4.5.6) while the meditators

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performed a cognitive task. We observed meditation proficiency related distinct brain wave patterns pertaining to attention, information and error related processing in the meditator groups. These findings indicate meditation proficiency related brain activity differences in the meditator groups and are suggestive of meditation practice related higher order cognitive transformations.

Such studies would provide insight into the neural changes associated with meditation proficiency and pave way for the understanding of neural correlates of higher states of consciousness and well-being.

VIPASSANA MEDITATION

Vipassana meditation as expounded in the P±li literature is based primarily upon the experience of the Buddha Himself and upon the method adopted by him in the attainment of enlightenment (Vajiranana, 1975). This ancient Buddhist practice is a means to transform the mind. It improves and develops concentration, clarity, emotional positivity, calmness and peace of mind. Conscientious practice sharpens perceptual processes and heightens awareness ensuing in a calm view of the true nature of things. The practitioner develops insight into the fundamental characteristics of the way things are and such an insight is the key factor in mitigating unhappiness and suffering.

VIPASSANA MEDITATION IN THE TRADITION OF SAYAGYI UBA KHIN

Vipassana Meditation is the process of cultivating 'insight' into the fundamental characteristics (Impermanence, Insubstantiality and Suffering) of mind-body phenomena. To cultivate 'insight', Vipassana meditators training in the tradition of Sayagyi UBa Khin (as taught by S.N. Goenka) employs a set of three inter-related meditative states. The outcome of long-term Vipassana practice is collectively influenced by all three meditative states. The following are the three meditative states.

*An*apana *Sati* (known as Focused Attention-FA)

Vipassana Bhavana (known as Mindfulness/Open Monitoring Meditation-OM)

Metta Bhavana (known as Loving Kindness/Compassion Meditation)

We have employed the technique of EEG to identify the distinct neural correlates of each of these practices in proficient Vipassana practitioners and their functional significance.

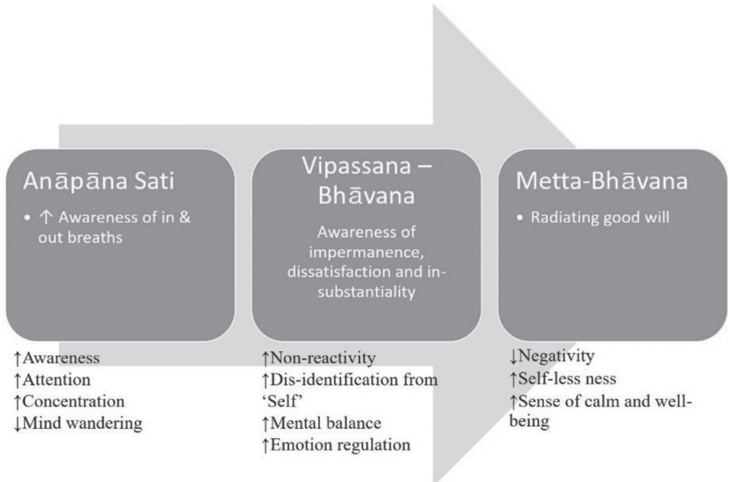

Figure 1 Outline of Vipassana Meditation Practice (in the tradition of Sayagyi Uba Khin)

The salient features and the outcomes of each practice have been represented. (Note: The outcomes are never strictly isolated).

SCIENTIFIC STUDIES ON VIPASSANA MEDITATION

The technique of Vipassana meditation has resurfaced in modern times as a way to cultivate "Well-Being" in mind and body and has received considerable attention in neuroscience research over the past two decades. In recent times meditation is also the most researched psycho-therapeutic discipline worldwide, with hundreds of millions of people turning to meditative practices for health reasons. People adopt meditation techniques for a wide variety of health reasons ranging from emotional distress to chronic diseases. There is convincing amount of research on the wide-ranging health benefits of Vipassana practice. New experimental studies show meditation to have powerful protective effects on the grey matter of the brain and its connections. Studies showed meditation alters brain functions and capacities in ways that actually rewire the brain with improved cognitive functioning. Vipassana practice in particular, enables practitioners to strengthen and re-orient their cognitive capacities. It does this by directing their practitioners attention towards the physical and mental phenomena they and enables them to experience the mental phenomena as impermanent and unsubstantial. As a consequence, with continued practice the meditators may reframe the mental phenomena such as dysfunctional attitudes, moodiness, unwarranted and harmful emotional reactivity in a meta-cognitive perspective, and experience them as series of arising and passing phenomena instead of allowing them to occupy full attention (Wallace, 1999; Teasdale *et al.*, 2002). An earlier study of the Vipassana Meditation course in a prison population in India found evidence of reduced recidivism, depression, anxiety and hostility (Ivanovski and Malhi, 2007). Some studies provide convincing evidences to its efficacy in the regulation of sleep structure and endocrine functions (Pattanashetty *et al.*, 2010). A variant of the technique of Vipassana meditation has come to be known as 'Mindfulness' in contemporary neuropsychology and has been adopted as a clinical approach for treating pain, depression, anxiety, OCD, addiction, emotional distress, maladaptive behaviors (Bishop and Bishop, 2004), chronic diseases and psychosomatic ailments.

MEDITATION, EEG & EVENT-RELATED POTENTIALS (ERP'S)

Several investigations in recent times provided insight into the neurophysiology of meditation including evidence of resultant immediate and long-term changes in cortical activity (Aftanas and Golosheikin, 2003; Takahashi *et al.*, 2005)individually determined δ -, θ -, α 1 -, α 2 - , and α 3 -frequency bands were studied by means of high-resolution EEG (62 channels. Meditation enhances oscillatory events in certain EEG (Electro-encephalography) frequency bands such as theta and alpha. Theta-alpha oscillations reflect the activity of neural networks associated with cognitive processes such as orientation, attention, memory and perception (Aftanas and Golocheikine, 2001). Altered emotional and cognitive experiences reported in meditators are found to be associated with enhanced theta-alpha powers (6-10Hz) (Takahashi *et al.*, 2005) but the psychophysiological properties and personality traits that characterize this meditative state have not been adequately studied. We quantitatively analyzed changes in psychophysiological parameters during Zen meditation in 20 normal adults, and evaluated the results in association with personality traits assessed by Cloninger's Temperament and Character Inventory (TCI. Several studies carried out in recent times on electrical potentials generated by the brain such as P3-ERP (Event Related Potential) and ERN (error related negativity) show the influence of meditative practices on cognitive and error related processing mechanisms of the brain.

EEG AND EVENT-RELATED POTENTIALS (ERN-PE)

Electroencephalography (EEG) is the recording of intrinsic electrical activity in the brain, and is based on the propagation of electric impulses along a nerve fiber when the neuron fires using electrodes placed on the scalp. EEG represents dozens of different neural sources of activity and is a summation of several ongoing brain rhythms or oscillations which can be classified into various frequency bands called delta (0 to 4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), gamma (30-100 Hz). It is typically analyzed in frequency bands that correspond to different mental states, e.g. is the alpha-frequency (8-13 Hz) associated with a relaxed mental state. By recording small potential changes in the EEG signal immediately after the presentation of a sensory stimulus it is possible to extract these the specific sensory, cognitive and other mental events (Kappenman and Luck, 2012) from the overall EEG by means of a simple averaging technique (and more sophisticated techniques, such as time-frequency analyses). This method is called Event-Related Potentials (ERPs) and is one of the classic methods for investigation of psychophysiological states and information processing. At the present time, research studies are applying ERP analysis to identify meditation induced cognitive alterations in meditation practitioners.

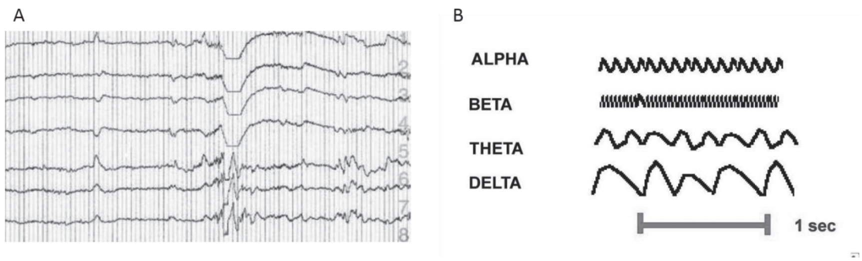

Figure 1 Panel A: Electrical activity in the brain is recorded as a 'wave' and an EEG is a record of several brain waves (Adapted from https://www.healthgrades.com/procedures/understanding-your-eeg-results)

Panel B: Examples of alpha, beta, theta, and delta electroencephalography frequencies. (Adapted from emedicine.medscape.com/article/1139332-overview)

The study of the brain in this way provides a noninvasive means of evaluating brain functioning.

Error-related negativity (ERN) and error positivity (Pe) event-related brain potentials (ERPs) are widely investigated neuro-physiological indices of cortical error processing. Error processing and corresponding behavioral adaptations in response to errors committed, involve the activity of higher cognitive control and performance monitoring system in the brain. Recent neuroimaging studies and neuropsychological studies suggest that error processing mechanisms may be implemented in a brain circuit involving the anterior cingulate cortex (ACC) and lateral prefrontal cortex (lPFC) (Carter, 1998; Nieuwenhuis *et al.*, 2001). Meditation is known to modulate brain (fronto-central) networks implicated in the generation of both ERN and Pe - ERPs.

CURRENT RESEARCH STUDY

1 Methodology

To further understand nuances of brainwave patterns associated with cognitive transformations in meditators, we carried out EEG and ERP (ERN-Pe) studies in three groups (novices, senior practitioners and teachers) of Vipassana meditators (practitioners trained in the tradition of Sayagyi U Ba Khin as taught by Acharya S.N. Goenka) who differed in terms of duration and quality of their meditation experience. Fifty nine people were selected for the study in manner independent of factors such as age, gender, education, geographical origin and economic status. They were categorized into three groups: Novice practitioners (completed two or three ten-day courses with <2 years of practice), senior practitioners (completed at least one long retreat with daily practice for 7 years) and Vipassana Teachers (instructors of Vipassana courses at meditation centers with a daily practice of >10 years who have undergone several long retreats).

EEG/ ERP data was acquired using sophisticated technology (Geodesic EEG System 300 with 128 channel Hydrocel Sensor Nets and Net Station software version 4.5.6) while the meditators performed a cognitive task. All EEG recordings were carried out in the sound attenuated cabin of the Human Cognitive Research laboratory of the Department of Neurophysiology, NIMHANS Bengaluru, India. EEG/ERP data was analyzed using appropriate statistical tools.

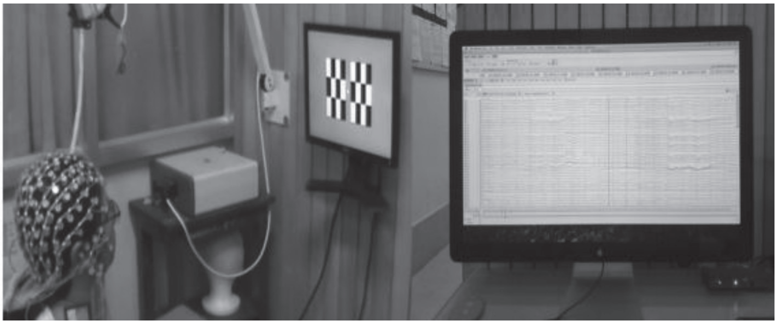

Figure 2. Recording of EEG on the left. EEG and extraction of ERP's of the participant from the graph on the right.

2 Selection Criteria

The participants in the age range 30-70 years from both genders with an ability to follow instructions in English and participate in electrophysiological assessments were included in the study. Participants with neurological/psychological disorders, history of substance abuse, on psychiatric/central nervous system medication or practicing any other form of meditation were excluded from the study. Subjects who fulfilled inclusion/exclusion criteria were recruited for the study after obtaining informed consent as approved by NIMHANS Institute Ethics Committee. Participants were all healthy, right handed, non-smokers and refrained from any caffeinated beverages on the day of the study. They were recruited from all over India. Food, accommodation and travel expenses were offered with no other kind of financial incentives.

Fifty-nine healthy Vipassana meditators participated in the game-based visual odd ball paradigm called 'ANGEL' (Assessing Neuro-cognition via Gamified Experimental Logic) designed in the Cognitive Research Laboratory (CRL) at NIMHANS (Nair *et al.*, 2016).

3 Results & Discussion

Compared to novices, teachers and senior practitioners showed noticeable morphological differences with relatively large ERN amplitude for incorrect responses. ERN morphological differences in this context, indicate a trend in favor of meditation practice related heightened response awareness and monitoring capacities. The observed Pe behavior in proficient meditators with decreased processing time is a resultant of meditation induced fundamental alterations in theta-phase resetting mechanisms related to error processing. However, studies are sparse to understand the cognitive mechanisms underlying emotional regulation in general, and specifically following meditative experience.

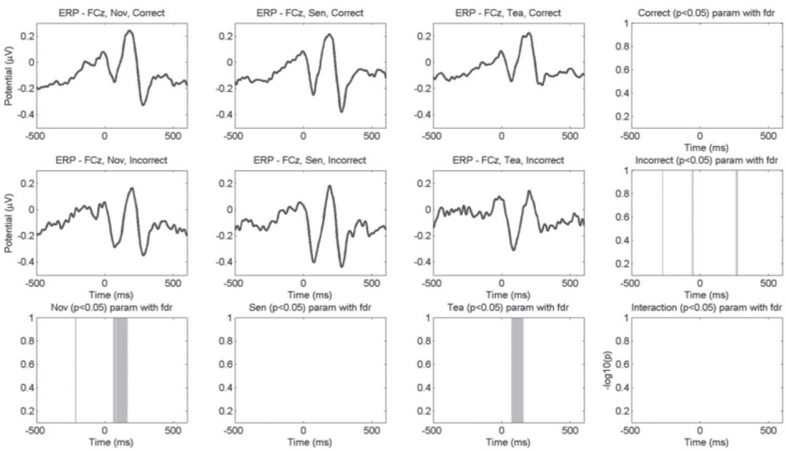

Figure 3: Ern-Pe Plot At Fcz For All Groups

Top row shows ERN and Pe for correct trials across novices, seniors and teachers from left to right. Middle row from left to right shows ERN and Pe waveforms for novices, seniors and teachers for incorrect trials. Grey lines in the bottom row indicate significant ERN amplitude differences between conditions for Novices and Teachers. Right most column (Grey bands) shows statistically significant group differences at various pre and post response intervals in the incorrect condition. Statistical significance was done using two-way ANOVA with 2000 permutations; FDR corrected at $p < 0.05$.Grey bands when present in the bottom row or right most column indicate significant condition and group differences respectively. (Nov: Novice Practitioners; Sen: Senior Practitioners; Tea: Teachers.)

Further, as we see from the figure 3 above there are large activation differences in various brain regions across meditator group's during error processing.

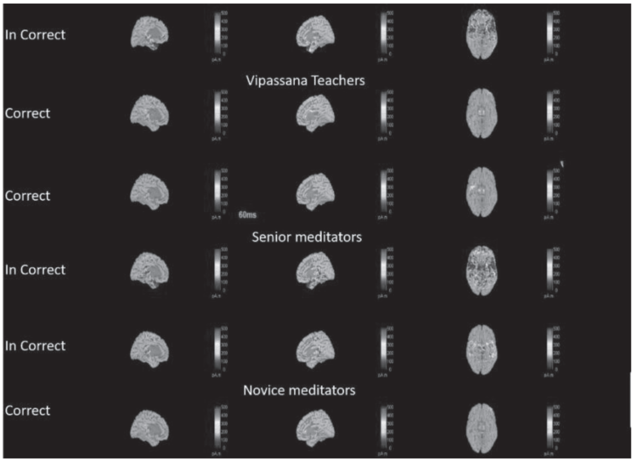

Figure4. Shows brain activations differences across the meditator groups at 60ms of response for correct and incorrect trials. (Obtained using brainstorm). Mid-sagittal and ventral sections of the brain show large activation differences between groups.

CONCLUSION

Taken together, the findings indicate relatively improved efficiency of Vipassana teachers to engage and disengage from relevant target stimuli and indicates their discretionary capacities compared to senior practitioners and novices. These changes may be linked to meditation related improved awareness and reduced rumination on any single event and a fundamental tendency to not to hold on to but let go of phenomena.

FUTURE STUDIES

The study can be extended to understand the relation between ERN and Pe components of error processing. We also propose to identify the neural sources of performance monitoring along with the meditation related neural networks activity differences.

REFERENCES

Aftanas, L. I. and 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), pp. 57–60. doi: 10.1016/S0304-3940(01)02094-8.

Aftanas, L. I. and Golosheikin, S. a (2003) 'Changes in Cortical Activity in Altered States of Consciousness : The Study of Meditation by High-Resolution EEG', *Hum Physiol.*, 29(2), pp. 143–151. doi: 10.1023/A:1022986308931.

Bishop, S. R. and Bishop, S. R. (2004) 'Mindfulness : A Proposed Operational Definition Mindfulness : A Proposed Operational Definition'. doi: 10.1093/clipsy/bph077.

Carter, C. S. (1998) 'Anterior Cingulate Cortex, Error Detection, and the Online Monitoring of Performance', *Science*, 280(5364), pp. 747–749. doi: 10.1126/science.280.5364.747.

Ivanovski, B. and Malhi, G. S. (2007) 'The psychological and neurophysiological concomitants of mindfulness forms of meditation', *Acta Neuropsychiatrica*, 19(2), pp. 76–91. doi: 10.1111/j.1601-5215.2007.00175.x.

Kappenman, E. S. and Luck, S. J. (2012) *The Oxford Handbook of Event-Related Potential Components, The Oxford Handbook of Event-Related Potential Components*. Oxford University Press.

Nair, A. K. *et al.* (2016) 'Assessing neurocognition via gamified experimental logic: A novel approach to simultaneous acquisition of multiple ERPs', *Frontiers in Neuroscience*, 10(January), pp. 1–14. doi: 10.3389/fnins.2016.00001.

Nieuwenhuis, S. *et al.* (2001) 'Error-related brain potentials are differentially related to awareness of response errors: Evidence from an antisaccade task', *Psychophysiology*, 38(5), pp. 752–760. doi: 10.1111/1469-8986.3850752.

Pattanashetty, R. *et al.* (2010) 'Practitioners of vipassana meditation exhibit enhanced slow wave sleep and REM sleep states across different age groups', *Sleep and Biological Rhythms*, 8(1), pp. 34–41. doi: 10.1111/j.1479-8425.2009.00416.x.

Takahashi, T. *et al.* (2005) 'Changes in EEG and autonomic nervous activity during meditation and their association with personality traits', *International Journal of Psychophysiology*, 55(2), pp. 199–207. doi: 10.1016/j.ijpsycho.2004.07.004.

Teasdale, J. D. *et al.* (2002) 'Metacognitive awareness and prevention of relapse in depression: empirical evidence.', *Journal of consulting and clinical psychology*, 70(2), pp. 275–287. doi: 10.1037/0022-006X.70.2.275.

Vajiranana, P. (1975) 'Theory of Buddhist Meditation', in *Buddhist Meditation In Theory And Practice*. 3rd edn. Kuala Lumpur, Malaysia: Buddhist Missionary Society.

Wallace, B. A. (1999) 'Afterword: Buddhist Reflections', *Consciousness at the cross-roads: Conversations with the Dalai Lama on brain science and Buddhism*, pp. 153–174.