NEURONAL ACTIVITY AND CEREBRAL BLOOD FLOW CHANGES IN MEDITATIVE STATES AS DEFINED IN YOGA TEXTS

Thesis submitted by

DEEPESHWAR SINGH

Towards the partial fulfillment of

DOCTOR OF PHILOSOPHY (YOGA)

JANUARY 2015

SWAMI VIVEKANANDA YOGA ANUSANDHANA SAMSTHANA

(declared as Deemed University under Section 3 of the UGC Act, 1956)

BANGALORE - 560 019

INDIA

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C E R T I F I C A T E

The Doctoral committee confirms that this is an authentic approved copy of the thesis titled **"NEURONAL ACTIVITY AND CEREBRAL BLOOD FLOW CHANGES IN MEDITATIVE STATES AS DEFINED IN YOGA TEXTS"**. The committee recommends the award of Ph.D. Degree.

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D E C L A R A T I O N

I, hereby declare that this study was conducted by me at Swami Vivekananda Yoga Anusandhana Samsthana (S-VYASA), Bangalore, under the guidance of Dr. K.V. Naveen, Joint Research Director, Dr. H.R. Nagendra, Chancellor and Dr. G. Ramchandra Bhat, Vice-Chancellor, Swami Vivekananda Yoga Anusandhana Samsthana, Deemed University, Bengaluru.

I also declare that the subject matter of my thesis entitled "**NEURONAL ACTIVITY AND CEREBRAL BLOOD FLOW CHANGES IN MEDITATIVE STATES AS DEFINED IN YOGA TEXTS"** has not previously formed the basis of the award of any degree, diploma, associate-ship, fellowship or similar titles.

Date: **DEEPESHWAR SINGH**

Place: Bengaluru (Candidate)

A C K N O W L E D G E M E N T

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I also place on record, my sense of gratitude to one and all who, directly or indirectly, have lent their helping hand in this venture.

Finally I thank that unseen Divine without whose wish, this work wouldn't have been possible.

Date:

Place: Bengaluru Deepeshwar Singh

STANDARD INTERNATIONAL TRANSLITERATION CODE USED TO TRANSLITERATE SANSKRIT WORDS

a	=	**अ**	**ṅa**	=	**ङ**	**pa**	=	**प**
ā	=	**आ**	**ca**	=	**च**	**pha**	=	**फ**
i	=	**इ**	**cha**	=	**छ**	**ba**	=	**ब**
ī	=	**ई**	**ja**	=	**ज**	**bha**	=	**भ**
u	=	**उ**	**jha**	=	**झ**	**ma**	=	**म**
ū	=	**ऊ**	**ñ**	=	**ञ**	**ya**	=	**य**
ṛ	=	**ऋ**	**ṭa**	=	**ट**	**ra**	=	**र**
ṝ	=	**ॠ**	**ṭha**	=	**ठ**	**la**	=	**ल**
e	=	**ए**	**ḍa**	=	**ड**	**va**	=	**व**
ai	=	**ऐ**	**ḍha**	=	**ढ**	**śa**	=	**श**
o	=	**ओ**	**ṇa**	=	**ण**	**ṣa**	=	**ष**
au	=	**औ**	**ta**	=	**त**	**sa**	=	**स**
ṁ	=	**अं**	**tha**	=	**थ**	**ha**	=	**ह**
ḥ	=	**अः**	**da**	=	**द**	**kṣa**	=	**क्ष**
ka	=	**क**	**dha**	=	**ध**	**tra**	=	**त्र**
kha	=	**ख**	**na**	=	**न**	**jña**	=	**ज्ञ**
ga	=	**ग**						
gha	=	**घ**						

ABSTRACT

BACKGROUND

Meditation is a training in awareness, which over a long period produces definite changes in perception, attention and cognition. This connection between meditation and attention has been mentioned in traditional yoga texts, particularly Patanjali's Yoga *Sutras*. There are two states of meditation, focused awareness (*dhāraṇā*) and effortless mental expansion (*dhyāna*). *Dhāraṇā* is supposed to lead to meditation (*dhyāna*). Two non-meditative states, focused thinking (*ekāgratā)* and random thinking (*cañcalatā*) have been described in the *Bhagavad gītā*. The practice of meditation is often associated with altered brain physiology and neuropsychological measures. Brainstem auditory evoked potentials (BAEPs) and midlatency auditory evoked potentials (MLAEPs) were studied in four mental states as described above i.e., *cañcalatā, ekāgratā, dhāraṇā*, and *dhyāna*. The results showed a significant increase in wave V peak latency of BAEPs during *cañcalatā*, *ekāgratā*, and *dhāraṇā* but not in *dhyāna*, suggesting the auditory information transmission was delayed at the inferior collicular level during *cañcalatā*, *ekāgratā*, and *dhāraṇā* (Kumar, Nagendra, Naveen, Manjunath, & Telles, 2010). MLAEPs components, the Na and Pa waves were prolonged, suggesting that auditory information at the level of the medial geniculate and primary auditory cortex (i.e., the neural generators corresponding to the Na and Pa waves) was delayed (Telles et al., 2013). Another study assessed the performance in cancellation task and attention d2 test with the digit symbol substitution test in aforementioned sessions. The performance in cancellation task was improved significantly after *dhāraṇā* and

worsened after *cañcalatā* (Kumar & Telles, 2009), whereas in d2 test of attention showed that after *ekāgratā*, and *dhāraṇā* there was an improvement in all measures of d2 test of attention and digit symbol substituion test (Raghavendra & Telles, 2012). The effect of two meditative states on long latency auditory evoked potentials (LLAEPs), P300 event related potentials with autonomic variables and cerebral blood flow changes in prefrontal cortex during cognitive task have not been studied.

AIMS AND OBJECTIVES

The present study was intended to obtain a greater understanding in the growth of individual awareness or consciousness described in traditional texts. The objectives of the study were to investigate the effect of *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* on:

(i) Long latency auditory evoked potentials (LLAEPs),

(ii) Simultaneous recordings of P300 event related potentials (ERPs) and autonomic changes,

(iii) Cerebral blood flow changes in cognitive task,

(iv) Mindfulness and anxiety,

(v) Positive states of mind (POSM), executive functions, and positive and negative affect (PANAS),

(vi) Subjective assessment of following the guided instructions for *cañcalatā, ekāgratā*, *dhāraṇā*, and *dhyāna* using visual analog scale (VAS), and also

(vii) Correlation of VAS with attention (measured in P300 ERPs), and accuracy (counted clicks during Oddball task).

METHODS

Participants

Sixty males with ages between 18 and 31 years (group means ± S.D., 20.5 ± 3.8 years) were recruited as participants by announcements in the university newsletter and flyers on the notice boards. Participants were all students of Swami Vivekananda Yoga Aunsandhana Samsthana (S-VYASA, a yoga University) and Veda Vijnana Gurukulam (VVG, a Vedic School), Bangalore, South India. They had a minimum of 6 months of experience in meditation on *OM* (with a group average experience ± S.D. of 20.9 ± 14.2 months).

Design

Each participant was assessed in 4 sessions. Two of them were meditation sessions (*dhāraṇā* and *dhyāna*) and two of them were non-meditation sessions (*cañcalatā* and *ekāgratā*). All 4 sessions consisted of three states: 'Before' (5 minutes), 'During' (20 minutes), and 'After' (5 minutes). Assessments were made on four different days, which were not necessarily on consecutive days, but at the same time of the day. The allocation of participants to the four sessions was random using a standard random number table.

Assessments

(i) Long latency auditory evoked potentials [LLAEPs] recorded at Cz electrode site referenced to linked earlobes (A1-A2), using the Nicolet Bravo system (Nicolet Biomedical, U.S.A.)

LLAEPs have been used to assess cortical changes

(ii) Simultaneous recording of P300 event related potentials (ERPs) and heart rate variability (HRV)

P300 ERPs and HRV assess Attention and autonomic changes

(iii) Hemodynamic changes in meditation related to cognitive task; recorded at prefrontal cortex (PFC) using 16 channel near infrared spectroscopy

Hemodynamic responses in stroop color word task

(iv) Mindfulness and state & trait anxiety

Freiburg Mindfulness Inventory (FMI) and STAI inventory

(v) Positive states of mind and executive control in meditators

Mood, affect and attention

(vi) Visual analogue scale (VAS), Accuracy of counted clicks during oddball task, P300 event related potentials latency and amplitude

Correlation of VAS with attention and accuracy

Intervention

Throughout all the sessions, participants sat cross-legged and kept their eyes closed and followed the pre recorded instructions.

(a) *Cañcalatā* (Random thinking)

Participants were asked to allow their thoughts to wander freely as they listened to a compiled audio CD consisting of brief periods of conversations, announcements, advertisements and talks on diverse topics recorded from a local radio station transmission. These conversations were not connected and hence it was thought that listening to them could induce a state of random thinking.

(b) *Ekāgratā* (Non-meditative focused thinking)

Participants listened to a pre-recorded lecture on the process of meditating and the object of meditation, i.e., the Sanskrit syllable '*OM*'. This was intended to induce a state of non-meditative focusing.

(c) *Dhāraṇā* (Meditative focusing)

Participants were asked to open their eyes and gaze at the syllable '*OM*' as it is written in Sanskrit. During this time guided instructions required them to direct their thoughts to the physical attributes of the syllable, i.e., the shape and color, and then to close their eyes and continue to visualize the syllable mentally. The main emphasis during meditative focusing was that thoughts are consciously brought back (if they wander) to the single thought of '*OM*'.

(d) ***Dhyāna*** **(Meditative de-focusing or effortless meditation)**

During this session participants were instructed to keep their eyes closed and dwell on thoughts of *OM*, without any effort, particularly on the subtle (rather than physical) attributes and connotations of the syllable. This would gradually allow the participants to experience brief periods of silence, which they reported after the session.

Data analysis

Statistical analysis was done using SPSS (Version 16.0 or 18.0). Data were tested for normality by the Kolmogorov-Smirnov test. Since the participants of the experimental group were assessed in repeat sessions on separate days i.e., *cañcalatā* (random thinking), *ekāgratā* (non-meditative focused thinking), *dhāraṇā* (meditative focusing), and *dhyāna* (meditation), the repeated measures analysis of variance (ANOVA) was used. ANOVA was performed with two 'Within subjects' factors, i.e., Factor 1: Sessions such as *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*, and Factor 2: States that is 'Before', 'During (1 to 4)', and 'After'. This was followed by a *post-hoc* analyses with Bonferroni adjustment for multiple comparisons between the mean values of different states ('During' and 'After') and all comparisons were made with the respective 'Before' state.

Results and Discussion

(i) **Long latency auditory evoked potentials [LLAEPs]:** LLAEPs are generated by thalamo-cortical, cortico-cortical auditory pathways, primary auditory cortex, and association cortical areas. The present study assessed LLAEPs during four mental states i.e., *cañcalatā, ekāgratā, dhāraṇā*, and *dhyāna*. The results showed that during *dhyāna* the peak latency of the P2 component significantly reduced. A decrease in peak latency is suggestive of a facilitation of auditory sensory transmission due to increased speed of conduction in the underlying neural generators.

(ii) **Simultaneous recording of P300 event related potentials (ERPs) and heart rate variability (HRV):** Meditation was associated with an increase in the P300 ERPs peak amplitude, decrease in peak latency and a simultaneous increase in HF power with a decrease in the LF/HF ratio. In contrast, in *dhāraṇā*, there was an increase in the P300 amplitude but simultaneously recorded HRV showed decreased HF power.

(iii) **Hemodynamic changes in meditation related to cognitive task:** The hemodynamic responses were assessed in *dhyāna* (meditation) and *cañcalatā* (random thinking) while performing a color word stroop task. The results showed that, meditation increases concentration of relative oxyhemoglobin change (ΔHbO) and total hemoglobin change (ΔTHC) at the right prefrontal cortex. The behavioral results of the stroop color word task showed a significant improvement in cognitive performance after meditation in all three conditions (neutral, congruent and incongruent). This suggests that meditation improves cerebral blood flow in the prefrontal, superior, inferior and orbital frontal cortex, dorsolateral prefrontal cortex (DLPFC), right dorsal medial frontal lobe, cingulate gyrus and right sensorimotor cortex areas related to attention.

(iv) **Mindfulness and state & trait anxiety:** Long-term meditators reported significantly lower state anxiety and total anxiety scores of STAI and a higher level of total mindfulness scores, acceptance and presence of FMI compared to the non-meditators. There was a strong positive correlation between the experience of meditation with the total scores of mindfulness, acceptance, and presence while there was a negative correlation with state and total anxiety. The acceptance component of the mindfulness scale related to the nonjudgmental acceptance of the situation while mindfulness presence related to the experience of the moment and a cognitive reflection of all actions.

(v) **Positive states of mind and executive control in meditators:** Meditation practice was associated with better performance in color task compared to word task and color word task in the meditation group compared to the non-meditation group. Assessments on PANAS and PSOM showed that meditation experience is associated with a larger positive affect and lower negative affect (PANAS) in meditation group and similar changes in positive states of mind (POSM) in both groups. The results suggest that meditation improved the positive states of mind and positive affect as well as reduces the interference on the Stroop task with enhanced executive control.

(vi) **Visual analogue scale, Accuracy of counted clicks during oddball task, P300 event related potential (peak latency and peak amplitude):** The correlations between the Visual Analogue Scale (VAS), attention (P300 latency and amplitude) and accuracy of counted clicks in P300 oddball task in four mental states i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* was assessed. The findings showed that there was a significant negative correlation found between VAS scores and amplitude of *cañcalatā* session, while there was a significant positive correlation in the P300 latency of *dhyāna* session and amplitude of *dhāraṇā* and *dhyāna* sessions. Similarly, accuracy of counted clicks during auditory P300 oddball task positively correlated with a VAS score of *dhyāna* session, whereas there was a negative correlation found in *ekāgratā* session.

Conclusions

The present study suggests that:

(a) *cañcalatā* (random thinking) and *ekāgratā* (non-meditative focusing) resulted in fewer neurons being recruited in auditory association areas

(b) *dhyāna* (meditation) facilitates the processing of auditory information in the auditory association cortex

(c) *dhyāna* improves attention along with reduced sympathetic activation supporting the characteristics of the classical definition of meditation as a ‘state of alertful rest’

(d) behavioral results showed that, meditation practice was associated with better performance and sustained attention in stroop color word task

(e) *dhyāna* showed that there was an improvement in oxy-hemoglobin (ΔHbO) responses in the right prefrontal cortex, whereas there was a reduced cerebral oxygen supply during *cañcalatā* session

(f) meditators reported significantly lower state anxiety and total anxiety scores in STAI Inventory and higher scores in level of mindfulness, acceptance, and presence of FMI compared to the non-meditators

(g) the correlations between the visual analogue scale (VAS), attention (P300 latency and amplitude) and the accuracy of counted clicks (in P300 oddball task) in four mental states suggest that participants were more involved in *dhāraṇā* and *dhyāna* with focused awareness and attentiveness while performing an attention task

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CHAPTER-1

INTRODUCTION

1.0 INTRODUCTION

Meditation is an ancient concept, grounded in a wide range of spiritual and religious traditions, including Yoga, Tai Chi, Buddhism, Zen, Taoism, Hinduism etc. Meditation can be defined as the intentional self-regulation of attention from moment to moment through which mindfulness is cultivated (Corsini, 2001). The well-known meditation techniques are Transcendental Meditation (TM), Zazen, Bramakumaris Raja Yoga Meditation, Sahaja Yoga Meditation, Vipassana Meditation, Ananda Marga Meditation, *OM* meditation and Cyclic meditation (CM). '*OM*' is one of the fundamental symbols of meditation in the Indian yogic tradition. During the last decade, scientific interest in meditation practice has an explosive and unprecedented surge.

Meditation is a self-regulated conscious process and mental training (Murata et al., 2004). The functional changes in the brain during meditation have been studied with various techniques which have different spatial and temporal resolutions. Long term practice of meditation has been found to improve sustained attention, general wellbeing, and mental health, as well as enhanced potency of positive feelings and reduce anxiety (Shapiro, Schwartz, & Bonner, 1998; Wachholtz & Pargament, 2005). Evoked potentials have been used in meditation studies, since the correlation between the different components of evoked potentials and the underlying neural generators are fairly well known (Woods & Clayworth, 1985). Evoked potentials allow us to understand changes in a sensory pathway, from the periphery through brainstem evoked potentials, to central areas with long latency auditory evoked potentials.

Brainstem auditory evoked potentials (BAEPs) have been studied in Transcendental Meditation (McEvoy, Frumkin, & Harkins, 1980) and in practitioners of meditation on *OM* (Kumar, Nagendra, Manjunath, Naveen, & Telles, 2010). Midlatency auditory evoked potentials (MLAEPs) have been studied in different meditations, including the eyes-open Brahmakumaris Raj Yoga Meditation, (Telles & Naveen, 2004) meditation on *OM* (Kumar et al., 2010; Telles & Desiraju, 1993; Telles, Nagarathna, Nagendra, & Desiraju, 1994) and Sahaja Yoga, which involves mental silence and awareness devoid of any thought (Panjwani et al., 2000). For both brainstem and midlatency evoked potentials the results have differed with each meditation technique. The results of a single study on long latency auditory evoked potentials in Transcendental Meditation are detailed below (Barwood, Empson, Lister, & Tilley, 1978). Transcendental meditators showed no changes in long latency auditory evoked potentials.

Meditation is associated with attention. The P300 component of auditory event related brain potentials is considered a cognitive neuroelectric phenomenon, since it is generated when subjects attend to and discriminate between stimuli which differ from one another in specific characteristics (Polich 2004). The P300 is believed to reflect fundamental cognitive events requiring attention and immediate memory processing (Polich, Ladish, & Burns 1990). A study on forty-two practitioners in whom the P300 was recorded, changes in peak amplitude (with Cohen's $d = 0.62$) showed enhanced cognitive processes after 30 minutes practice of moving meditation called cyclic meditation, which suggests meditation may increase attentional resources, stimulus processing speed, and efficiency (Sarang & Telles 2006).

Focused attention and vigilance are associated with increased sympathetic activity (Telles, Raghuraj, Maharana, & Nagendra 2007). In thirty practitioners, meditation was associated with a reduction in sympathetic nervous system activity in different subdivisions such as increased sudomotor activity (based on raised skin resistance level), reduced sympathetic cutaneous vasomotor activity and changes in heart rate variability (HRV) suggestive of a shift towards vagal dominance (Telles et al., 2013). This would suggest that meditation reduces sympathetic activity which is considered necessary for alertness, while performance in tasks for alertness was paradoxically better after meditation. A single study simultaneously recorded P300 and HRV on ten *Vipassana* meditators and reported increased attentional engagement (with Cohen's $d = 0.82$) and autonomic regulation with a shift towards reduced vagal tone after meditation (Delgado-Pastor, Perakakis, Subramanya, Telles, & Vila 2013).

Previous studies on psychological and neuropsychological meditation training have been shown to improve levels of mindfulness, attention, working memory and creativity (Orme-Johnson, 1977). Practicing meditation may reduce psycho-physiological arousal, improve concentration, selective attention and visual scanning abilities compared to resting in a supine posture (Sarang & Telles, 2007; Subramanya & Telles, 2009). Mental chanting of *OM* (with experience of 5 to 20 years) showed an increase in the efficiency with which sensory information was processed as revealed by activated higher neural centers, i.e., the association cortices leading to a single thought state, and a subjective feeling of deep relaxation (Telles & Desiraju, 1993). A cyclical combination of yoga postures and supine rest in cyclic meditation (CM) improved memory scores immediately after the practice and decreased state anxiety when compared to resting in a classical yoga relaxation posture (*shavasana*) (Subramanya & Telles, 2009).

Mindfulness meditation and gentle yoga improve mood, affective processes, and are associated with improvements in immune system functioning, stress and emotional regulation (Davidson, 2003). Meditation practice stabilizes the mind, and decreases mental proliferation which are helpful to cultivate the ethical qualities i.e., compassion, mindfulness, loving kindness, and forgiveness. The open monitoring meditation practice, (is trying to enlarge the attentional focus to all incoming sensations, emotions, and thoughts from moment to moment without focusing on any of them) is associated with increased theta activity (Mu & Han, 2010). A recent study found that 3 days of meditation training was effective at reducing pain ratings and sensitivity, as well as anxiety scores when compared to baseline and other manipulations, such as relaxation and a math distracting task. A similar training regimen improved mood and reduced heart rate when compared to a sham meditation and the control group (Zeidan, Johnson, Gordon, & Goolkasian, 2010).

The meditation practice increases performance on attentional tasks, suggesting improved allocation of attentional resources, enhanced sustained attention skills, faster re-allocation of attentional resources, and improved cognitive flexibility with reduction in automatic responding (Carter et al., 2005; Tomasino, Fregona, Skrap, & Fabbro, 2012). A recent study on immediate and long term practice of meditation in 34 adults reported the immediate effect of meditation associated with a physiological relaxation response and an improvement in scores on the Stroop test of reaction times. In the long-term, meditation brought significant improvements in IQ and scores for cognitive functions, whereas participants' stress levels decreased (Singh, Sharma, & Talwar, 2012).

Earlier studies reported that positive effect of meditation on attention modulation and cognitive function in neuropsychological and cognitive assessments. Transcendental Meditation (TM), a sitting meditation technique designed to quieten the mind and induce physical and mental relaxation, enhances restful alertness which may facilitate growth in social-emotional capacities necessary for regulating the emotional liability and interpersonal stress of adolescence, academic performance, and flexibility in emotional response in students (Rosaen & Benn, 2006). Positive physiological and psychological changes following meditation are supported by a number of research studies (Chan and Polich, 2006; Keng et al., 2011).

Other behavioral and neurophysiological studies have shown that meditation is associated with improved conflict scores on the attention network test (Tang et al., 2007), reduced interference (Chan & Woollacott, 2007) and have better attentional performance during the stroop task compared with a meditation-naïve control group (Moore & Malinowski, 2009). The stroop task is one of the most frequently used models of the conflict processing in neuroscience and psychology. Stroop color word task performance, evaluating flexibility in the control of cognitive processes and behavior which requires both attention and impulse control.

However, the results are ambiguous and different. A possible reason for this is the differences in the methods used in different meditation techniques, even though they all aim at facilitating spiritual evolution (Saraswati & Swami, 1998; Taimni, 1999). Most of these techniques have evolved in the last 200 years. This is relatively recent compared to the ancient texts (e.g., Patanajli's Yoga *Sutras*; *circa* 900 B.C.). The present study has attempted to overcome the possible cause of these differences by assessing the effects of meditation when practiced as described in traditional yoga texts (Kumar et al., 2010). The first, most recent and comprehensive compilation of descriptions in the ancient texts is the Patanjali's Yoga *Sutras* (*circa* 900 B.C.). There are two meditative states described here. The first is meditative focusing (called *dhāraṇā* in Sanskrit) during which the mind is confined to a fixed and defined area of functioning. This is often considered a preparatory phase (Patanjali's Yoga *Sutra*, Chapter III, Verse 1). The second state is considered the actual meditation (called *dhyāna* in Sanskrit), characterized by effortless, mental expansion (Patanjali's Yoga *Sutra*, Chapter III, Verse 2). During this stage there is an uninterrupted flow of the mind towards the object of meditation.

In this study, meditative focusing was compared to another mental state, non-meditative focusing (called *ekāgratā* in *Saṁskṛta*; *Bhagavad Gita*, *Circa* 400-600 B.C.; Chapter VI, Verse 12). This is focusing the attention, while not in meditation and it did not result in any changes in the cancellation task (Kumar & Telles 2009). Both non-meditative focused thinking (*ekāgratā)* and another mental state which is random thinking (called *cañcalatā* in *Saṁskṛta*) have been described in the *Bhagavad Gita* (Chapter VI, Verse 12, 34).

There are no reports of Long latency auditory evoked potentials, simultaneously recording P300 ERPs and HRV, cerebral blood flow during cognitive task on the traditionally described mental states, i.e., (i) meditation with focused attention leading to (ii) meditation. Hence, the present study was designed to assess whether the differences in both meditative states (meditation with focusing and meditation without focusing) would cause changes in the long latency auditory evoked potentials (LLAEPs), simultaneous recordings of P300 ERPs and HRV, hemodynamic responses in attentional task, mindfulness, anxiety, positive states of mind, and visual analog scale.

C H A P T E R - 2

LITERARY RESEARCH ON MEDITATION

2.0 LITERARY RESEARCH ON MEDITATION

2.1 BACKGROUND AND SCOPE

The word "conscious" is originally derived from the Latin, *conscious* (con- "together" and Scio "to know"). Consciousness is undoubtedly the most valuable attribute of all of humanity’s possessions. From the beginning of human presence, consciousness has continued to rise in depth, comprehension, intelligence, skills, and creativity. Looking at our world today, we cannot help but be enormously awed by the developments that have been made through the centuries. Inspite of our growth in consciousness and incredible developments, humanity, for the most part has a very long way to go to experience the higher levels of consciousness that await us. It is an unexplored area of life that has always eluded the scientists, philosophers, and mystics alike. The story of search into consciousness is as old as the human race itself. But we have yet to reach any concrete conclusion. There are three approaches to explore consciousness i.e., experimental (realm belonging to the scientist), expositional (domain of the philosophers), and experiential (area of mystics).

The states of consciousness have interested Indians for many centuries and they have made great contribution to this science. The approaches, the definition and the language used to describe the consciousness differ widely between the East and the West. Some of the definitions used by Western Scientists interested in the study of consciousness are mentioned below:

Western Concepts of Consciousness

John Horgan Science says, “The most elusive and inescapable of all phenomena is consciousness, our immediate subjective awareness of the world and ourselves”. Consciousness is revealed as the order of the function, with pattern (structure), precision (quality), and regularity (timing) in the physical universe, and as cognition, experience, and discrimination in living beings. Consciousness is revealed when a man realizes mind, life-force (astral body), and the primordial Static-Silent State (Unified Force). The precisional devices of the mind are named, and the mind’s capacity to shrink to the particle level and expand to encompass the universe is revealed. It is the supreme level of mental reflection of objective reality, inherent in man exclusively by virtue of his sociohistoric essence. Another statement says, “Consciousness is the general master of psychological functions, improperly identified with some mental functions, (most often with attention or thinking)” and “for scientific psychology, consciousness is complete fiction”. William James, the philosopher, stated that the “stream of consciousness” is a river flowing through a man’s consciousness waking hours.

Neurobiologists define the term consciousness as the ability of the organism to respond purposefully to change in the environment, and thus consciousness is a basis function of life at all levels of evolution.

Indian Concept of Consciousness

The Indian approach appeals more to reason and scientific analysis compared to the Western concepts of mind and consciousness. The Indian concept of consciousness is known as *prajñā* or *cetanā*. On this base, the *gyānendriyā* and the *karmendriya* create the mind (*manas*, *chittam*), which responds to the impulses from the senses (*īndriyā*). The response could be positive or negative, leading to the attraction (*raga*) or repulsion (*dveṣā*). These build up emotions and create enjoyment (sukham) and distress (dukkham) resulting in the desire (*kama*), anger (*krodha*), avarice (*lobha*), and hatred (*dvesa*). All these are still at the mind level (*manas*) and the whole system is included in the *īndriyā*. Above this, mind or manas or chitta, operates an intelligence (*buddhi*) which is capable of discrimination and also capable of imposing its decision on the mind. Above this level is the feeling of "I" ness or self awareness (*ahamkara*). This "I" ness leads to the feelings of possession, "mine" the sense of ownership of the whole body and of all the mental activities including all emotions. In Indian scriptures, consciousness is known as cit, caitanya, prajna, atman etc deviod of intentionality and mental representations. It is pure 'contentless' awareness. It is absolute self-awareness that transcends the senses.

Yoga is the process of shifting the center of our consciousness from the empirical self to the eternal Self. The first step required in this endeavor is to separate the eternal from the empirical, the *Purusha* from *Prakriti*, the Being of Becoming. This is achieved by following a process of detachment which is normally referred to attaining the "state of the witness" or *Saksi-Bhava*.

2.2 SUMMARY OF EARLIER WORKS ON MEDITATION

Meditation and mental activity has been discussed in the earlier PhD thesis from S-VYASA, Bengaluru, India (Naveen, 2005; Patil, 2007; Pailoor, 2009; Kumar, 2019; Raghvendra, 2012). Meditation follows concentration. It is very difficult to say where concentration ends and meditation begins. In *dhyāna*, all worldly thoughts are shut out from the mind. The mind is filled or saturated with divine thoughts, with the divine glory or with the divine presence. Meditation is the continuous flow of thought of one thing, God or Atman. It is keeping up with one idea of God alone, always like the continuous flow of oil from one vessel to another, *tailadhāravat*.

Meditation is the seventh rung or step in the ladder of *Ashtanga* Yoga of Patanjali. *Yamā* (self-restraint), *niyama* (religious observance), *āsana* (posture), *prāṇāyama* (restraint or regulation of breath), *pratyāhāra* (abstraction or withdrawal of the senses), is *bahiranga* (external) yoga for the physical body. *Dhāraṇā* (concentration), *dhyāna* (meditation) and *samādhī* (superconsciousness state or blissful union with the Supreme Self) are the eight steps of Yoga. The last three steps are referred as *Antarang* (internal) yoga.

Regular meditation opens the avenues of intuitional knowledge, makes the mind calm and steady, awakens as ecstatic feeling and brings the aspirant in contact with the source or the Supreme *puruśā*. If there are doubts, they are all cleared when the aspirant follows the path of *dhyāna* yoga steadily.

The concept of *OM* meditation and its benefits were explained in the earlier PhD thesis entitled "Concept of Om meditation and its components (*cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*) according to ancient yogic texts and spiritual lore" (Kumar, 2009). The mind is disciplined in the beginning by fixing it on a concrete object or symbol. AUM, the *Praṇavaḥ*, the Omkara is the only symbol of God (*Īśvara*, Brahman), the absolute, described in *Māṇḍukyopaniṣat* (Sivananda, 1998). This symbol denotes the all-pervading immortal, indivisible, self-luminous, unchanging Brahman, the Supreme Self.

A technique of 'moving meditation', which combines the practice of yoga postures with guided meditation was devised, called Cyclic Meditation (CM), by H.R. Nagendra, Ph.D., which is conducive to getting into a meditative state. This technique has been covered in the earlier PhD thesis entitled "Concepts of meditation in traditional yogic and spiritual literature" (Patil, 2007) and "Concept of cyclic meditation with special reference to traditional yogic and spiritual literature" (Pailoor, 2009). The *Māṇḍukyopaniṣat* describes four conditions of the self, which are different degrees of consciousness. The soul is four-footed, or has four conditions. The first condition is the waking state in which the soul is conscious of external objects. It enjoys gross things through five cognitive organs, five motor organs, five vital principles, the mind, intellect, egoism, and memory and is called *Vaisvanaraḥ*. The second condition is the dream state in which the soul is conscious of internal objects, enjoys subtle things through the mind invested with the subconscious impressions of waking cognitions, and implied by nescience, attachment, merits, and demerits, independent of the external sense-organs. This is called *Taijasa*. The third condition is deep sleep in which there are no desires. In this state the soul is centered in itself, filled with consciousness and bliss. Experience pure consciousness is called *prajñā*. The fourth condition is superconsciousness in which the soul is neither conscious of external objects, internal objects, nor of consciousness, and transcends both consciousness and unconsciousness.

States of meditation (*cañcalatā, ekāgratā, dhāraṇā,* and *dhyana*) were briefly compiled in another PhD thesis entitled "Psychophysiology of meditation, including responses to external stimuli" (Naveen, 2005). Similarly, these four mental states are described in details in another thesis by Raghvendra, 2012, entitled, "Concept of meditation in traditional yogic texts & spiritual lore" using traditional Indian texts.

2.3 AIMS AND OBJECTIVES

The present study was intended to obtain a greater understanding on growth of awareness or consciousness (*cañcalatā*, *ekāgratā*, *dhāraṇā*, *dhyana*, *samādhi*, stages of *samādhi*, and *kaivalya*) as described in classical yogic texts and spiritual literature.

2.4 Materials and Methods

2.4. A - Vedic sources and Classical Yogic Texts includes:

- ***Upaniṣad* (उपनिषद्)**
  - *Kaṭhopaniṣat̠ (*कठोपनिषत*)*
  - *Kenopaniṣad* (केनोपनिषद्)
  - *Māṇḍukyopaniṣat* (माण्डुक्योपनिषत्)
  - *Māṇḍūkyopaniṣat Kārikā* (माण्डूक्योपनिषत् कारिका)
  - *Muṇḍakopaniṣat* (मुण्डकोपनिषत्)
  - *Śvetāśvataropaniṣat* (श्वेताश्वतरोपनिषत्)
  - *Aitareyopaniṣat* (ऐतरेयोपनिषत्)
  - *Praśnopaniṣat* (प्रश्नोपनिषत्)
- ***Vivekacūḍāmaṇi Śaṅkarācārya* (विवेकचूडामणि शंकराचार्य)**
- ***Patañjali Yogasūtra* (पतंजलि योगसूत्र)**
- ***Śrīmadbhagavadgītā* (श्रीमद्भगवद्गीता)**

2.4. B – METHODS

The above mentioned traditional texts were studied to understand the different stages of awareness or consciousness. These *vaidik* sources and classical yogic texts were studied to compile the authentic information on ‘growth of awareness’. The aphorism and verses related to the present topic were collected, compiled, and presented in a systematic way.

2.5 GROWTH OF AWARENESS or CONSCIOUSNESS

Yoga provides systematic methods for ceasing to identify with the fluctuation or modifications [thought waves, whirlpools of the mind (*citta-vřtti*)] and for ultimately achieving complete awareness, independence, and isolation from matter/mind (*citta-vřtti*) liberation as pure consciousness. In a spiritual discipline of constant practice (*tapas*) and detachment (*vairāgya*), one encounters various obstacles or hindrances (*kleṣa*, afflictions) that disturb the equilibrium of the mind: ignorance (*avidyā*), egoism (*asmitā*), attachment (*rāgā*), aversion (*dveṣa*), and clinging to life (*abhiniveśa*). These five hindrances are the chief causes of confusion and suffering in life.

Patañjali identified eight practices that help one overcome the hindrances, increase discriminative discernment, and move forward in one's psychospiritual development. These are eight limbs (*aṣṭāng*) of yoga praxis: abstentions or restraints (*yama*), observances or disciplines (*niyama*), posture (*asana*), control of breath/*prānā* (*prāṇāyāma*), withdrawing sensory activity from control by external objects (*pratyāhāra*), concentration (*dhāraṇā*), meditation (*dhyana*), and absorption (*samādhi*). By engaging in these practices diligently and intensively, a yogi can acquire progressively greater control of the body, senses, emotion, and thoughts; recognize and discriminate these limited and limiting disturbances (the Seen) from one's true Self (the Seer); become capable of direct supersensory knowing; and ultimately become fully Self-realized in attaining liberation (*kaivalya*). At certain stages of the yogi's progressive development, various attainments or accomplishments (*siddhis*, powers) emerge. The overall progress of awareness form distorted thinking to reaching ultimate reality (*Purusha*) are treated below.

2.5.1 *Cañcalatā* (Random thinking or Distracted attention)

Mind is very unsteady and always moves from one state to another state. Most of the time it dwells either in the past or the future. Haphazard, unconnected, multiple thoughts are experienced most of the time. This randomness is the nature of the mind. This random state of mind is called *Cañcalatā* state.

Śrīmadbhagavadgītā **(श्रीमद्भगवद्गीता)**

This has been mentioned in the ***Śrīmadbhagavadgītā*** and presented in the form of conversation between Lord *Kṛṣṇa* and Arjuna.

Arjuna says: चञ्चलं हि मनः कृष्ण प्रमाथि बलवद्दृढम् ।
तस्याहं निग्रहं मन्ये वायोरिव सुदुष्करम् ॥

Cañcalam hi manaḥ kṛṣṇa pramāthi balavaddṛḍham
Tasyāham nigraham manye vāyoriva suduṣkaram.

(Śrīmadbhagavadgītā, 6-34)

The mind verily is, O *Kṛṣṇa*, restless, turbulent, strong and unyielding; I deem it quite as difficult to control as the wind.

Arjuna experiences the restless mind. He feels his mind cannot be controlled deeming it ever “turbulent, strong, and unyielding”. The turbulence shows not only the speed in the flow of thoughts, but also their restlessness and agitations, creating undulating waves rising to the surface. When turbulence becomes strong it is difficult to control and bring it back from its attachments. When the mind has flickered into any new channel of its own choice, for a moment, it is ‘unyielding’.

काम एष क्रोध एष रजोगुणसमुद्भवः।
महाशनो महापाप्मा विद्धयेनमिह वैरिणम्॥

Kāma eṣa krodha eṣa rajoguṇasamudbhavaḥ ।

Mahāśano mahāpāpmā viddhyenamiha vairiṇam ।।

(Śrīmadbhagavadgītā, 3-37)

It is lust, it is anger, born of Rajoguna, insatiable and prompting man to greater sin. Know this to be the enemy here.

धूमेनाव्रियते वह्निर्यथादर्शो मलेन च।
यथोल्बेनावृतो गर्भस्तथा तेनेदमावृतम्॥

Dhūmenāvriyate vahniryathādarśo malena ca ।

Yatholbenāvṛto garbhastathā tenedamāvṛtam ।।

(Śrīmadbhagavadgītā, 3-38)

As fire is enveloped by smoke, as a mirror by dirt, and as a fetus remains enclosed in the womb, so is this shrouded by lust.

आवृतं ज्ञानमेतेन ज्ञानिनो नित्यवैरिणा।
कामरूपेण कौन्तेय दुष्पूरेणानलेन च॥

Āvṛtaṁ jñānametena jñānino nityavairiṇā ।

Kāmarūpeṇa kaunteya duṣpūreṇānalena ca ।।

(Śrīmadbhagavadgītā, 3-39)

Knowledge, O son of Kunti, is covered up by this constant enemy of the wised in the form of desire, which is an insatiable fire of lust.

इन्द्रियाणि मनो बुद्धिरस्याधिष्ठानमुच्यते।
एतैर्विमोहयत्येष ज्ञानमावृत्य देहिनम्॥

Indriyāṇi mano buddhirasyādhiṣṭhānamucyate |
Etairvimohayatyeṣa jñānamāvṛtya dehinam ||

(Śrīmadbhagavadgītā, 3-40)

The senses, the mind and the *Buddhi* are said to be in the seat. With these it veils knowledge and deludes the embodied spirit.

ध्यायतो विषयान्पुंसः सङ्गस्तेषूपजायते।
सङ्गात्सञ्जायते कामः कामात्क्रोधोऽभिजायते॥

Dhyāyato viṣayānpuṁsaḥ saṅgasteṣūpajāyate |
Saṅgātsañjāyate kāmaḥ kāmātkrodho'bhijāyate ||

(Śrīmadbhagavadgītā, 2-62)

In one who dwells longing on sense objects, an inclination towards them is generated. This inclination develops into desire, and desire begets anger.

क्रोधाद्भवति सम्मोहः सम्मोहात्स्मृतिविभ्रमः।
स्मृतिभ्रंशाद् बुद्धिनाशो बुद्धिनाशात्प्रणश्यति॥

Krodhādbhavati sammohaḥ sammohātsmṛtivibhramaḥ |
Smṛtibhraṁśād buddhināśo buddhināśātpraṇaśyati ||

(Śrīmadbhagavadgītā, 2-63)

Anger generates delusion, and delusion results in loss of memory. Loss
of memory brings about the destruction of discriminating intelligence,
and loss of discriminative intelligence spells ruin to a man.

When the mind has flickered into any new channel of its own choice, for the moment, it is 'unyielding'. He beautifully describes controlling the mind is as difficult than controlling the wind.

Lord *Kṛṣṇa* answers:

असंशयं महाबाहो मनो दुर्निग्रहं चलम् ।
अभ्यासेन तु कौन्तेय वैराग्येण च गृह्यते ॥

Asaṁśayaṁ mahābāho mano durnigrahaṁ calam'
Abhyāsena tu kaunteya vairāgyeṇa ca gṛhyate.

(Śrīmadbhagavadgītā; 6-35)

Undoubtedly, O mighty-armed one, the mind is difficult to control
and is restless; but, by practice,
O Son of Kunti, and by dispassion, it is restrained.

Lord *Kṛṣṇa* accepts the argument of Arjuna and answers that there is a method by which the invincible mind can be brought under control. He mentions *abhyāsa* (practice) and *vairāgya* (renunciation) as a method to control the mind.

Sage Patañjali also mentions *abhyāsa* (practice) and *vairāgya* (renunciation) as a means to control the mind.

अभ्यासवैराग्याभ्याम् तन्निरोधः।

Abhyāsavairāgyābhyām tannirodhaḥ।

(Patañjali Yogasūtra; 1-12)

Their suppression by persistent practice and non-attachment.

When consciousness takes the lead, naturally the seer takes a back seat. The seed of change is in the consciousness and not in the seer. Consciousness sees objects in relation to its own idiosyncrasies, creating fluctuations and modifications in one's thoughts.

तत्र स्थितौ यत्नोऽभ्यासः।

Tatra sthitau yatno'bhyāsaḥ।

(Patañjali Yogasūtra; 1-13)

Abhyāsa is the effort of being firmly established in that state

(of *Citta-Vrtti-Nirodha*).

According to Patañjali, *abhyāsa* is entire effort directed towards the attainment of that ultimate state, in which cessation of the modifications of the mind happens. He further says in the next sutra, *abhyāsa* (practice) should be uninterrupted and continuous with devotion.

दृष्टानुश्रविकविषयवितृष्णस्य वशीकारसंज्ञा वैराग्यम्।

Dṛṣṭānuśravikaviṣayavitṛṣṇasya vaśīkārasañjñā vairāgyam।

(Patañjali Yogasūtra; 1-15)

The consciousness of perfect mastery (of desires) in the case of one

who has ceased to crave for objects, seen or unseen, is *vairāgya*.

Vairāgya plays an important role in gaining mastery over the mind. *Vairāgya* means the absence of any attraction towards objects which give pleasure. Attraction and repulsion are a pair of opposites and repulsion binds the soul to the objects as much as an attraction. The desire, in its two expressions of *rāga* (attachment) and *dveśa* (repulsion), is a tremendous driving and disturbing force which is continually creating *vṛttis* in the mind. Hence, one has to be free from both attraction and repulsion.

***Yogavāsiṣṭha* (येगवासिष्ठ)**

Sage ***Vasiśthā*** explains the fickleness of mind in the ***Yogavāsiṣṭha***

चेतश्चञ्चलया वृत्त्या चिन्तानिचयचञ्चुरम् ।

धृतिं बध्नाति नैकत्र पञ्जरे केसरि यथा ॥

Cetaścañcalayā vṛttyā cintānicayacañcuram|

Dhṛtiṁ badhnāti naikatra pañjare kesari yathā||

(Yogavāsiṣṭha; 1-5)

The mind, expert in its collection of sorrowful thoughts, does not fasten its hold on one place because of its fickle condition, as a lion in a cage.

चेतः पतति कार्येषु विगतः स्वामिषेष्विव ।

क्षणेन विरन्ति याति बालः क्रीडनकादिव ॥

Cetaḥ patati kāryeṣu vigataḥ svāmiṣeṣviva|

Kṣaṇena viranti yāti bālaḥ krīḍanakādiva||

(Yogavāsiṣṭha; 1- 6)

The mind descends on actions (or things) like a bird on its prey. It becomes indifferent in a moment like a child with a toy.

न हि चञ्चलताहीनं मनः क्वचन दृश्यते ॥
चञ्चलत्वं मनोधर्मो वह्नेः धर्मो यथोष्णता ।

Na hi cañcalatāhīnaṁ manaḥ kvacana dṛaśyate ॥
Cañcalatvaṁ manodharmo vahneḥ dharmo yathoṣṇatā ॥

(Yogavāsiṣṭha; 7-31)

Devoid of movement, the mind is not perceived anywhere indeed. Movement is the nature of the mind as heat is the characteristic of fire.

संसाराख्ये महारण्ये प्रभ्रमन्ति मनांसि हि ॥

Saṁsārākhye mahāraṇye prabhramanti manāṁsi hi ॥

(Yogavāsiṣṭha; 6-33)

In this great forest of worldly existence, minds indeed wonder about.

क्वचित् क्वचित् कदाचिच्च तस्मात् उद्यन्ति शक्तयः ।
देशकालादिवैचित्र्यात् क्ष्मातलादिव शालयः ॥

Kvacit kvacit kadācicca tasmāt udyanti śaktayaḥ ।

Deśakālādivaicitryāt kṣmātalādiva śālayaḥ ॥

(Yogavāsiṣṭha; 6-44)

In one place and in another and at some time or other, energies rise from it like rice (rising) from the surface of the earth, by the diversity of place, time and the like.

चिन्मात्रं चेत्यरहितं अनन्तं अजरं शिवम ।

अनादिमध्यपर्यन्तं यदनादि निरामयम् ॥

Cinmātraṁ cetyarahitam anantam ajaraṁ śivama।

Anādimadhyaparyantaṁ yadanādi nirāmayam।।

(Yogavāsiṣṭha; 3-35)

The nature of pure Consciousness free from the things perceived, boundless, undecaying, blissful, devoid of beginning, middle and end, existing from eternity and without taint.

विबोधैकानुसन्धानात् चिदंशात्मतया मनः ॥

चिदेकतां उपायाति दृढाभ्यासवशादिह ।

Vibodhaikānusandhānāt cidaṁśātmatayā manaḥ ॥

Cidekatāṁ upāyāti dṛḍhābhyāsavaśādiha.

(*Yogavāsiṣṭha; 7-32)*

The mind, because of its being of the nature of a part of consciousness (or pure intelligence) attains to the state of the one undivided consciousness by inquiry into (or reflection on) pure intelligence (or perception) and by the power of firm practice.

***Vivekacūḍāmaṇi –Śaṅkarācārya* (विवेकचूडामणि शंकराचार्य)**

पञ्चेन्द्रियैः पञ्चभिरेव होतृभिः प्रचीयमानो विषयाज्यधारया ।
जाज्वल्यमानो बहुवासनेन्धनैः मनोमयाग्निर्दहति प्रपञ्चम् ॥

Pañcendriyaiḥ pañcabhireva hotṛbhiḥ pracīyamāno viṣayājyadhārayā ।
Jājvalyamāno bahuvāsanendhanaiḥ manomayāgnirdahati prapañcam ॥

(Vivekacūḍāmaṇi; 168)

The *manomaya kośa* is the sacrificial fire. The five organs are the sacrificing priests. They pour into the fire the oblations of the sense-objects. The various *vāsanās* are the fuel. With these the *manomaya kośa* burns out the world.

विषयाभिमुखं दृष्ट्वा विद्वांसमपि विस्मृतिः ।
विक्षेपयति धीदोषैर्योषा जारमिव प्रियम् ॥

Viṣayābhimukhaṁ dṛṣṭvā vidvāṁsamapi vismṛtiḥ ।
Vikṣepayati dhīdoṣairyoṣā jāramiva priyam ॥

(Vivekacūḍāmaṇi; 323)

Finding him inclined to sense-objects, forgetfulness confound even a learned man through defects of the intellect like a damsel distracting a paramour.

***Māṇḍūkyopaniṣat Kārikā* (माण्डूक्योपनिषत् कारिका)**

The *mandukya karika* discusses the nature of the material and mental worlds, the nature of consciousness, and the meaning of causality. It accomplishes this by offering an experiential interpretation of the three states of the individual i.e., waking (*vaisvanara*), dreaming (*taijasa*), and deep sleep (*prajna*). The fourth state is the state of pure consciousness (*turiya*), which is absolute reality – Brahman, Atman. This Upanishad also focuses on the eternal sound *AUM* represents the entire universe, and how *AUM* relates to the four states of consciousness.

मनसो निग्रहायत्तमभयं सर्वयोगिनाम् ।
दुःखक्षयः प्रबोधश्चाप्यक्षया शान्तिरेव च ॥

Manaso nigrahāyattamabhayaṁ sarvayogināṁ ॥

Duḥkhakṣayaḥ prabodhaścāpyakṣayā śāntireva ca ॥

(*Māṇḍūkya Kārikā; 3-40)*

Yogīs who do not follow the Path of knowledge as declared in this *Kārikā* depend upon the control of their mind for fearlessness and destruction of misery, and also the knowledge of the Self and eternal peace.

उत्सेक उदधेर्यद्वत्कुशाग्रेणैकबिन्दुना ।
मनसो निग्रहस्तद्वद्भवेदपरिखेदतः ॥

Utseka udadheryadvatkuśāgreṇaikabindunā ।

Manaso nigrahastadvadbhavedaparikhedataḥ ॥

(*Māṇḍūkya Kārikā; 3-41)*

The mind can be brought under control only by relentless effort like that which is required to empty the ocean drop by drop with the help of the front tip of a *Kuśā*-grass-blade.

Cañcalatā state of mind is featured by (i) multiple subjects and multiple thoughts (ii) unconnected thoughts (iii) turbulent thoughts and (iv) *rājasik* in nature.

2.5.2 *Ekāgratā* (Concentration)

In *Saṁskṛta, ekāgratā* (moving in one direction) means concentration. In concentration, there are multiple connected thoughts and a single object. The channelizing of all thoughts in a single direction. Concentration cannot be done for a long duration since this leads to fatigue. The *cañcala* mind has to be brought under control and focused on a single thought. Though the mind is difficult to control, this can be done by steady practice and cultivation of dispassion for worldly enjoyments, coupled with strong aspiration of the higher life. One who practices the discipline of concentration is immensely greater than one engaging himself entirely in scripture-ordained works. Concentration is restraining the mind into smaller and smaller limits.

However, the mind is defocused, wandering, and restless in nature. Most of the time we spend in *cañcalatā* state. By practice one has to train the mind. In the *Bhagavad Gita*, Lord Krishna mentions about how to concentrate the mind.

तत्रैकाग्रं मनः कृत्वा यतचित्तेन्द्रियक्रियः।

उपविश्यासने युन्ज्यात् योगमात्मविशुद्धये ॥

Tatraikāgraṁ manaḥ kṛtvā yatacittendriyakriyaḥ ।

Upaviśyāsane yunjyāt yogamātma viśuddhaye ॥

(Śrīmadbhagavadgītā; 6 -12)

There, having made the mind one-pointed, with the actions of the mind and the senses controlled, let him, seated on the seat, practice yoga, for the purification of the self.

Sitting in a proper place, in an appropriate pose one has to make the mind single pointed. Concentration is the beginning of meditation. The wandering mind has to be controlled and channelised on a single point. This concentration can be inside our body (on certain special spiritual centers) or outside the body. Single pointedness is the very potent nature of the mind. The mind gets stunned by its own silence, or confused and even mad when it gets dynamised by either the inner forces of its own surging imaginations or the outward pull exerted by the attachments of the sense organs. If these two sources of distractions are blocked, the mind becomes single pointed.

Kaṭhopaniṣat (कठोपनिषत्)

आत्मानँ रथितं विद्धि शरीरँ रथमेव तु ।

बुद्धिं तु सारथिं विद्धि मनः प्रग्रहमेव च ॥

Ātmānam̐ rathitaṁ viddhi śarīram̐ rathameva tu ।

Buddhiṁ tu sārathiṁ viddhi manaḥ pragrahameva ca ।।

(Kaṭhopaniṣat, 1-3-3)

Know the Atman as the Lord of the Chariot, the body as the chariot;

know the intellect as the charioteer and the mind again as the reins.

इन्द्रियाणि हयानाहुर्विषयाँ स्तेषु गोचरान् ।

आत्मेन्द्रियमनोयुक्तं भोक्तेत्याहुर्मनीषिणः ॥

Indriyāṇi hayānāhurviṣayām̐ steṣu gocarān ।

Ātmendriyamanoyuktaṁ bhoktetyāhurmanīṣiṇaḥ ।।

(Kaṭhopaniṣat, 1-3-4)

They say, the senses are the horses and their objects are the roads;

the Atman, the senses and the mind united, the wise call the enjoyer.

तां योगमिति मन्यन्ते स्थिरामिन्द्रियधारणाम् ।

अप्रमत्तस्तदा भवति योगो हि प्रभवाप्ययौ ॥ ११ ॥

Tāṁ yogamiti manyante sthirāmindriyadhāraṇām ।

Apramattastadā bhavati yogo hi prabhavāpyayau ।। 11।।

(Kaṭhopaniṣat, 2-3-11)

The firm control of the senses and the mind is the yoga of concentration. One must be ever watchful for this yoga is difficult to acquire and easy to lose.

Pure Atman is ever the silent witness (*saksi*). He is actionless (*Niṣkriya*, *Akriya*). He is a non-doer (*Akarta*). He appears as the agent or enjoyer when He is united with the mind, senses and the body through *Avidya*, ignorance. The mind acts and enjoys through the senses and the body. The attributes of the mind, senses, *Prana* and body are transferred to the pure Atman and the attributes of Atman are transferred to the mind and the body.

Śvetāśvataropaniṣat **(श्वेताश्वतरोपनिषत्)**

प्राणान् प्रपीड्येह संयुक्तचेष्टः क्षीणे प्राणे नासिकयोच्छ्वसीत ।

दुष्टाश्वयुक्तमिव वाहमेनं विद्वान् मनो धारयेताप्रमत्तः ॥

Prāṇān prapīḍyeha saṁyuktaceṣṭaḥ kṣīṇe prāṇe nāsikayocchvasīta ।

Duṣṭāśvayuktamiva vāhamenaṁ vidvān mano dhārayetāpramattaḥ ।।

(Śvetāśvataropaniṣat; 2-9)

Keeping down the sense, subduing his desires, and gently breathing through the nostril, let the wise diligently attend to the mind, as the charioteer to a car, drawn by vicious horses.

युञ्जानः प्रथमं मनस्तत्त्वाय सविता धियः।
अग्नेर्ज्योतिर्निचाय्य पृथिव्या अध्याभरत्॥

Yuñjānaḥ prathamaṁ manastattvāya savitā dhiyaḥ ।
Agnerjyotirnicāyya pṛthivyā adhyābharat ॥

(Śvetāśvataropaniṣat; 2-1)

Concentrating first the mind and the senses (upon Brahman) for realising the Truth, may *Savitri*, having seen the illuminating fire, bring it out of the earth.

The ways to develop concentration on Brahman are described here. The aspirant should purify his mind first through selfless service (*Niṣkāma Karma Yoga*), *Japa*, *Kirtan*, *Sattvic* food, service of the Guru and the poor. Then only will he be able to realise the benefits of concentration. The senses should be brought under control. They should be withdrawn from their respective objects. One cannot have concentration of mind if the senses are not controlled.

युक्त्वाय मनसा देवान् सुवर्यतो धिया दिवम्।
बृहज्ज्योतिः करिष्यतः सविता प्रसुवाति तान्॥

Yuktvāya manasā devān suvaryato dhiyā divam ।
Bṛhajjyotiḥ kariṣyataḥ savitā prasuvāti tān ॥

(Śvetāśvataropaniṣat; 2-3)

Having controlled the senses through which heaven is attained
with the mind and the intellect, let *Sāvitrī* cause them to manifest
the divine infinite light.

The senses have a natural tendency to run towards the external objects. The *Sādhaka* should check the outgoing tendency of the senses through the practice of *dama* (self-restraint) and *pratyāhāra* (abstraction or withdrawal). He should not allow the senses to come in contact with the object. He should disconnect the senses from the mind by allowing the mind to think constantly of the form of the Lord or the attributes of Brahman. This is a trying discipline indeed, but the fruits of the practice is everlasting peace and immortality.

This is withdrawing sensory activity from control by external objects. "The senses disunite themselves from their own objects and resemble, as it were, their own form of consciousness". The sensory processes remain active, but there are no external sources of information for them to detect; the senses, now, are akin to searchlights that shine upon nothing in particular. This sensory restriction frees the attention from external, environmental distractions; the mind becomes more tranquil and pure.

2.5.3 *Dhāraṇā* (Focused Meditation)

Dhāraṇā usually is translated as focused attention – the binding of consciousness to one place, object, or idea. Attention is exclusively focused upon one object or idea for sometime. As a result, the mind becomes steady and less disturbed. The ambient in which the mind is allowed to wander is greatly reduced; thought waves lessen in number and magnitude. Focused thinking should involve holding the mind within a center of spiritual consciousness in the body, or fixing it on some divine form, either within the body or outside it, i.e., it is important that concentration has a spiritual focus.

The sage *Patañjali* defines *dhāraṇā* as, “fixing the mind in one place”.

देशबन्धश्चित्तस्य धारणा ॥ १ ॥

Deśabandhaścittasya dhāraṇā ||1||

(Patañjali Yogasūtra; 3-1)

Fixing the mind in one place is *dhāraṇā.*

Dhāraṇā means the focus of attention. Focusing the attention on a chosen point or area, within or outside the body, is concentration. By it the functions of the mind are controlled and brought to one focal point. *Dhāraṇā* may be focused on external or internal objects. External object should be auspicious and associated with purity. Internally, the mind penetrates to the soul, the core of one’s being: the object is, in reality, pure existence. While *Patañjali* only mentioned fixing the mind on any place as ‘*dhāraṇā*, *Vyāsa* further explains about the places where one can concentrate.

नाभिचक्रे हृदयपुण्डरीके मूर्ध्नि ज्योतिषि नासिकाग्रे
जिह्वाग्रे इत्येवमादिषु देशेषु बाह्ये वा
विषये चित्तस्य वृत्तिमात्रेण बन्ध इति धारणा ।१।

Nābhicakre hṛdayapuṇḍarīke mūrdhni jyotiṣi nāsikāgre
jihvāgre ityevamādiṣu deśeṣu bāhye vā
viṣaye cittasya vṛttimātreṇa bandha iti dhāraṇā |1|

> *Dhāraṇā* is fixing the mind, through its modifications, to places such as the navel circle, the heart lotus, the shining center of the head, the tip of the nose, the tip of the tongue, and other such locations; and to external objects.

These are all the special energy centers in the body and concentrating the mind on them would be ideal. One can also do *dhāraṇā* on outside objects like the moon, sun, fire, top of the mountain, deity of god etc. Performing *saṁyama* on them leads to the attainment of divine powers. The mind cannot come into contact with an external object directly, but only through the senses. Hence, the word modification (*vṛtti*) is used here. When the object is one's navel, heart lotus etc., the outer sense organs are not involved as in the case of outer objects like moon, sun etc.

Īśvara Gītā mentions the following:

हृत्पुण्डरीके नाभ्यां वा मूर्ध्नि पर्वतमस्तके ।

एवमादिप्रदेशेषु धारणा चित्तबन्धनमं् ॥३९ ॥

देशावस्त्थितमालक्षय बुध्धेर्या वृत्तिसन्ततिः ।

वृत्यन्तरैररसंस्पृष्टा तद्धचानं सूरयो विदुः ॥४० ॥

एकाकारसमाधिः स्याद्देशालम्बनवर्जितः ।

प्रत्ययो ह्यर्थमात्रेण योगसाधनमुत्तमम् ॥इति ॥४१ ॥

Hṛtpuṇḍarīke nābhyāṁ vā mūrdhni parvatamastake |

Evamādipradeśeṣu dhāraṇā cittabandhanam ||39||

Deśāvastthitamālakṣaya budhdheryā vṛttisantatiḥ।

Vṛtyantarairasaṁspṛṣṭā taddhacānaṁ sūrayo viduḥ॥40॥

Ekākārasamādhiḥ syāddeśālambanavarjitaḥ।

Pratyayo hyarthamātreṇa yogasādhanamuttamam॥iti॥41॥

Dhāraṇā is the fixing of the mind on places like heart lotus, the navel region, the head and the top of the mountain. The wise understand *dhyana* to be a continues flow of modifications of the mind with reference to the object being concentrated upon. *Samadhi* is the subject becoming one with the object; thus it is devoid of supporting object such as place. There is knowledge only with reference to the object and this is the best means of yoga.

Object of *dhāraṇā* AUM is explained here.

***Praśnopaniṣat* (प्रश्नोपनिषत्)**

AUM represents the manifested *Saguna* Brahman by its audible sound, and the unmanifested Para Brahman or *Nirguna* Brahman by its inaudible or unexpressed form known as *Ardhamantra*. Aspirants who meditate on *AUM* with a pure and one-pointed mind, understanding its right significance attain Brahman, either higher or lower.

स यद्ध्येकमात्रमभिध्यायीत स तेनैव संवेदितस्तूर्णमेव

जगत्याभिसंपध्यते। तमृचो मनुष्यलोकमुपनयन्ते स तत्र

तपसा ब्रह्मचर्येण श्रद्धया संपन्नो महिमानमनुभवति॥

Sa yadhyekamātramabhidhyāyīta sa tenaiva saṁveditastūrṇameva

jagatyābhisampadhyate। tamṛco manuṣyalokamupanayante sa tatra *tapasā brahmacaryeṇa śraddhayā sampanno mahimānamanubhavati ||*

(Praśnopaniṣat; 5-3)

If he meditates on one *Matra* (measure) of it (A) then, he being enlightened by that, comes quickly to earth. The *Rik*-verses lead him to the world of men, and being endowed there with austerity, celibacy and faith, attains greatness.

अथ यदि द्विमात्रेण मनसि संपध्यते सोऽन्तरिक्शं यजुर्भिरुन्नीयते सोमलोकम्।
स सोमलोके विभुतिमनुभूय पुनरावर्तते॥

Atha yadi dvimātreṇa manasi sampadhyate so'ntarikśaṁ
yajurbhirunnīyate somalokam |
Sa somaloke vibhutimanubhūya punarāvartate ||

(Praśnopaniṣat; 5-4)

If he meditates on its second *Matra* only, he becomes one with the mind. He is led up by the *Yajus*-verses to the sky, the world of the moon. Having enjoyed greatness there, he returns again.

यः पुनरेतं त्रिमात्रेणोमित्येतेनैवाक्शरेण परं पुरुषमभि-
ध्यायीत स तेजसि सूर्ये संपन्नः। यथा पादोदरस्त्वचा
विनिर्भुच्यत एवं ह वै स पाप्मना विनिर्भुक्तः स
सामभिरुन्नीयते ब्रह्मलोकं स एतस्माज्जीवघनात् परात्परं
पुरुशयं पुरुषमीक्शते। तदेतौ श्लोकौ भवतः॥

Yaḥ punaretaṁ trimātreṇomityetenaivākśareṇa paraṁ
puruṣamabhidhyāyīta sa tejasi sūrye sampannaḥ | yathā pādodarastvacā

vinirbhucyata evaṁ ha vai sa pāpmanā vinirbhuktaḥ sa sāmabhirunnīyate brahmalokaṁ sa etasmājjīvaghanāt parātparaṁ puruśayaṁ puruṣamīkśate |
Tadetau ślokau bhavataḥ ||

(Praśnopaniṣat; 5-5)

If he meditates on the Highest *Purusha* with this syllable *AUM* of three *Matras*, he becomes united with the bright sun. As a snake is freed from its slough, so is he freed from sin. He is led up by the *Sama*-hymns to the world of the Supreme *Purusha* residing in the heart.

When each of the three Matras A, U, M is taken separately and meditated upon, the meditator has to be born again and again in this world. But if one meditates on the three Matras in combination in respect of every one of the three aspects of Brahman, viz., *Vaisvanara* or *Visva*, representing the waking condition (represented by A), *Taijasa* representing the dreaming condition (represented by U), and *Isvara* or *Prajna* representing the sleeping condition (represented by M). He cannot be shaken. He trembles not, because he has attained the Supreme Brahman, he has become the Atman, the inner Self of all, and one with *AUM*.

Dhāraṇā involves intense focusing on the object chosen for meditation. There is an effort involved while concentrating on the object. The concentration here mentioned is not the ordinary one. It is of the highest form and moving within the limited mental area (or object chosen). The mind has to be concentrated on the chosen object of meditation to be brought back immediately if it wanders. Every object has innumerable aspects and the mind can consider these aspects only one by one. Or it may be that the object may involve a process of reasoning consisting of many steps connected logically with each other and forming an integrated whole. Hence, there is a movement without really leaving the object of concentration. *Sadhaka* has to focus continuously on the object chosen. If the continuity breaks, the mind has to be brought back immediately.

***Śvetāśvataropaniṣat* (श्वेताश्वतरोपनिषत्)**

तिलेषु तैलं दधिनीव सर्पिरापः स्रोतःस्वरणीषु चाग्निः ।
एवमात्माऽत्मनि गृह्यतेऽसौ सत्येनैनं तपसायोऽनुपश्यति ॥ १५ ॥

Tileṣu tailaṁ dadhinīva sarpirāpaḥ srotaḥsvaraṇīṣu cāgniḥ ।
Evamātmā'tmani gṛhyate'sau satyenainaṁ tapasāyo'nupaśyati ।। 15।।

(Śvetāśvataropaniṣat; 15)

As Oil in sesame seeds, as butter in curd, as water in riverbeds, and as fire in wood, even so is the Atman perceived within his own Self by a person who beholds Him by truth and austerity (by controlling his senses and the mind).

युञ्जते मन उत युञ्जते धियो विप्रा विप्रस्य हतो विपश्चितः ।
वि होत्रा दधे वयुनाविदेक इन्मही देवस्य सवितुः परिष्टुतिः ॥ ४ ॥

Yuñjate mana uta yuñjate dhiyo viprā viprasya bṛ̆hato vipaścitaḥ ।
Vi hotrā dadhe vayunāvideka inmahī devasya savituḥ pariṣṭutiḥ ।।

(Śvetāśvataropaniṣat; 4)

Great is the glory of the *Savitri* who is all-pervading, infinite, all-knowing, the one alone who knows the rules, has arranged the sacrificial rites by the *Brahmanas*. The wise control their mind and intellect and practice meditation.

The *vrittis* or thought-waves of the mind should be controlled. Then only one can realize the Self within, which is ever serene. Just as you cannot see the bottom of the lake when there are waves on the surface of the lake, so also you cannot see the Atman, if there are thought waves on the surface of the mind-lake. Yoga is the restraint of the modifications of the mind.

Vague and blurred impressions should be replaced by sharply defined mental images by increasing the degree of alertness and power of attention. The mastery in the practice of *dharana* leads to *dhyāna*.

2.5.4 *Dhyāna* (Meditation)

Dhyāna usually translates as meditation. This is the unbroken flow of thought towards the object of concentration. *Dhyāna* is prolonged and well-mastered concentration; it is more effortless than *dhāraṇā*. The difference between *dhāraṇā* and *dhyāna* is that *dhāraṇā* is more concerned with the elimination of fluctuating thought-waves in order to achieve single-pointed concentration; in *dhyāna*, the emphasis is on the maintenance of steady and profound contemplative observation.

Meditation is keeping the mind focused uninterruptedly on a subject for a certain length of time. It is a mental process by which a meditator becomes one with the object of meditation. Meditation is the seventh stage in *asṭāṅga* yoga of *Patañjali*. He defines *dhyāna* as follows:

तत्र प्रत्ययैकतानता ध्यानम् ॥ ३-२ ॥

Tatra pratyayaikatānatā dhyānam || 3-2||

(Patañjali Yogasūtra; 3-2)

Uninterrupted flow of the mind towards the object of meditation.

The steady, continuous flow of attention directed towards the same point or region is meditation (*dhyāna*).

The sage ***Vyāsa*** further explains about *dhyāna* in his commentary into Yoga *Sūtra*.

तस्मिन्देशे धेयालम्बनस्य प्रत्ययस्यैकतानता सदृशः प्रवाहः प्रत्ययन्तरेणापरामृष्टो ध्यानम् ॥

Tasmindeśe dheyālambanasya pratyayasyaikatānatā sadṛśaḥ pravāhaḥ pratyayantareṇāparāmṛṣṭo dhyānam||

Meditation is a continuous flow of knowledge which is supported by the object of meditation; i.e., A similar flow of knowledge untouched by any other knowledge.

Continuity of mind towards the chosen object is meditation. *Dhāraṇā* on the navel circle, heart lotus, or any other external objects when becomes continuous and devoid of other thoughts it culminates into *dhyāna*. Meditation is achieved through continuous and effortless *dhāraṇā*.

The sanskrit word '*tatra*' means 'in that place' and refers to the place where *dhāraṇā* has been done.The word *pratyaya* means the total content of the mind. '*pratayayaīkatānatā'* meaning continuous flow of mind, refers to the absence of interruptions of distractions which are present in *dhāraṇā*. This can be compared to the flow of oil from one vessel into another. Meditation is cultivating a single thought of the object of meditation by repeating it over and over again. By following the same method and concentrating on the same subject at the same center of consciousness, that single thought becomes a giant thought-wave. In course of time the mind develops a channel for that thought-wave and the practice becomes effortless.

स तु दीर्घकालनैरन्तर्यसत्कारासेवितो दृढभूमिः ॥१४ ॥

Sa tu dīrghakālanairantaryasatkārāsevito dṛḍhabhūmiḥ ।14।

(Patañjali Yogasūtra; 1-14)

Abhyasa becomes firmly grounded on being continued for a long time, without interruption and with reverent devotion.

If a man is able to surrender himself completely to *Isvara* he can pass into *Samadhi* immediately.

Muṇḍakopaniṣat **(मुण्डकोपनिषत्)**

धनुर् गृहीत्वौपनिषदं महास्त्रं शरं ह्युपासा निशितं सन्धयीत ।

आयम्य तद्भावगतेन चेतसा लक्ष्यं तदेवाक्षरं सोम्य विद्धि ॥

Dhanur gṛhītvaupaniṣadaṁ mahāstraṁ śaraṁ hyupāsā niśitaṁ sandhayīta ।

Āyamya tadbhāvagatena cetasālakṣyaṁ tadevākṣaraṁ somya viddhi ।।

(Muṇḍakopaniṣat; 2-2-3)

Having taken the bow supplied by the Upanishad, the great weapon, and fixed on it the arrow sharpened by incessant meditation and having drawn

it with the mind fixed on the Brahman, hit, O gentle youth, at that mark,
the immortal Brahman.

In other words, after fixing the arrow in the bow and drawing it i.e., drawing the mind and the senses from their external objects, and bending i.e., concentrating on Brahman, hit the mark or target, the immortal Brahman, i.e., merge in Brahman through deep meditation.

प्रणवो धनुः शारो ह्यात्मा ब्रह्म तल्लक्ष्यमुच्यते ।
अप्रमत्तेन वेद्धव्यं शरवत् तन्मयो भवेत् ॥

Praṇavo dhanuḥ śāro hyātmā brahma tallakṣyamucyate |
Apramattena veddhavyaṁ śaravat tanmayo bhavet ||

(Muṇḍakopaniṣat; 2-2-4)

Pranava (AUM) is the bow, the Atman is the arrow, and Brahman is called its aim. It is to be hit by a man who is self-collected (with concentration) and then as the arrow becomes one with the target, he will become one with Braham. The constant repetition of *AUM* purifies the mind.

When the mind is purified by *Japa* of *AUM*, it becomes fixed in Brahman, just as the arrow is fixed on the target by the force of the bow. Just as the bow helps the arrow to enter into the target or mark, so also the repetition or, *Japa* of *AUM* and meditation on *AUM* helps the mind to get it fixed in Brahman.

The Brahman which is the mark or target should be hit by one who is self-collected, with undistracted or one-pointed mind, has subdued his senses and mind, who is disgusted with sensual pleasure, who is free from attraction for sensual objects, who is free from the excitement caused by the thirst to possess sensual objects. When Brahman is hit or meditated upon with one-pointed mind, the mind or the individual soul becomes like the arrow, one with the mark, Brahman. When the arrow becomes one with the mark, he who aims attains success. So also, he meditates on Brahman attains success; obtains the fruit of his meditation when he merges himself in Brahman removing the erroneous notion that the body etc., is the Atman.

Meditate on *AUM* with all its attributes. Meditate on *AUM* as the Self or Brahman. Meditate in the heart in order to attain the Supreme Brahman with the help of the sacred Mantra *AUM*. All evils will cease. You will attain immortality and eternal bliss.

स वेदैतत् परमं ब्रह्म धाम यत्र विश्वं निहितं भाति शुभ्रम्।
उपासते पुरुषं ये ह्यकामास्ते शुक्रमेतदतिवर्तन्ति धीराः॥

Sa vedaitat paramaṁ brahma dhāma yatra viśvaṁ nihitaṁ bhāti śubhram |
Upāsate puruṣaṁ ye hyakāmāste śukrametadativartanti dhīrāḥ ||

(Muṇḍakopaniṣat; 3-2-1)

He knows this supreme Brahman, the place where all this universe rests and which shines brightly. The wise, who are free from desires, worship that person, and transcend this seed (are not born again).

Śvetāśvataropaniṣat **(श्वेताश्वतरोपनिषत्)**

ते ध्यानयोगानुगता अपश्यन् देवात्मशक्तिं स्वगुणैर्निगूढाम्।
यः कारणानि निखिलानि तानि कालात्मयुक्तान्यधितिष्ठत्येकः॥

Te dhyānayogānugatā apaśyan devātmaśaktiṁ svaguṇairnigūḍhām |

Yaḥ kāraṇāni nikhilāni tāni kālātmayuktānyadhitiṣṭhatyekaḥ ||

(Śvetāśvataropaniṣat; 3)

They who practiced meditation realized or saw as the cause of creation, the power of God (*Devatma-Sakti*) hidden in His own qualities (*Gunas*) which alone rules over all these causes beginning with time and ending with the individual soul.

Meditation leads to realization. Devatma-Sakti: this is the power of God. It is Maya. Its qualities are *Sattva* (purity, goodness), *Rajas* (activity, passion), *Tamas* (darkness, inertia).

स्वदेहमरणिं कृत्वा प्रणवं चोत्तरारणिम् ।

ध्याननिर्मथनाभ्यासादेवं पश्यन्निगूढवत् ॥

Svadehamaraṇiṁ kṛtvā praṇavaṁ cottarāraṇim |

Dhyānanirmathanābhyāsādevaṁ paśyannigūḍhavat ||

(Śvetāśvataropaniṣat; 14)

By making one’s own body the lower piece of wood or friction stick, and the syllable AUM the upper friction stick and by practicing the friction or churning of meditation, one will realize God who is hidden, as it were. Just as fire becomes visible by rubbing the sticks, so also God becomes visible when one meditates on AUM.

The five main features of the *dhyāna* state are (i) single thought, (ii) effortlessness, (iii) slowness, (iv) wakefulness and (v) expansiveness. Continuous and dedicated practice of meditation helps one to gain mastery over the mind and leads to a state of super consciousness called *samādhi*.

2.5.5 Merging of Seer & Seen – *Samadhi*

In both *dhāraṇā* and *dhyāna* there is still an object and a subject; there continues to be mental self-awareness. In *samādhi*, both distractions and self-awareness disappear and the "object" of attention, alone, remains in the field of awareness. In *samādhi*, the distinction between subject, object and their interrelationship vanishes; one "becomes" the object upon which one is meditating. The "meditator" disappears, and the true nature of the meditative object shines forth, undistorted and untainted by the mind of the meditator. The essence of the "object" is known directly. This Samadhi process is often translated as absorption, cognitive absorption, or ecstasy. An alternative translation of *Samadhi* has described it as, "Cognitive absorption [*samādhi*] is that meditation the whole object [i.e., consciousness] shines forth, as if devoid of its own form". According to Swami Vivekananda, *samādhi* occurs when *dhyāna* "gives up all forms and reveals only the meaning".

Meditation alone will lead to the attainment of the Knowledge of the self. He who contemplates on the significances of the first line will become a Seer of Oneness, a Knower of the Self.

Patañjali Yogasūtra **(पतंजलि योगसूत्र)**

दृष्टानुश्रविकविषयवितृष्णस्य वशीकारसंज्ञा वैराग्यम् ॥

Dṛṣṭānuśravikaviṣayavitṛṣṇasya vaśīkārasañjñā vairāgyam ||

(Patañjali Yogasūtra; 1-15)

The consciousness of perfect mastery (of desires) in the case of one

who has ceased to crave for objects, seen or unseen, is *Vairagya*.

Vairagya means the absence of any attraction towards object which give pleasure. It plays an important part in restraining and then eliminating *Chitta-Vrttis*.

तत्परं पुरुषख्यातेर्गुणवैतृष्ण्यम् ॥

Tatparaṁ puruṣakhyāterguṇavaitṛṣṇyam ||

(Patañjali Yogasūtra; 1-16)

That is the highest *Vairagya* in which, on account of the awareness

of the *Purusa*, there is the cessation of the least desire for the *Gunas*.

In that state the *Purusa* having realized his true nature and having shaken off the yoke of matter has no attraction left even for the subtlest kinds of bliss experienced on the higher planes of existence. He is completely self-sufficient and above all such attractions which are based on the play of the *Gunas*.

Samadhi*: *Samprajñātaḥ

वितर्कविचारानन्दास्मितारूपानुगमात् सम्प्रज्ञातः ॥

Vitarkavicārānandāsmitārūpānugamāt samprajñātaḥ ||

(Patañjali Yogasūtra; 1-17)

Samprajñāta samādhi is that which is accompanied by reasoning,

reflection, bliss and a sense of pure being.

Samādhi is defined as a process of diving into the deeper layers of one's consciousness which functions through different grades of the mind. *Samprajñāta samādhi* develop absorption of consciousness, achieved through engrossment in conjecture, inference and analytical study; synthesis, consideration and discrimination; bliss or elation; and a state of pure being.

Vitarka is an act of involvement by deliberate thinking and study, which leads to the final point or root cause. It is an attempt to distinguish the cause from the effect, a process of judicious experimental research from the gross to the subtle.

Vicara means differentiating knowledge. It is a process of investigation, reflection, and consideration through which the wandering mind is stilled and the *sādhaka* develops mental depth, acuteness, refinement and subtlety.

As the growing body of experience brings maturity, fulfillment is reached and a state of bliss, *anandā*, ensues, freeing the *sādhaka* from the mechanism of study, investigation and fulfillment and leading him to dwell in the self alone. This state is called *asmitā* rupa *samprajñāta samādhi*. Thus, all six gradations of *Sabija samādhi* (*Samādhi* with support or seed) – *savitarka*, *nirvitarka*, *savicāra*, *nirvicāra*, *anandā* and *asmitā* – are explained. This is the gradual progress from the gross body towards the subtle mind, and from the subtle mind towards the source, the core of being.

Savitarka and ***nirvitarka*** *samādhi* belong to the function of the subtle mind and are attained by contemplation on gross elements and objects knowable through the senses. It is also defined as when the mind meditates upon an object again and again, by isolating it from other objects. That sort of meditation where the external gross elements are the objects is called *savitarka samādhi*. When one struggles to take the elements out of time and space, and think of them as they are, it is called *nirvitarka samādhi.* There are two sorts of objects for meditation, the categories of nature, and the *purusḥa*. *Savicāra* and *nirvicāra samādhi* belong to the realm of the mind and are attained by contemplation of subtle elements (*tanmātrā*) and when the same meditation gets beyond time and space, and thinks of the fine elements as they are called *nirvicāra samādhi*. *Ananda* belongs to the realm of mature intelligence. *Anandā* must be attributed not to the senses, but to pure wisdom. Contemplation by the self of the self brings one close to *purusḥa*.

विरामप्रत्ययाभ्यासपूर्वः संस्कारशेषोऽन्यः ॥

Virāmapratyayābhyāsapūrvaḥ saṁskāraśeṣo'nyaḥ ||

(Patañjali Yogasūtra; 1-18)

The void arising in these experiences is another *samādhi.* Hidden
impressions lie dormant, but spring up during moments of awareness,
creating fluctuations and disturbing the purity of the consciousness.

This is the perfect super-consciousness *asamprajñāta samādhi*, the state which gives us freedom. It is experienced with the cessation of all functions of mind, leaving behind only the residual merits, or samskara, of good practices. In this state one is free from passions, desire and appetites. When this state *asamprajñāta samādhi*, super-consciousness, is reached, the *samādhi* becomes seedless.

भवप्रत्ययो विदेहप्रकृतिलयानाम् ।

Bhavapratyayo videhaprakṛtilayānām

(*Patañjali Yogasūtra, 1* -19)

This *Samadhi*, when not followed by extreme non-attachment
becomes the cause of the re-manifestation of the gods and of
those that become merged with nature.

श्रद्धविर्यस्म्रितिसमधिप्रज्नपोर्वक इतरेशम्।

Śraddhaviryasmritisamadhiprajnapoorvaka itareśam

(*Patañjali Yogasūtra, 1* -20)

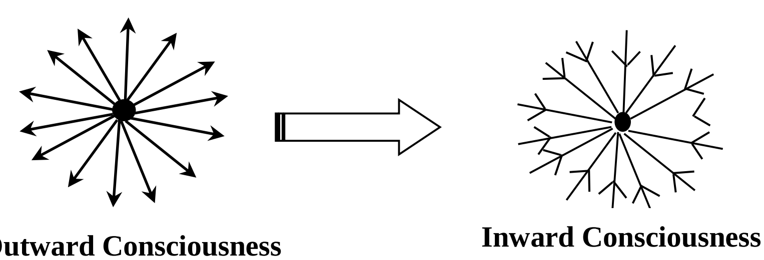
To others (this Samadhi) comes through faith, energy, memory, concentration, and discrimination of the real. These are they who do not want the position of gods, or even that of the rulers of cycles. They attain to liberation.

ततः प्रत्यकच्चेतनाधिगमोऽप्यन्तरायाभावश्च ।

Tataḥ pratyakacetanādhigamo'pyantarāyābhāvaśca

(*Patañjali Yogasūtra, 1*-29)

From the practice of meditation the obstacles (destructive thoughts) will disappear and the consciousness (attention) turns inward.



Apart from the above descriptions, meditation has also been described as a 'specific consciousness state in which deep relaxation and increased internal attention co-exist'. The description of increased internal attention is in the same direction of thinking as that given by the sage *Patanjali* (Taimini, 1961):

सर्वार्थतैकाग्रतयोः क्षयोदयौ चित्तस्य समधि-परिणामः।

Sarvārthataikāgratayoḥ kṣayodayau cittasya samadhi-pariṇāmaḥ

(*Patañjali Yogasūtra, 4* -11)

The gradual setting of the distractions and simultaneous rising of one pointedness is the gradual transformation called *samadhi-pariṇāmaḥ* is the state of meditating mind.

***Śrīmadbhagavadgītā* (श्रीमद्भगवद्गीता)**

योगस्थः कुरु कर्माणि सङ्गं त्यक्त्वा धनञ्जय।
सिद्ध्यसिद्ध्योः समो भूत्वा समत्वं योग उच्यते॥

Yogasthaḥ kuru karmāṇi saṅgaṁ tyaktvā dhanañjaya |
Siddhyasiddhyoḥ samo bhūtvā samatvaṁ yoga ucyate ||

(Śrīmadbhagavadgītā; 2-48)

Engage yourself in action with the mind steadfast in Yoga. Abandon attachments, O Arjuna, and be unperturbed in success and failure. This unpreturbed sameness in all conditions is Yoga.

दूरेण ह्यवरं कर्म बुद्धियोगाद्धनञ्जय।
बुद्धौ शरणमन्विच्छ कृपणाः फलहेतवः॥

Dūreṇa hyavaraṁ karma buddhiyogāddhanañjaya |
Buddhau śaraṇamanviccha kṛpaṇāḥ phalahetavaḥ ||

(Śrīmadbhagavadgītā; 2-49)

The mere action with attachment is far inferior to action done with the mind poised in evenness. Seek shelter in this state of unperturbed evenness which can arise only in a desireless mind in communion with the Divine. Those who work for selfish gains are indeed pitiable.

विषया विनिवर्तन्ते निराहारस्य देहिनः ।
रसवर्जं रसोऽप्यस्य परं दृष्ट्वा निवर्तते ॥

Viṣayā vinivartante nirāhārasya dehinaḥ ।
Rasavarjaṁ raso'pyasya paraṁ dṛṣṭvā nivartate ।।

(Śrīmadbhagavadgītā; 2-59)

From the abstinent soul sense objects fall away, but not the taste for them. When the Supreme Truth is realized, even the taste departs.

The objects of sense, but not the relish for them, turn away from an abstemious dweller in the body; and even relish turned away from him after the Supreme is seen.

Īśopaniṣat **(ईशोपनिषत्)**

यस्तु सर्वाणि भूतान्यात्मन्येवानुपश्यति ।
सर्वभूतेषु चात्मानं ततो न विजुगुप्सते ॥ ६ ॥

Yastu sarvāṇi bhūtānyātmanyevānupaśyati ।
Sarvabhūteṣu cātmānaṁ tato na vijugupsate ।।

(Īśopaniṣat; 6)

He who sees all beings in the Self (Atman) and the Self in all beings, shrinks not from anything thereafter.

The self, harmonized by Yoga, *seeth* the Self abiding in all beings and all beings in the Self; everywhere he *seeth* the same. He who *seeth* me everywhere, the *seeth* everything in Me, of Him I never lose hold, and He shall never lose hold of Me.

यस्मिन्सर्वाणि भूतान्यात्मैवाभूद्विजानतः ।

तत्र को मोहः कः शोक एकत्वमनुपश्यतः ॥७॥

Yasminsarvāṇi bhūtānyātmaivābhūdvijānataḥ ।

Tatra ko mohaḥ kaḥ śoka ekatvamanupaśyataḥ ।।7।।

(Īśopaniṣat; 7)

When, to the knower, all beings become one with his own Atman, how shall he be deluded, what grief is there when he sees everywhere oneness?

Ṭarati sokam atmavit – The Knower of Atman crosses over grief, is the emphatic declaration of the *Srutis*. The three knows are *Avidya*, Kama, Karma (ignorance, desire and action).

***Kaṭhopaniṣat* (कठोपनिषत्)**

एष सर्वेषु भूतेषु गूढोऽऽत्मा न प्रकाशते ।

दृश्यते त्वग्र्यया बुद्ध्या सूक्ष्मया सूक्ष्मदर्शिभिः ॥

Eṣa sarveṣu bhūteṣu gūḍho''tmā na prakāśate ।

Dṛśyate tvagryayā buddhyā sūkṣmayā sūkṣmadarśibhiḥ ।।

(Kaṭhopaniṣat; 1-3-12)

This Atman is hidden in all beings and does not shine forth, but it is seen by subtle seers through their sharp and subtle intellect.

यच्छेद्वाङ्मनसी प्राज्ञस्तद्यच्छेज्ज्ञान आत्मनि ।

ज्ञानमात्मनि महति नियच्छेत्तद्यच्छेच्छान्त आत्मनि ॥

Yacchedvāṅmanasī prājñastadyacchejjñāna ātmani ǀ

Jñānamātmani mahati niyacchettadyacchecchānta ātmani ǀǀ

(Kaṭhopaniṣat; 1-3-13)

Let the wise sink his speech into the mind, the mind into the intellect and the intellect into the Great Atman and the Great Atman into the Peaceful Atman.

In other words, withdraw the speech and other organs into the mind through the process of abstraction (*Pratyahara*) and self-restraint (*Dama*). Merge the mind into the intellect, the intellect into the Cosmic Intelligence, and Intelligence into the Peaceful Atman i.e., the pure unconditional Para Brahman, the substratum and support for everything which is the inner Self of all and which is the witness of all modifications of the intellect. Practice introspection and self-analysis. Control lowers mind by the higher. Stop all the activities of the senses and focus the consciousness in the mind. Afterwards, withdraw the consciousness from the mind and fix it in the intellect. Then withdraw the consciousness from the intellect and fix it on the Cosmic Intelligence. Finally withdraw the consciousness from the Cosmic Intelligence and fix it on the Absolute Consciousness, Brahman, the Absolute.

Kenopaniṣad **(केनोपनिषद्)**

यच्चक्षुषा न पश्यति येन चक्षूँषि पश्यति ।

तदेव ब्रह्म त्वं विद्धि नेदं यदिदमुपासते ॥१-६ ॥

Yaccakṣuṣā na paśyati yena cakṣūm̐ṣi paśyati ।

Tadeva brahma tvaṁ viddhi nedaṁ yadidamupāsate ।। 1-6।।

(Kenopaniṣad; 1-6)

What cannot be seen by the eye, but by which the eyes are able to see – know That alone as Brahman, and not is which people here worship here. Brahman is the real unseen Seer of sight. He is the silent Witness of the activities of the eye. By the light of the Brahman, connected with the activities of the mind, man beholds the activity of the mind.

प्रतिबोधविदितं मतममृतत्वं हि विन्दते ।

आत्मना विन्दते वीर्यं विद्यया विन्दतेऽमृतम् ॥ ४ ॥

Pratibodhaviditaṁ matamamṛtatvaṁ hi vindate ।

Ātmanā vindate vīryaṁ vidyayā vindate'mṛtam ।।2- 4।।

(Kenopaniṣad; 2-4)

Brahman is known well when it is known as the witness of every state of consciousness, because (by such knowledge) he attains immortality. By his self he attains strength, and by knowledge, immortality.

Pratibodhaviditaṁ – Known as a witness of or behind every act of cognition, understood as an object of intuitive knowledge, realized by direct perception in *Samadhi*. *Pratibodham* is the realization through direct intuition (*Aparoksha*), direct beatific vision.

Muṇḍakopaniṣat **(मुण्डकोपनिषत्)**

यथा नद्यः स्यन्दमानाः समुद्रेऽस्तं गच्छन्ति नामरूपे विहाय।
तथा विद्वान् नामरूपाद्विमुक्तः परात्परं पुरुषमुपैति दिव्यम्॥

Yathā nadyaḥ syandamānāḥ samudre'staṁ gacchanti nāmarūpe vihāya ।
Tathā vidvān nāmarūpādvimuktaḥparātparaṁ puruṣamupaiti divyam ||

(Muṇḍakopaniṣat; 3-2-8)

Just as the flowing rivers disappear in the sea, losing their names and forms, so also a seer freed from name and form, goes to the Divine person who is greater than the great.

Taittirīyopaniṣat **(तैत्तिरीयोपनिषत्)**

यतो॒ वाचो॒ निव॑र्तन्ते। अप्रा॑प्य॒ मन॑सा स॒ह। आनन्दं ब्रह्मणो विद्वान्। न बिभेति कदाचनेति। तस्यैष एव शारीर आत्मा। यः पूर्वस्य। तस्माद्वा एतस्मान्मनोमयात्। अन्योऽन्तर आत्मा विज्ञानमयः। तेनैष पूर्णः। स वा एष पुरुषविध एव। तस्य पुरुषविधताम्। अन्वयं पुरुषविधः। तस्य श्रद्धैव शिरः। ऋतं दक्षिणः पक्षः। सत्यमुत्तरः पक्षः। योग आत्मा। महः पुच्छं प्रतिष्ठा। तदप्येष श्लोको भवति॥ १॥ इति चतुर्थोऽनुवाकः॥

Yato` vāco` nivártante । *Aprā́pya` manásā sa`ha* । *Ānandaṁ brahmaṇo vidvān* । *Na bibheti kadācaneti* । *Tasyaiṣa eva śārīra ātmā* । *Yaḥ pūrvasya* ।

Tasmādvā etasmānmanomayāt । *Anyo'ntara ātmā vijñānamayaḥ* । *Tenaiṣa pūrṇaḥ* । *Sa vā eṣa puruṣavidha eva* । *Tasya puruṣavidhatām* । *Anvayaṁ puruṣavidhaḥ* । *Tasya śraddhaiva śiraḥ* । *Ṛtaṁ dakṣiṇaḥ pakṣaḥ* । *Satyamuttaraḥ pakṣaḥ* । *Yoga ātmā* । *Mahaḥ pucchaṁ pratiṣṭhā* । *Tadapyeṣa śloko bhavati* ।। 1।। *iti caturtho'nuvākaḥ* ।।

(Taittirīyopaniṣat; 1-4)

Whence all speech turn back with the mind without reaching, he who knows the bliss of Brahman fears not at any time. This mind is the embodied soul of the former. Of the Pranayama, this one, namely, the *Manomaya*, is the self, having the Pranayama of his body.

Different from that made of mind is another inner soul made of knowledge (*Vijnana*). By that, he is filled. It also has the shape of a man. According to the human shape of that, is the human form of this. Faith is its head. Righteousness (*Ritam*) is the right side or wing. Truth (*Satyam*) is the left side or wing. Yoga (concentration – meditation) is the trunk (Self). *Mahah* is the tail, the support.

***Śvetāśvataropaniṣat* (श्वेताश्वतरोपनिषत्)**

क्षरं प्रधानममृताक्षरं हरः क्षरात्मानावीशते देव एकः ।
तस्याभिध्यानाद्योजनात्तत्त्वभावात् भूयश्चान्ते विश्वमायानिवृत्तिः ॥

Kṣaraṁ pradhānamamṛtākṣaraṁ haraḥ kṣarātmānāvīśate deva ekaḥ ।
Tasyābhidhyānādyojanāttattvabhāvāt bhūyaścānte viśvamāyānivṛttiḥ ।।

(Śvetāśvataropaniṣat; 10)

Matter is perishable, but God (Hara) is immortal and imperishable. He the only God, rules over the perishable matter and the individual souls. By meditating upon Him, there is finally cessation of all illusion.

2.5.6 HIGHER *SAMADHI* (3D TO ALL PERVASIVE AWARENESS)

When *dharana*, *dhyana*, and *Samadhi* (focused meditation, meditation, and profound absorption) are practiced together, the composite process is called *samyama*. *Samyama* might be translated as constrain; thorough, complete, or perfect restraint; or full control; it might also be translated as communion or mind-poise. *Samyama* conveys a sense of knowing through being or awareness through becoming what is to be known. Through mastery of *samyama* comes insight (*prajna*), and through its progressive application, in stages, comes knowledge of the Self and of the various principles of reality (*tattvas*). With increasing yogic practice come a variety of mystical, intuitive experiences, states, conditions, or fulfillments – the various *samadhis*.

Śrīmadbhagavadgītā **(श्रीमद्भगवद्गीता)**

यदा विनियतं चित्तमात्मन्येवावतिष्ठते ।

निःस्पृहः सर्वकामेभ्यो युक्त इत्युच्यते तदा ॥

Yadā viniyataṁ cittamātmanyevāvatiṣṭhate I

Niḥspṛhaḥ sarvakāmebhyo yukta ityucyate tadā II

(Śrīmadbhagavadgītā; 6-18)

When the disciplined mind is able to remain established in the Atman alone, when it is free from longing for all objects of desire-then is it spoken of as having attained to spiritual communion.

यथा दीपो निवातस्थो नेङ्गते सोपमा स्मृता ।

योगिनो यतचित्तस्य युञ्जतो योगमात्मनः ॥

Yathā dīpo nivātastho neṅgate sopamā smṛtā |

Yogino yatacittasya yuñjato yogamātmanaḥ ||

(Śrīmadbhagavadgītā; 6-19)

The flame of a lamp sheltered from wind does not flicker. This is the comparison used to describe a Yoga's mind that is well under control and united with the Atman.

Patañjali Yogasūtra **(पतंजलि योगसूत्र)**

सर्वार्थतैकाग्रतयोः क्षयोदयौ चित्तस्य समाधिपरिणामः ॥

Sarvārthataikāgratayoḥ kṣayodayau cittasya samādhipariṇāmaḥ ||

(*Patañjali Yogasūtra*, *3* -11)

The gradual setting of the distructions and simultaneous rising of one pointedness is the gradual transformation called *samadhi parinama* is the state of meditating mind.

Samādhi Pariṇāma is a kind of mental transformation really begins with the practice of *ekägratä* and continues until the *dharana* and *dhyana* states are reached. Its essential nature is the gradual reduction of the all-pointed condition of the mind to the one-pointed condition.

Kaṭhopaniṣat **(कठोपनिषत्)**

नित्योऽनित्यानां चेतनश्चेतनानामेको बहूनां यो विदधाति कामान्।

तमात्मस्थं येऽनुपश्यन्ति धीरास्तेषां शान्तिः शाश्वती नेतरेषाम्॥

Nityo'nityānāṁ cetanaścetanānāmeko bahūnāṁ yo vidadhāti kāmān |

Tamātmasthaṁ ye'nupaśyanti dhīrāsteṣāṁ śāntiḥ śāśvatī netareṣām ||

(Kaṭhopaniṣat; 13)

The wise who behold the Self as the eternal among the transient, as conscious among the conscious, who, though one, grants the desires of many, as dwelling in their own selves, to them belongs eternal peace, not to others.

इन्द्रियेभ्यः परं मनो मनसः सत्त्वमुत्तमम्।

सत्त्वादधि महानात्मा महतोऽव्यक्तमुत्तमम्॥

Indriyebhyaḥ paraṁ mano manasaḥ sattvamuttamam |

Sattvādadhi mahānātmā mahato'vyaktamuttamam ||

(Kaṭhopaniṣat; 13)

Beyond the senses is the mind, higher than the mind is the intellect, higher than the intellect is the great Atman, higher than the *Mahat* is *Avyaktam* (the unmanifested).

Samadhi is superconscious state or union with Brahman or the Absolute. Mind, intellect and the senses cease functioning. It is a subjective consciousness of Brahman. All visible objects merge in the invisible or the Unseen.

2.5.7 INFINITE AWARENESS (*KAIVALYA*)

Knower of Brahman attains liberation while living (*Jivanmukti*). They practice meditation on the Self and behold the one essence of the Atman, i.e., the Brahman in all objects of this world, movable and immovable. They realize the oneness of the Self or unity of the Atman in all and become immortal i.e., become Brahman itself.

Śrīmadbhagavadgītā **(श्रीमद्भगवद्गीता)**

इन्द्रियाणि पराण्याहुरिन्द्रियेभ्यः परं मनः ।
मनसस्तु परा बुद्धिर्यो बुद्धेः परतस्तु सः ॥ ३-४२ ॥

Indriyāṇi parāṇyāhurindriyebhyaḥ paraṁ manaḥ ।
Manasastu parā buddhiryo buddheḥ paratastu saḥ ।। 3-42।।

(Śrīmadbhagavadgītā; 3-42)

The senses are great, they say. Superior to the senses is the mind, and
superior even to the mind is the intellect.
What is superior even to the intellect is He, the Atman.

The senses, the mind, the intellect, and the Atman are the four layers of human personality. The Atman which is the ultimate foundation of man, is pure consciousness and the uninvolved witness of the modifications of these three layers associated with Him are inert in themselves, but become living and conscious when His light of consciousness percolates through them, just as the dull shades of a lamp are illumined when the rays of the central light passes through them.

अभयं सत्त्वसंशुद्धिर्ज्ञानयोगव्यवस्थितिः ।
दानं दमश्च यज्ञश्च स्वाध्यायस्तप आर्जवम् ॥

Abhayaṁ sattvasaṁśuddhirjñānayogavyavasthitiḥ ।
Dānaṁ damaśca yajñaśca svādhyāyastapa ārjavam ।।

(Śrīmadbhagavadgītā; 16-1)

Fearlessness, purity of heart, steadfastness in knowledge and devotion, benevolence, control of the senses, worship, study of scriptures, austerity, uprightness.

अहिंसा सत्यमक्रोधस्त्यागः शान्तिरपैशुनम् ।
दया भूतेष्वलोलुप्त्वं मार्दवं ह्रीरचापलम् ॥

Ahiṁsā satyamakrodhastyāgaḥ śāntirapaiśunam ।
Dayā bhūteṣvaloluptvaṁ mārdavaṁ hrīracāpalam ।।

(Śrīmadbhagavadgītā; 16-2)

Nonviolence, truthfulness, freedom from anger, renunciation, tranquility, aversion to slander, compassion for living beings, freedom from sensuality, gentleness, modesty, steadfastness.

तेजः क्षमा धृतिः शौचमद्रोहो नातिमानिता ।
भवन्ति सम्पदं दैवीमभिजातस्य भारत ॥

Tejaḥ kṣamā dhṛtiḥ śaucamadroho nātimānitā ।
Bhavanti sampadaṁ daivīmabhijātasya bhārata ।।

(Śrīmadbhagavadgītā; 16-3)

Vigor, patience, fortitude, purity, harmlessness, freedom from vanity – all these, O scion of the *Bhratas*, are present in those born to a divine heritage.

प्रजहाति यदा कामान्सर्वान्पार्थ मनोगतान् ।

आत्मन्येवात्मना तुष्टः स्थितप्रज्ञस्तदोच्यते ॥

Prajahāti yadā kāmānsarvānpārtha manogatān ।

Ātmanyevātmanā tuṣṭaḥ sthitaprajñastadocyate ।।

(Śrīmadbhagavadgītā; 2-55)

O Son of Partha! When all the desires of the heart have been abandoned, and the Spirit finds joyous satisfaction in Itself (without dependence on any external factor) – then is one spoken of as a person of steady wisdom.

दुःखेष्वनुद्विग्नमनाः सुखेषु विगतस्पृहः ।

वीतरागभयक्रोधः स्थितधीर्मुनिरुच्यते ॥

Duḥkheṣvanudvignamanāḥ sukheṣu vigataspṛhaḥ ।

Vītarāgabhayakrodhaḥ sthitadhīrmunirucyate ।।

(Śrīmadbhagavadgītā; 2-56)

Whose mind is not agitated is adversity, who is free from desire, and who is devoid of attachments, fear and anger – such a person is called a sage of steady wisdom.

या निशा सर्वभूतानां तस्यां जागर्ति संयमी ।

यस्यां जाग्रति भूतानि सा निशा पश्यतो मुनेः ॥

Yā niśā sarvabhūtānāṁ tasyāṁ jāgarti saṁyamī ।

Yasyāṁ jāgrati bhūtāni sā niśā paśyato muneḥ ।।

(Śrīmadbhagavadgītā; 2-69)

What is like night to all ignorant beings, to that Atman consciousness

the self-controlled sage is awake; and the sensual life which all

ignorant beings are awake, that is like night to this illumined sage.

***Patañjali Yogasūtra* (पतंजलि योगसूत्र)**

तदा द्रष्टु स्वरुपेऽवस्थानम् ।

Tadā draṣṭu svarupe'vasthānam

(Patañjali Yogasūtra; 1-3)

Then the Seer is established in his own essential and fundamental nature.

This Sutra points out in a general way what happens when all the modifications of the mind at all levels have been completely inhibited. The Seer is established in his Svarupa or in other words attains Self-realization.

तद्भवात् संयोगाभावो हानं तद्दशेः कैवल्यम् ।

Tadabhavāt saṁyogābhāvo hānaṁ taddaršeḥ kaivalyam ।

(*Patañjali Yogasūtra, 4*-24)

There is the absence of that (ignorance) there is an absence of junction,

which is the thing-to-be-avoided; that is the independence of the seer.

पुरुषार्थशून्यानां गुणानां प्रतिप्रसवः कैवल्यं

स्वरूपप्रतिष्ठा वा चितिशक्तिरिति ॥

Puruṣārthaśūnyānāṁ guṇānāṁ pratiprasavaḥ kaivalyaṁ

svarūpapratiṣṭhā vā citiśaktiriti ||

(Patañjali Yogasūtra; 4-34)

Kaivalya is the state (of Enlightenment) following the re-emergence of the Gunas because of their becoming devoid of the object of the Purusa. In this state the Purusa is established in his Real nature which is pure Concsiousness.

This Sutra defines and sums up the ultimate state of Enlightenment, which is called *Kaivalya*. The meaning of the Sutra may be expressed simply in the following words: '*Kaivalya* is that state of Self-realization in which the Purusa gets established finally when the purpose of his long evolutionary unfoldment has been attained. In this state the *Gunas*, haying fulfilled their purpose, recede to a condition of equilibrium and therefore the power of pure Consciousness can function without any obscuration or limitation.' It should be noted that this is not a description of the content of Consciousness in the state of *Kaivalya*.

***Kenopaniṣad* (केनोपनिषद्)**

This Upanishad explains how one can realize Brahman or the Supreme Self by transcending mind and senses.

इह चेदवेदीदथ सत्यमस्ति न चेदिहावेदीन्महती विनष्टिः।

भूतेषु भूतेषु विचित्य धीराः प्रेत्यास्माल्लोकादमृता भवन्ति॥

Iha cedavedīdatha satyamasti na cedihāvedīnmahatī vinaṣṭiḥ |

Bhūteṣu bhūteṣu vicitya dhīrāḥ pretyāsmāllokādamṛtā bhavanti ||

(Kenopaniṣad; 5)

If one knows (That – Brahman) here (i.e., in the world), then the true end (of all human aspiration) is (gained). If one knows not (That) here, great is the destruction. The wise, seeing the one Atman in all beings, rise from sense-life and become immortal.

यो वा एतामेवं वेदापहत्य पाप्मानमनन्ते स्वर्गे लोके ज्येये प्रतितिष्ठति प्रतितिष्ठति ॥

Yo vā etāmevaṁ vedāpahatya pāpmānamanante svarge loke jyeye pratitiṣṭhati pratitiṣṭhati ||

(Kenopaniṣad; 9)

He who knows this thus, after having shaken off all sins, abides firmly seated in the endless, blissful and highest Brahman. He is established in Him.

***Kaṭhopaniṣat* (कठोपनिषत्)**

The wise man withdraws the mind from external objects, realizes this Atman by means of meditation on the inner Self and renounces both joy and grief. This Atman is beyond pleasure and pain, joy and grief. It is an embodiment of Bliss. It is *Sat-Chit-Ananda Svarupa*.

कामस्याप्तिं जगतः प्रतिष्ठां क्रतोरानन्त्यमभयस्य पारम् ।

स्तोममहदुरुगायं प्रतिष्ठां दृष्ट्वा धृत्या धीरो नचिकेतोऽत्यस्राक्षीः ॥

Kāmasyāptiṁ jagataḥ pratiṣṭhāṁ kratorānantyamabhayasya pāram |

Stomamahadurugāyaṁ pratiṣṭhāṁ dṛṣṭvā dhṛtyā dhīro naciketo'tyasrākṣīḥ ||

(Kaṭhopaniṣat; 1-2-11)

The end of all desires, the foundation of the world, the endless rewards of sacrifice, the other shore where there is no fear, the praiseworthy, the great, the wide-extended sphere and the abode of the soul – all these thou hast seen, and being wise.

तं दुर्दर्शं गूढमनुप्रविष्टं गुहाहितं गह्वरेष्ठं पुराणम्।
अध्यात्मयोगाधिगमेन देवं मत्वा धीरो हर्षशोकौ जहाति॥

Taṁ durdarśaṁ gūḍhamanupraviṣṭaṁ guhāhitaṁ gahvareṣṭhaṁ purāṇam |
Adhyātmayogādhigamena devaṁ matvā dhīro harṣaśokau jahāti ||

(Kaṭhopaniṣat; 1-2-12)

The wise sage who, by means of meditation on his Self, recognizes the Ancient, who is difficult to be seen, who is unfathomable and concealed, who is hidden in the cave of the heart, who dwells in the abyss, who is lodged in intelligence, indeed renounces joy and sorrow.

एतद्ध्येवाक्षरं ब्रह्म एतद्ध्येवाक्षरं परम्।
एतद्ध्येवाक्षरं ज्ञात्वा यो यदिच्छति तस्य तत्॥

Etaddhyevākṣaraṁ brahma etaddhyevākṣaraṁ param |
Etaddhyevākṣaraṁ jñātvā yo yadicchati tasya tat ||

(Kaṭhopaniṣat; 1-2-16)

This word is verily Brahman; this word is verily the highest; he who knows this word, obtains, verily, whatever he desires.

एतदालम्बनँ श्रेष्ठमेतदालम्बनं परम्।

एतदालम्बनं ज्ञात्वा ब्रह्मलोके महीयते॥

Etadālambanaṁ̐ śreṣṭhametadālambanaṁ param ।
Etadālambanaṁ jñātvā brahmaloke mahīyate ।।

(Kaṭhopaniṣat; 1-2-17)

This is the best support. This is the highest support. He who knows

this support is worshipped in the world of Brahman.

If one meditates on Om with both *Saguna Bhava* he will attain the manifested or *Saguna* Brahma; if he meditates on Om with *Nirguna Bhava* he will attain the *Nirguna* Brahman. He who meditates on Brahman becomes identical with Brahman and becomes fit to be worshipped like Brahman. The knower of Brahman becomes Brahman.

अणोरणीयान्महतो महीयाजन्तोर्निहितो गुहायाम्।

तमक्रतुः पश्यति वीतशोको धातुप्रसादान्महिमानमात्मनः॥

Aṇoraṇīyānmahato mahīyājantornihito guhāyām ।

Tamakratuḥ paśyati vītaśoko dhātuprasādānmahimānamātmanaḥ ।।

(Kaṭhopaniṣat; 1-2-20)

The Atman, subtler than the subtlest, greater than the great, is seated in the heart of each living being. He who is free from desire, with his mind and the senses composed, beholds the majesty of the Self and becomes free from sorrow.

अशरीरँ शरीरेष्वनवस्थेष्ववस्थितम् ।

महान्तं विभुमात्मानं मत्वा धीरो न शोचति ॥

Aśarīraṁ̐ śarīreṣvanavastheṣvavasthitam ।

Mahāntaṁ vibhumātmānaṁ matvā dhīro na śocati ।।

(Kaṭhopaniṣat; 1-2-22)

The wise man, who knows the Atman as bodies, seated firmly in perishable bodies, great and all pervading, does never grieve.

In other words, the sages who have attained Self-realization, i.e., who have known the Atman through direct, intuitive perception (*aparokṣānubhūti*), do not grieve. The Atman is like *Akasa*, the all-pervading ether.

न संदृशे तिष्ठति रूपमस्य न चक्षुषा पश्यति कश्चनैनम् ।

हृदा मनीषा मनसाऽभिक्लृप्तो य एतद्विदुरमृतास्ते भवन्ति ॥

Na sandṛśe tiṣṭhati rūpamasya na cakṣuṣā paśyati kaścanainam ।

Hṛdā manīṣā manasā'bhiklṛpto ya etadviduramṛtāste bhavanti ।।

(Kaṭhopaniṣat; 2-3-9)

His form is not to be seen. No one beholds Him with the eye. By controlling the mind by the intellect and by incessant meditation He is revealed. Those who know this (Brahman) become immortal. He is transcendental, beyond the reach of the senses and mind.

यदा पञ्चावतिष्ठन्ते ज्ञानानि मनसा सह ।

बुद्धिश्च न विचेष्टते तामाहुः परमां गतिम् ॥

Yadā pañcāvatiṣṭhante jñānāni manasā saha |

Buddhiśca na viceṣṭate tāmāhuḥ paramāṁ gatim ||

(Kaṭhopaniṣat; 2-3-10)

When the five organs of knowledge are at rest together with the

mind, and when the intellect ceases functioning (becomes calm),

that they call the highest state.

In other words, when the five organs are withdrawn from the external objects and merged in the mind, when the mind is centered or fixed in the Atman, when the intellect characterized by determination is not active or does not exert itself, the state they call the highest.

When the senses are quietened, when the emotions are controlled, when the intellect ceases to exert, that is the supreme state, the sages say. This is called Yoga. Yoga is the highest path, because it leads to Moksha, the final emancipation. Yogi can disconnect himself from everything and is resting in his own Atman which is free from all superimposition of ignorance and all dualities.

***Aitareyopaniṣat* (ऐतरेयोपनिषत्)**

यदेतद्धृदयं मनश्चैतत् ।

संज्ञानमाज्ञानं विज्ञानं प्रज्ञानं मेधा दृष्टिर्धृतिमतिर्मनीषा

जूतिः स्मृतिः संकल्पः क्रतुरसुः कामो वश इति ।

सर्वाण्येवैतानि प्रज्ञानस्य नामधेयानि भवंति ॥

Yadetaddhṛdayaṁ manaścaitat |

Sañjñānamājñānaṁ vijñānaṁ prajñānaṁ medhā dṛṣṭirdhṛtimatirmanīṣā

jūtiḥ smṛtiḥ saṅkalpaḥ kraturasuḥ kāmo vaśa iti |

Sarvāṇyevaitāni prajñānasya nāmadheyāni bhavanti ||

(Aitareyopaniṣat; 5-2)

This which is known as the heart, this mind, consciousness, mastery, knowledge of arts, comprehension, reflection, independent power of thinking, distress of mind caused by diseases, etc., memory, volition, applications, any pursuit for maintenance of life, desire, desire for the company of women, all these are indeed the names of consciousness.

स एतेन प्राज्ञेनाऽऽत्मनाऽस्माल्लोकादुत्क्रम्यामुष्मिन्स्वर्गे लोके सर्वान् कामानाप्त्वाऽमृतः समभवत् समभवत् ॥

Sa etena prājñenā''tmanā'smāllokādutkramyāmuṣminsvarge loke sarvān kāmānāptvā'mṛtaḥ samabhavat samabhavat ||

(Aitareyopaniṣat; 5-4)

He was exalted to the state of Brahmanhood on account of his knowledge of Atman. He left this world and obtained all that he desired in that world of supreme bliss and attained immortality.

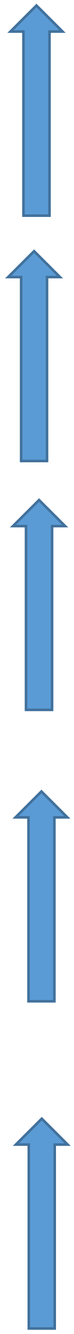
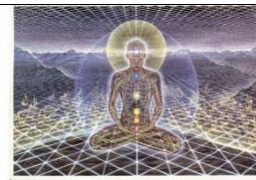
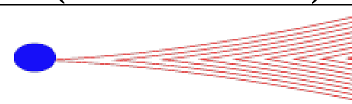
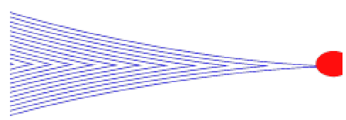
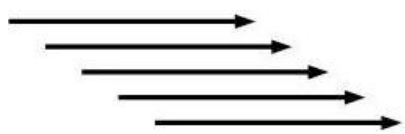
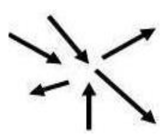
The yogi with a stream of virtuous knowledge is devoid of all aims of life as he is free from the qualities of nature. Purusarthas are man's four aims in life: dharma (science of duty), artha (purpose by means of life), kama (enjoyments of life) and moksha (freedom from worldly pleasures). They leave the fulfilled seer and merge with nature.

Kaivalya is the final goal, those who have trodden the Path and passed further along it, as well as Occult tradition, declare with one voice that *Kaivalya* is only a stage in the unending unfoldment of consciousness. When the Purusha attains this stage of Self-realization he sees opening before his new vistas of achievement which are utterly beyond human imagination. As Lord Buddha said 'Veil upon veil shall life, but still veil upon veil will be found behind.'

2.6 SUMMARY

Yoga is not merely a theory of mind or mental states, but also a practical discipline that claims provide empirical support of its ideas. *Gita* is indicated by its theory of meditation is "a deepening and broadening of consciousness beholding all beings in consciousness and consciousness in all beings". Yoga tradition and practices, it is quite apparent that yoga has several possibilities and important applications. In the classical yoga tradition, the emphasis was on a single application, viz., achieving a state of *Kaivalya*. Considering that yoga is an endeavor to harmoniously link the body and the mind on the one hand and the mind and consciousness on the other, there exists the possibility for a variety of applications of yoga for physical well-being, mental health and for enhancing cognitive and other human abilities. With increasing yogic practice come a variety of mystical, intuitive experiences, states, conditions, or fulfillments.

Figure 1. Schematic representation of the Growth of Awareness described in yoga texts

Growth of Awareness	Levels	States of Consciousness	
	**All Pervasive Awareness Unchanging**	 **Kaivalya – Infinite Awareness/Consciousness**	Being one with Reality
	Higher States of Exposed Awareness	 **Higher Samadhi – 3D to All Pervasive Awareness**	Contained Quantum jumps to subtler & Causal Levels of the Subject
	Quantum Jump higher levels of Awareness	 **Samadhi: Merging Seer and Seen (Total 3D awareness)**	Identified intro the object totally
	Exposed Attention Awareness	 **Defocused meditation or effortless meditation (*Dhyāna*)**	Effortless single thought flow
	Focused Attention Awareness	 **Focused meditation (*Dhāraṇā*)**	One Object, One thought stream
	Channelized Attention	 **Non-meditative concentration (*Ekāgratā*)**	One Subject and Multiple Thoughts
	Disturbed Attention	 **Random Thinking (*Cañcalatā*)**	Multiple subjects underlined thoughts

Reaching *Purusha* by overcoming the bondages of *Prakriti* - *svarupe'vasthānam*

CHAPTER-3

REVIEW OF SCIENTIFIC LITERATURE ON MEDITATION

3.0 REVIEW OF SCIENTIFIC LITERATURE ON MEDITATION

3.1 MEDITATION AND EVOKED POTENTIALS (EPs)

Meditation is a self-regulated conscious process and mental training (Murata et al., 2004). The functional changes in the brain during meditation have been studied with various techniques which have different spatial and temporal resolutions (Mishra & Kalita, 1999). Evoked potentials also allow changes in a sensory pathway to be understood, from the periphery through brainstem evoked potentials, to central areas with long latency auditory evoked potentials. It is an electrical response of the brain (especially from the spinal cord, brainstem, midbrain and cerebral cortex) to a given stimulus (e.g., auditory, visual or somatosensory) which occur in a time locked fashion (Chiappa, 1997).

The auditory evoked response has been well established with components measured at the scalp that arises from the brainstem, midbrain and auditory cortex of the brain regions during the first 300 ms following the tone onset. Functional imaging studies have shown the temporal patterns of music and speech that activate auditory cortical regions that play an important role in auditory evoked response generation. The generation of each component in the brainstem (I-VII), midbrain (Na, Pa, Nb), and the long latency (P1, N1, P2, N2) of human auditory evoked potentials at different peak latencies indicate that this activity must arise from parallel subsystems in the thalamo-cortical pathway and peak amplitude indicate the sum of neuronal recruitment. A decrease in peak latency of evoked potentials is considered suggestive of facilitated transmission due to increased speed of conduction in the underlying neural generators (Malhotra et al., 2004). On the other hand, an increase in peak latency can be assumed to suggest inhibited transmission due to slower conduction in the underlying neural generators. Increased amplitudes of evoked potential components are interpreted as activation of the underlying neural generator with the recruitment of a greater number of neurons (Woods & Clayworth, 1986).

Evoked potentials have been used in meditation studies, since the correlation between the different components of evoked potentials and the underlying neural generators are fairly well known (Woods & Clayworth, 1985). Several studies have been reported to be anatomically different between meditators and controls, to show associations with the meditation practice, and or to change as a consequence of meditation (Luders, Clark, Narr, & Toga, 2011; Pagnoni & Cekic, 2007). Apart from this, it appears that the cerebral cortex is actively involved in processes related to meditation. Auditory evoked potentials were chosen to begin with, instead of somatosensory or visual evoked potentials to avoid compounding with any sensory motor potentials produced during the movement, and to reveal changes of a generalized nature that might be induced by the consciously attentive yogic exercise in the processing of information in a modality other than the somatosensory or visual evoked potentials (Telles, Joseph, Venkatesh, & Desiraju, 1993). It is also premised that conscious processes actively involve several cortical mechanisms and also that corticofugal control processes may exert significant alterations in the processing of information at the brainstem and thalamic levels (Desiraju, 1979, 1984; Steriade & Llinás, 1988).

Long latency auditory evoked potential (LLAEP) is an important tool to assess the auditory information processing at the central level. LLAEPs are extracted from the EEG by means of computer based signal averaging techniques in response to repeated click stimuli and their components are P1 (P100), N1 (N100), P2 (P200), and N2 (N200). These auditory late responses (ALR) assess central auditory processing by the neuroelectric activity of the auditory pathway in response to an acoustic stimulus or event. These long latency components are generated by thalamocortical and corticocortical auditory pathways, the primary auditory cortex and association cortical areas picked up between 100–300 ms after giving acoustic click stimuli. Regarding generators of these waves, some have suggested fronto-central cortex to be responsible for their generation (Picton & Hillyard, 1974; Vaughan & Ritter, 1970; Woods, Clayworth, Knight, Simpson, & Naeser, 1987) while others have suggested the neural generators of these waves as various polysensory association areas. Long latencies are recorded between 100 and 600 ms after stimulus presentation and are described as exogenous: N1 (negative wave with a latency of approximately 80 to 150 ms and 5 to 10 µV of amplitude), P2 (positive wave with a latency ranging from 145 to 200 ms and 3-6 µV of amplitude); and endogenous: N2 (negative wave range 180-250 ms and 3 to 6 µV of amplitude) and P3 (positive wave with a latency of approximately 220-400 ms and the range of 8 to 15 µV of amplitude). The LLAEPs have also shown to be an effective method of investigating the auditory process which could reflect the cortical activity involved in discrimination, integration and attention abilities (McPherson, 1996). The LLAEPs component has strongly influenced by the physical characteristics of the stimuli like intensity and frequency. Meditators sometimes produced altered amplitudes and shorter potentials latencies when stimuli were presented and EEG recorded, thereby suggesting increased attentional control and CNS quiescence (Banquet & Lesèvre, 1980).

The first evoked potential study on Transcendental Meditation (TM) was done in 1976, where slow cortical auditory responses were recorded. TM meditators presented with auditory tones (1/s) demonstrated decreased P1, N1, P2 and N2 component latencies for meditators at baseline and meditation or rest states compared to non-meditators control group values. The initial peak latencies during TM as well as during normal consciousness were significantly shorter than in a matched control group in a dozing state or during normal consciousness (Wandhöfer, Kobal, & Plattig, 1976). In another similar study on long latency auditory evoked potentials (LLAEPs) to tone stimuli were recorded from eight experienced meditators 'Before', 'During' and 'After' meditation, and also during light sleep AEPs. Although N1 latency was longer in the before-control relative to the meditation condition, this effect was unreliable and no consistent changes were noted between baseline and meditation of long latency auditory evoked potentials or between meditation and sleep (Barwood, Empson, Lister, & Tilley, 1978). In a subsequent study, AEPs were obtained from Zen, TM, Yoga, and two groups of non-meditator control subjects who were instructed either to 'attend' or 'ignore' loud click stimuli (115 dB) presented at 15s intervals. No AEP components demonstrated any differences other than the production of larger passive P300 amplitudes in the attend group as observed previously (Becker & Shapiro, 1981). N100 amplitude for the TM and Yoga meditation subjects increased over the first 30 stimulus presentations, then reduced to the same size as the other groups' after 40-50 stimulus presentations. The authors suggested that given the mantras used by both groups, the attentional state of the TM and Yoga meditators may have been attuned to 'inner sounds' that could have contributed to a greater sensitivity of the auditory stimulus input.

Short latency auditory evoked potentials provides an objective physiological index of auditory function at a subcortical level. Brainstem auditory evoked potentials (BAEPs) have been studied in Transcendental Meditation (McEvoy, Frumkin, & Harkins, 1980), Qigong meditation and in practitioners of meditation on *OM* (Kumar, Nagendra, Manjunath, Naveen, & Telles, 2010). In a study, BAEPs were measured in five advanced practitioners of Transcendental Meditation (TM) to assess perceptual acuity to auditory stimuli following meditation (McEvoy et al., 1980). Peak latencies as well as interwave latencies between major BAEPs components were evaluated. Results showed no pre-post meditation differences for experimental subjects were observed at low stimulus intensities (0-35 dB). At moderate intensities (40-50 dB), latency of the inferior collicular wave (wave V) increased following meditation, but at higher stimulus intensities (55-70 dB), latency of this wave was slightly decreased. In another study, Qi-gong meditators were assessed by presenting 10 ms tones and recording ‘Before’, ‘During’, and ‘After’ a 30 min Qi- gong meditation session (Liu, Cui, Li, & Huang, 1990). P200 amplitude decreased 44% from the baseline to the meditative state and returned to baseline after meditation. This outcome suggests that later AEP measures may be sensitive to the meditation state. Subsequently, BAEPs were assessed in 30 practitioners of meditation on *OM* in four sessions, i.e., two meditation (*dhāraṇā,* and *dhyāna*) and two non-meditation (*cañcalatā,* and *ekāgratā*) (Kumar, Nagendra, Naveen, Manjunath, & Telles, 2010). Results showed that the wave V peak latency significantly increased in *cañcalatā, ekāgratā* and *dharana* suggest delayed information transmission along auditory pathway, but no change occurred during the *dhyāna* session. It suggests that information transmission was delayed at the inferior collilular level as the wave V corresponds to the tectum.

The middle latency auditory evoked potential (MLAEP) was initially reported by Geisler et al (1958), who described an EP that began at 20 milliseconds (ms) and peaked around 30 ms post onset of the auditory stimulus (Geisler, Frishkopf, & Rosenblith, 1958).

In a subsequent research by Goldstein and colleagues and others investigated the effect of stimulus characteristics, the effect of arousal on the response, response characteristics in neonates, response characteristics in patients with hearing loss, and the effects of noise in the response (Goldstein & Rodman, 1967; McRandle, Smith, & Goldstein, 1974; Mendel & Goldstein, 1971). Midlatency auditory evoked potentials (MLAEPs) have been studied in different meditations, including the eyes-open Brahmakumaris Raj Yoga Meditation, (Telles & Naveen, 2004) meditation on *OM* (Kumar, Nagendra, Manjunath, et al., 2010; Telles & Desiraju, 1993b; Telles, Nagarathna, Nagendra, & Desiraju, 1994) and Sahaja Yoga, which involves mental silence and awareness devoid of any though (Panjwani et al., 2000). Changes in mid-latency auditory evoked potentials (MLAEPs) were assessed in seven experienced meditators during the practice of mediation on the syllable '*OM*' (Telles & Desiraju, 1993b). Results showed during meditation there was a small but significant reduction in the peak latency of the Nb wave (the maximum negativity occurring between 35 and 65 ms). The Nb wave corresponds to the dorso-posterior medial part of the Heschl's gyrus, i.e., the primary auditory cortex (Liégeois-Chauvel, Musolino, Badier, Marquis, & Chauvel, 1994). In another study on experienced (n = 9) and naïve meditators (n = 9), who were asked to mentally repeat syllable '*OM*' on one day and English syllable 'One' on another day (Telles et al., 1994). Experienced meditators showed increased peak amplitude of Na wave (the maximum negative peak between 14 and 18 ms) during meditation, while the same subjects showed a statistically significant reduction in the Na wave peak amplitude during control sessions. In contrast, the naive subjects had a significant decrease in the Na wave peak amplitude during meditation sessions and a non-significant trend of reduction during control sessions, as well. Hence, the decreased Na amplitude indicated a possible decrease in neurons recruited at the level of mesencephalic or diencephalic while mentally repeating ‘One’.

In another study on middle latency auditory evoked potentials during Brahmakumarish Raja Yoga meditation (n = 16 males) were assessed in meditation (*dhyāna*) and random thinking (*cañcalatā*) (Telles & Naveen, 2004). Meditation showed there was a decrease in the peak latency of the Na wave, suggest the neural generator of this wave lies at the midbrain-thalamic level, from the results one can infer that the meditation reduces conduction time at this level. Another study on cyclic meditation (CM; a technique combining yoga postures with meditation while supine) on MLAEPs studied before and after practice in 47 male volunteers (Subramanya & Telles, 2009). The results showed a significant increase in peak latency of Pa wave and Nb wave following CM compared to before the CM. There was a significant increase in the peak amplitude of the Nb wave compared to before the CM. The latency of the Na wave significantly increased after SR compared to before SR. Hence, following CM the latencies of neural generators corresponding to cortical areas was prolonged, whereas following SR a similar change occurred at mesencephalic-diencephalic levels. In a recent study on MLAEPs assessed in sixty participants during four mental states viz., random thinking, non-meditative focused thinking, meditative focusing and meditation (Telles, Raghavendra, Naveen, Manjunath, & Subramanya, 2012). The results showed that during meditation, there were prolonged latencies in Na and Pa waves which suggested that auditory information transmission at the level of the medial geniculate and primary auditory cortex (i.e., the neural generators corresponding to the Na and Pa waves) was delayed. For both brainstem and midlatency evoked potentials the results have differed with each meditation technique.

Long latency auditory evoked potentials (LLAEPs) assess the higher auditory processing capabilities in central and cortical components of the auditory pathway given the scarcity of data on LLAEPs in meditation the present study was designed to evaluate LLAEPs in practitioners during meditation practiced as described in the ancient texts. In fact, there is just one study on LLAEPs during Transcendental Meditation (Barwood et al., 1978). In that study, LLAEPs were recorded in 8 experienced meditators (meditation experience 6 years; Cohen's $d = 0.18$), before during and after meditation and also during light sleep. No consistent changes were noted between baseline and meditation auditory evoked potentials or between meditation and sleep. In another unpublished thesis reported long latency auditory evoked potentials in two meditation techniques i.e. OM and Brahamakumaris Meditation (BK) on 40 male participants. Results suggest that meditation on 'OM' facilitated neural transmission and better cortical neural synchrony. In the two phases of BK meditation the changes were almost directly opposite to those during meditation on 'OM'. During the *dhāraṇā* phase, there was a state of 'alertful rest' with facilitated cortical neural transmission and greater cortical neural synchrony. However, in the *dhyāna* phase the changes were suggestive of 'alertful rest'. These obvious differences between the two meditation techniques have been detailed and discussed as possibly due to meditation on '*OM*' being a concentrative type of meditation while BK meditation is mindfulness meditation technique.

Hence the present study was designed to assess the LLAEPs during the 4 mental states described above, to determine whether the differences in mental states would cause changes in the LLAEP components based on changes in the underlying neural generators.

3.2 MEDITATION AND P300 EVENT RELATED POTENTIALS (ERPs)

The P300 is a positive ERP recorded widely across the scalp approximately 300 ms after an auditory, visual, or somato-sensory "Oddball" stimulus, which must be random and standard, and also must be followed by a response from the patient, such as pressing a button. The P300 recorded from the scalp has several components that seem to be independently generated from different brain structures. These components include brain activities involved in selective attention, work update, and short-term memory in response to unexpected changes in the environment (Blackwood, 2000; Bonala & Jansen, 2012). The P300 latency, is presumed to indicate the time required for task evaluation independent of motor processing, can be used to study the cognitive processing in the healthy and disease conditions. The P300 component of auditory event related brain potentials is considered a cognitive neuroelectric phenomenon, since it is generated when subjects attend to and discriminate between stimuli which differ from one another in specific characteristics (Polich, 2004). The P300 is believed to reflect fundamental cognitive events requiring attentional and immediate memory processing (Polich, Ladish, & Burns, 1990). TM practice was studied using a passive auditory paradigm listening study with variable inter-stimulus intervals (1-4s) between identical tone stimuli (Cranson, Goddard, & Orme-Johnson, 1990). The subjects were non-meditator controls, novice, and highly experienced TM meditators with mean ages of 20, 28, and 41 years, respectively; IQ scores did not differ among the groups.

In an early study on auditory 'Oddball' task was used with closed-eyes to assess experienced TM meditators at pretest baseline, after 10 min of rest, or after 10 min of TM practice with conditions couter-balanced across subjects (Travis & Miskov, 1994). The

P300 latency decreased at Pz after TM practice relative to no change after the rest condition. In another study, auditory mismatch negativity (MMN) and P300 event related potentials (ERPs) were compared in normal children either with or without musical meditation training (Luo, Wei, & Weekes, 1999). The results showed that MMN amplitudes in the trained children were larger than those in the control group. In addition, the MMN amplitudes were identical in attend and ignore conditions for both groups. This evidence suggests that the auditory brain function has been affected by musical meditation training. It thus suggests that the MMN is capable of assessing changes to the brain function in normal subjects. There were no significant differences in the P300 latencies and amplitudes between the two groups.

Changes in P300 ERPs following cyclic meditation and supine rest were studied in 42 male volunteers (Sarang & Telles, 2006). The results showed there was a reduction in the peak latencies of P300 after cyclic meditation. A similar trend of reduction in P300 peak latencies was also observed after supine rest, although the magnitude of change was less after supine rest compared to after cyclic meditation. The P300 peak amplitudes (with Cohen's d = 0.62) after CM were higher compared to the "pre" values. In contrast, no significant changes were observed in the P300 peak amplitudes after supine rest. The results support the idea that cyclic meditation enhances cognitive processes underlying the generation of the P300 ERPs. Subsequently, another study on a three stimulus auditory oddball series was presented to experienced Vipassana meditators during meditation and a control thought period. The stimulus consisted of a frequent standard tone (500 Hz), an infrequent oddball tone (1000 Hz), and an infrequent distracter (white noise) (Cahn & Polich, 2009). The strongest meditation compared to control state effects occurred for the distracter stimuli: N1 amplitude from the distracter was reduced frontally during meditation; P2 amplitude from both the distracter and oddball stimuli were somewhat reduced during meditation; P3a amplitude from the distracter was reduced during meditation. The meditation-induced reduction in P3a amplitude was strongest in participants reporting more hours of daily meditation practice and was not evident in participants reporting drowsiness during their experimental meditative session. The findings suggest that meditation state can decrease the amplitude of neurophysiologic processes that subserve attentional engagement elicited by unexpected and distracting stimuli. Consistent with the aim of Vipassana meditation to reduce cognitive and emotional reactivity, the state effect of reduced P3a amplitude of distracting stimuli reflects decreased automated reactivity and evaluative processing of task irrelevant attention-demanding stimuli.

The effects of a short mindfulness meditation (MMI) was examined performance on P300 based brain-computer interface (BCI) task in 18 subjects using sixteen channel electroencephalogram (EEG). Nine subjects participated in a 6 min MMI and an additional nine subjects served as a control group. Subjects were presented with a 6 × 6 matrix of alphanumeric characters on a computer monitor. Stimuli were flashed at a stimulus onset asynchrony (SOA) of 125 ms. Calibration data were collected on 21 items without providing feedback (Lakey, Berry, & Sellers, 2011). These data were used to derive a stepwise linear discriminate analysis classifier that was applied to an additional 14 items to evaluate accuracy. Offline performance analyses revealed that MMI subjects were significantly more accurate than control subjects. Likewise, MMI subjects produced significantly larger P300 amplitudes than control subjects at Cz and PO7. A study on the middle latency response (MLR), even related potential P300-ERPs and contingent negative variation (CNV) were used to evaluate cognitive impairment after total sleep deprivation on ten healthy male volunteers (Chatterjee, Ray, Panjwani, Thakur, & Anand, 2012). The Indian Army participated in a 6-night study design executed before and after two months of meditation practice: night 1-adaptation, night 2-baseline, night 3-24 h SD, night 4-recovery sleep, night 5-24 h SD after 60 days meditation, night 6-recovery sleep after SD. A 36 h SD was obtained by keeping the subject awake for 12 h after 24 h SD. The results showed that the latency and the amplitude of P300 increased after 36 h SD. Amplitudes and latencies of both early and late CNV increased after 24 and 36 h SD, indicating deficient orientation and impairment of attention and perception. Prolonged CNV reaction time after 36 h SD manifested deficient motor response following second (imperative) stimulus. Latency of MLR Na registered significant change following 36 h SD compared to baseline and recovery. RAPM score showed significant decrease after 36 h of wakefulness indicating impaired analytical ability and difficulty in problem solving. None of these parameters showed any significant alteration after SD, following meditation practice. In a recent cross-sectional, controlled study utilized the P300 event-related potential (ERP) to compare executive network neural function between self-selected long-term Tai Chi (n =16), meditation (n= 16), aerobic fitness (n = 16), and sedentary (n = 12) groups (Hawkes, Manselle, & Woollacott, 2014). The results showed that only Tai Chi and meditation plus exercise groups demonstrated larger P3b ERP switch trial amplitudes compared to sedentary controls. This suggests the long-term Tai Chi practice, and meditation plus exercise may benefit the neural substrates of executive function.

3.3 MEDITATION AND PSYCHOPHYSIOLOGICAL CHANGES

Previous studies on the physiological effects of meditation have dealt with Transcendental Meditation (TM), Zen, and Tantric yoga. TM was adapted from the Indian yogic tradition by Maharishi Mahesh Yogi. Practicing TM, subjects sit in a comfortable posture and silently repeat a given mantra, returning their attention to it whenever attention wanders. Zen meditation forms an integral part of Zen Buddhism. Subjects sit in the lotus position, keep their eyes open and their attention focused (initially on their breathing, and later on, on a loan or riddle). Tantric yoga involves intense concentration of attention, with the ultimate aim of channeling all of ones' energies into the spiritual energy of union with the object of devotion.

The practice of TM was reported to cause reductions in heart rate, respiratory rate, and oxygen consumption and to increase the level or stability of the electrodermal response (Wallace, Benson, & Wilson, 1971; Wallace, 1970). TM was hence described as a 'wakeful hypometabolic physiologic state'. A later report (Heide, 1986), noted a difference in the heart rate response but not in the electrodermal response evoked by 80 dB tones, when TM meditators and non-meditators were compared. More recently, the practice of TM was shown to reduce cardiovascular sympathetic activity both at rest and during a simulated car driving stressor in adolescence at risk for hypertension (Barnes, Treiber, & Davis, 2001). These reports suggest that the practice of TM reduces sympathetic activity. This concept of predominant parasympathetic activity during TM was mentioned in a recent review (Newberg & Iversen, 2003).

Contradictory results were observed in Zen and Tantric meditations. One set of studies reported changes suggestive of autonomic activation (Corby, Roth, Zarcone, &

Kopell, 1978), while another set of studies reported changes suggestive of autonomic relaxation (Elson, Hauri, & Cunis, 1977; Kasamatsu & Hirai, 1966).

In a previous report of autonomic and respiratory changes in 18 males Brahmakumaris Raja Yoga meditators (Telles & Desiraju, 1993a). Results showed that the heart rate during the meditation period was increased compared to the preceding baseline period, as well as compared to the value during the non-meditation period of control sessions. In contrast to the change in the heart rate, there was no significant change during meditation, for the group as a whole, in palmar GSR, finger plethysmogram amplitude, and respiratory rate. On an individual basis, changes which met the following criteria were noted: (1) Changes which were greater during meditation (compared to its preceding baseline) than changes during post meditation or non-meditation periods (also compared to their preceding baseline); (2) Changes which occurred consistently during the three repeat sessions of a subject; and (3) Changes which exceeded arbitrarily-chosen cut-off points (described at length below). Heart rate variability in different form of respiratory exercise was observed in 32 volunteers showed that mental activity that affected respiration can influence the function of autonomic nervous system in a different way. When the mind was concentrated at the inspiration, the function of the autonomic nervous system was kept in balance, and both the sympathetic and the vagal activities enhanced significantly and while mind concentrated at the expiration could induce a reduction in vagal activity so as to produce a marked change in the sympathovagal balance (Sun, Li, & Li, 1996). Another study on autonomic changes while mentally repeating two syllables-one meaningful syllable ‘OM’ (MOM session) and the other neutral ‘ONE’ (COM) recorded in 12 volunteers in three sessions, before, during and after (Telles, Nagarathna, & Nagendra, 1998). The results showed during the test periods of both MOM and COM sessions the rate of respiration (RR) and heart rate (HR) decreased significantly. Mental repetition of 'OM' (but not 'one') caused a significant decrease in the skin resistance level (SRL). 22 healthy adults who had not previously practiced any form of meditation reported during meditation there was an increase in high-frequency (HF) power (as a parasympathetic index of HRV), and a decrease in the ratio of low-frequency to HF power (as a sympathetic index of HRV) were observed (Murata et al., 2004). Further evaluation of these changes in individuals showed a negative correlation between the percent change (with the control condition as the baseline) in slow alpha interhemispheric coherence reflecting internalized attention and the percent change in HF reflecting relaxation. The trait anxiety score was negatively correlated with the percent change in slow alpha interhemispheric coherence in the frontal region and was positively correlated with the percent change in HF.

In another study on changes in autonomic nervous activity during meditation was assessed during Zen meditation in 20 normal adults. The results showed an increase in the normalized unit of high-frequency (nuHF) power (as a parasympathetic index) and decreases in the normalized unit of low-frequency (nuLF) power and LF/HF (as sympathetic indices) were observed through analyses of heart rate variability (Takahashi et al., 2005). In a recent study on changes in autonomic variables following four mental states i.e., *cañcalatā, ekāgratā, dhāraṇā,* and *dhyāna* in thirty healthy male volunteers (Telles, Raghavendra, Naveen, Manjunath, Kumar, et al., 2012). The results suggest that during meditation (*dhyāna*) there was an increase in the skin resistance and also, there was a decrease in heart rate and breath rate. Additionally, there was a significant decrease in the low frequency (LF) power and increase in the high frequency (HF) power in the frequency domain analysis of the heart rate variability (HRV) spectrum, on which HF power is associated with parasympathetic activity. There was also a significant increase in the NN50 count (the number of interval differences of successive NN intervals greater than 50 ms and the pNN50 (the proportion derived by dividing NN50 by the total number of NN intervals in time domain analysis of HRV, both indicative of parasympathetic activity.

Focused attention and vigilance are associated with greater or increased sympathetic activity (Telles, Raghuraj, Maharana, & Nagendra, 2007). In thirty practitioners, meditation was associated with a reduction in sympathetic nervous system activity in different subdivisions such as increased sudomotor activity (based on raised skin resistance level), reduced sympathetic cutaneous vasomotor activity and changes in heart rate variability (HRV) suggestive of a shift towards vagal dominance (Telles et al., 2013). This would suggest that meditation reduces sympathetic activity which is considered necessary for alertness, while performance in tasks for alertness was paradoxically better after meditation. A single study simultaneously recorded P300 and HRV on ten *Vipassana* meditators and reported increased attentional engagement (with Cohen's d = 0.82) and autonomic regulation with a shift towards reduced vagal tone after meditation (Delgado-Pastor, Perakakis, Subramanya, Telles, & Vila, 2013). There are no reports of simultaneously recording P300 ERPs and HRV on the traditionally described mental states, i.e., (i) *dhāraṇā* (meditation with focused attention) leading to (ii) *dhyāna* (meditation).

3.4 MEDITATION AND CEREBRAL BLOOD FLOW

Meditation effects on cognitive functions and cerebral blood flow have recently become the subject of intensive scientific research. In order to examine neuronal activity and hemodynamic changes in the brain regions during activation in response to meditation, the application of different neuroimaging techniques would be beneficial. Event related potentials (ERP) studies provide high temporal information about the brain activity, but vague information regarding where the brain activity was originated (Yanagisawa et al., 2010). Functional magnetic resonance imaging (fMRI) also presents several challenges such as high sensitivity to participant motion, a loud, restrictive environment, low temporal resolution, and relatively high cost (Cui, Bray, Bryant, Glover, & Reiss, 2011). Some of these challenges are overcome with new optical imaging technique: NIRS measures changes in oxy-hemoglobin and deoxy-hemoglobin (ΔHbO and ΔHbR) concentration change from the cortical surface and is less invasive and less expensive than fMRI (Bunce, Izzetoglu, Izzetoglu, Onaral, & Pourrezaei, 2006). Functional near infrared spectroscopy is a compact and portable optical technique to monitor hemodynamics of the brain in real time (Lin, Lin, Penney, & Chen, 2009; Son, 2006).

In an early study on the effects of Transcendental Meditation on cardiac output, renal and hepatic blood flows, arterial lactate concentration, and minute volume were measured before, during, and after in twelve practitioners (Jevning, Wilson, Smith, & Morton, 1978). The result showed marked declines of renal blood flow and hepatic blood flow, increased cardiac output, decreased arterial lactate, and minute volume were also recorded in the TM-induced rest period. These changes imply a considerable increase of nonrenal, nonhepatic blood flow during TM (44%) and, to a lesser extent, during rest

(12%). Increased cerebral and/or skin blood flow is hypothesized to account for part of the redistributed blood flow in the practitioner. Another similar study on Transcendental meditation assessed peripheral circulatory and metabolic changes in ten practitioners (Jevning, Wallace, & Beidebach, 1992).

Meditation is a very relaxed, but at the same time, a very alert state. It is likely that such findings during meditation as increased cardiac output, probable increased cerebral blood flow, and findings reminiscent of the "extraordinary" character of classical reports: apparent cessation of CO2 generation by muscle, fivefold plasma AVP elevation, and EEG synchrony play critical roles in this putative response. Another study reported high correlation between increased CBF and decreased cerebrovascular resistance (CVR) during TM, suggesting that a contributing vascular mechanism to the increased CBF may be decreased CVR. Because only a small amount of stage 1 sleep was observed during TM and because stage 1 sleep has been reported to be accompanied by decreased CBF, we believe that sleep did not contribute to the CBF increase (Jevning, Anand, Biedebach, & Fernando, 1996).

Positron emission tomography (PET) was used to study cerebral blood flow in highly nine experienced yoga teachers assessed during relaxation meditation (Yoga Nidra), and during the resting state of normal consciousness (Lou et al., 1999). The results showed that in the resting state of normal consciousness (compared with meditation as a baseline), differential activity was found in dorso-lateral and orbital frontal cortex, anterior cingulate gyri, left temporal gyri, left inferior parietal lobule, striatal and thalamic regions, pons, and cerebellar vermis and hemispheres, structures thought to support an executive attentional network.

Recent studies reported that regular practice of meditation may change brain structure and function related to cognition. Evidences suggest that meditation practice is associated with neuroplastic changes in the anterior cingulate cortex, insula, temporo-parietal junction, fronto-limbic network, and default mode network structures (Holzel et al., 2011). Eight experienced Tibetan Buddhist meditators were injected at baseline with 7mCi HMPAO and scanned 20 min later for a duration of 45 min. The subject then meditated for 1 h at which time they were injected with 25 mCi HMPAO and scanned 20 min later for 30 min (Newberg et al., 2001). The results showed meditation increased rCBF in the cingulate gyrus, inferior and orbital frontal cortex, dorsolateral prefrontal cortex (DLPFC), and thalamus. The change in rCBF in the left DLPFC correlated negatively with that in the left superior parietal lobe. Increased frontal rCBF may reflect focused concentration and increased thalamic as well as an overall cortical activity during meditation. The correlation between the DLPFC and the superior parietal lobe may reflect an altered sense of space experienced during meditation. These results suggest a complex rCBF pattern during the task of meditation.

Subsequently, another study measured changes in cerebral blood flow during "verbal" based meditation by Franciscan nuns involving the internal repetition of a particular phrase and compared with eight Buddhist meditators (Newberg, Pourdehnad, Alavi, & D'Aquili, 2003). Three experienced practitioners of verbal meditation were injected via intravascular (i.v.) at rest with 260 MBq of Tc-99m HMPAO and scanned 30 min later on a triple head SPECT camera for 45 min. Following the baseline scan, subjects meditated for approximately 40 min, at which time they were injected with 925 MBq of HMPAO while they continued to meditate for 10 min more (total of 50 min of meditation).

Counts were obtained for regions of interest for major brain structures and normalized to whole-brain blood flow. Compared to the baseline, mean verbal meditation scans showed increased blood flow in the prefrontal cortex (7.1%), inferior parietal lobes (6.8%), and inferior frontal lobes (9.0%). There was also, a strong inverse correlation between the blood flow, change in the prefrontal cortex, and in the ipsilateral superior parietal lobe. Another study examined cerebral blood flow using single-photon emission computed tomography in 11 healthy individuals practicing meditation, (Khalsa, Amen, Hanks, Money, & Newberg, 2009) during chanting. Meditation showed there was a significant cerebral blood flow increase in the right temporal lobe and posterior cingulate gyrus, and decrease rCBF in the left parietotemporal and occipital gyri. This suggests that meditation practice is associated with changes in brain function in a way that is consistent with earlier studies of related types of meditation as well as with the positive clinical outcomes anecdotally reported by its users.

A study examined the effect of eight-week meditation program on cognitive function and cerebral blood flow (CBF) in 14 subjects with memory loss using IV inserted and were injected with 250 MBq of Tc-99m ECD before single photon emission computed tomography (SPECT) (Newberg, Wintering, Khalsa, Roggenkamp, & Waldman, 2010). The meditation program resulted in significant increases in baseline CBF ratios in the prefrontal, superior frontal, and superior parietal cortices. Scores on neuropsychological tests of verbal fluency, Trails B, and the logical memory showed improvements after training. Consequently, 12 advanced meditation and 14 non-meditators evaluated baseline brain functions using cerebral blood flow SPECT imaging at rest (Newberg, Wintering, Waldman, et al., 2010). The cerebral blood flow of long term meditators was significantly higher compared to non-meditator in the prefrontal cortex, parietal cortex, thalamus, putamen, caudate, and midbrain. Also, there was a significant difference in the thalamic laterality with long term meditators having greater asymmetry. These changes were associated with long term meditation appear in structures that underlie the attention network and also those that relate to emotion and autonomic function. In an effort to understand the neural pathways of meditation, the cerebral blood flow (CBF) responses associated with two different meditation practices performed by ten experienced meditators, a "focused-based" practice and a "breath-based" practice (Wang et al., 2011) were addressed. Functional magnetic resonance imaging (fMRI) was used during a baseline state, both meditation states, and a post mediation baseline state. Meditators showed that the frontal regions, anterior cingulate, limbic system and parietal lobes were affected and that there were different patterns of CBF between the two meditation states. Additionally, there were strong correlations between depth of meditation and neural activity in the left inferior forebrain areas including the insula, inferior frontal cortex, and temporal pole. There were also persistent changes in the left anterior insula and the precentral gyrus even after meditation was stopped. This suggests changes in the brain during two different meditation practices in the same individuals and that these changes correlated with the subjective experiences of the practitioners.

14 participants with memory impairment were selected for eight week meditation program and underwent for SPECT scanning before and after the program (Newberg, Wintering, Khalsa, Roggenkamp, & Waldman, 2012). A region of interest (ROI) (Inferior Frontal, Superior Frontal, Superior Parietal, DLPFC Sensorimotor, Posterior Cingulate, Orbitofrontal, Anterior Cingulate, Superior Frontal Thalamus, Superior Parietal, Medial

Frontal, Amygdala Precuneus areas were selected due to their activity as these regions are involved in executive decisions, learning, emotions spatial memory, self-awareness and self-position according to the surrounding environment) template obtained counts in each ROI normalized to whole brain to provide a CBF ratio. Baseline and meditation scans and neuropsychological testing were compared before and after the program.

In a clinical study, eighteen breast cancer patients were underwent with fMRI to evaluate changes in CBF associated with Mindfulness Based Art Therapy (MBAT) program (Monti et al., 2012). The patients received the diagnosis of breast cancer between 6 months and 3 years prior to enrollment and were not in active treatment. The result showed that patients in the MBAT arm demonstrated significant increases in CBF at rest and during meditation in multiple limbic regions, including the left insula, right amygdala, right hippocampus and bilateral caudate. Patients in the MBAT program also had a significant correlation between increased CBF in the left caudate and decreased anxiety scores.

A recent article (Travis, 2014) explores transcendental experiences during meditation practice and the integration of transcendental experiences and the unfolding of higher states of consciousness with waking, dreaming, and sleeping. The subject/object relationship during transcendental experiences is characterized by the absence of time, space, and body sense the framework that gives meaning to waking experiences. Physiologically, transcendental experiences during Transcendental Meditation practice are marked by slow inhalation, along with autonomic orientation at the onset of breath changes and heightened α1 (8-10 Hz) frontal coherence. The integration of transcendental experiences with waking, dreaming, and sleeping is also marked by distinct subjective and objective markers. This integrated state, called Cosmic Consciousness in the Vedic tradition, is subjectively marked by inner self-awareness coexisting with waking, sleeping, and dreaming. Physiologically, Cosmic Consciousness is marked by the coexistence of $\alpha 1$ electroencephalography (EEG) with delta EEG during deep sleep, and higher brain integration, greater emotional stability, and decreased anxiety during challenging tasks. Transcendental experiences may be the engine that fosters higher human development.

The only study on functional near infrared spectroscopy (fNIRS) was used to assess hemodynamics of the prefrontal cortex in Qigong meditation (Cheng, Borrett, Cheng, Kwan, & Cheng, 2010). Deoxyhemoglobin changes were recorded with the single-wavelength probe over the left prefrontal cortex during meditation by Qigong practitioners, and non-practitioners instructed in the technique. Practitioners showed a significant decrease in deoxyhemoglobin levels, suggesting an increase in prefrontal activation during meditation. The results were confirmed in a second set of experiments with the standard dual-wavelength probe, in which significant differences in the decrease in deoxyhemoglobin and the increase in oxyhemoglobin concentrations were observed in practitioners as compared with non-practitioners. The study thus provides evidence that Qigong meditation has a significant effect on prefrontal activation.

3.5 MINDFULNESS AND SCWT, POSM, PANAS, AND ANXIETY

Studies on mindfulness stroop color word task (SCWT), positive states of mind (PSOM), positive and negative affect (PANAS) and state and trait anxiety inventory (STAI).

Mindfulness meditation is an ancient concept, grounded in a wide range of spiritual and religious traditions, including Yoga, Tai Chi, Buddhism, Zen, Taoism, Hinduism etc. In Buddhist literature, mindfulness is described as the awareness that emerges through paying attention, on purpose, in the present moment, and non-judgmentally to the unfolding of an experience moment by moment' (Kabat-zinn, 2003). Meditation can be defined as the intentional self-regulation of attention from moment to moment through which mindfulness is cultivated (Corsini, 2001).

Previous studies have shown that the practice of meditation enhances behavioral improvements in perceptual discrimination and sustained attention during a visual discrimination task (MacLean et al., 2010). Meditation practice develops the ability to engage attention onto an object for extended periods of time (Jha, Krompinger, & Baime, 2007; Lutz, Slagter, Dunne, & Davidson, 2008). It improves the distribution of attentional resources in the temporal domain, as measured by the attentional blink task (Slagter, Davidson, & Lutz, 2011; Van Leeuwen, Müller, & Melloni, 2009), and the capacity to intend focus for prolonged periods of time (Carter et al., 2005). Long term meditation practice has been found to enhance cognitive performance (Cahn & Polich, 2006), attentional focus and alerting (Jha et al., 2007), processing speed (Lutz et al., 2009; Slagter, Lutz, Greischar, Nieuwenhuis, & Davidson, 2009), and information processing efficiency (Van Vugt & Jha, 2011). A study on Buddhist meditation practitioners showed mindfulness meditation was positively correlated with sustained attention, when compared to non-meditation practitioners (Moore & Malinowski, 2009). Meditation training revealed heightened activation in executive attention networks with improvements in sustained attention and error monitoring (Baron Short et al., 2010). These findings provide growing evidence of meditation promotion of higher-order cognitive processing; specifically facets of conflict monitoring and cognitive control processes. Other studies have shown that meditation is associated with improved conflict scores on the attention network test (Tang et al., 2007), reduced interference (Chan & Woollacott, 2007) and have better attentional performance during the stroop task compared to meditation-naïve control group (Moore & Malinowski, 2009).

The stroop task is one of the most frequently used models of the conflict processing in neuroscience and psychology. Stroop color word task performance evaluates flexibility in the control of cognitive processes and behavior which requires both attention and impulse control. The priming of color naming through the simultaneous presentation of a written word stimulus will therefore either facilitate (when the color and word stimuli are congruent, e.g., “b-l-u-e” written in the color blue) or interference (the incongruent Stroop trial, e.g., “blue” written in red) with color naming (MacLeod, 1991). Previous studies on stroop test have consistently shown that responses are much slower in naming the ink color of incongruent color words than in naming the ink color of neutral, and responses are often, but not always, faster when color and word are congruent (e.g., say red to the word red in red ink) than in the neutral condition. It supports the hypothesis that in the congruent condition of stroop tasks both the task relevant and task irrelevant dimensions activate the same response, whereas in the incongruent condition of stroop tasks these dimensions activate opposing response tendencies (Morton & Chambers, 1973; Posner & Snyder, 1975).

A study was conducted to examine the differences in various domains of attention in 15 long-term *Vihangam* meditation (Prakash et al., 2010). The Stroop test, trail-making, digit symbol substitution tests, and digit forward and digit backward tests were administered before and after meditation and control sessions. The performance on all tests of attention was better following *Vihangam* mediation group compared to control group. The results suggest that, long-term *Vihangam* meditation improves attention span, processing speed, attention alternation ability, and performance in interference tests. Recently, a study evaluated the performance of regular meditators and non-meditators during an fMRI adapted stroop color word task, which requires attention and impulse control (Kozasa et al., 2012). The findings suggested that meditation training improves efficiency, possibly via improved sustained attention and impulse control

Earlier studies reported that positive effect of meditation on attention modulation and cognitive function in neuropsychological and cognitive assessments. Transcendental Meditation (TM), a sitting meditation technique designed to quieten the mind and induce physical and mental relaxation, enhances restful alertness which may facilitate growth in social-emotional capacities necessary for regulating the emotional liability and interpersonal stress of adolescence, academic performance, and flexibility in emotional response in students (Rosaen & Benn, 2006). A recent study on immediate and long term practice of meditation on 34 adults reported the immediate effect of meditation associated with a physiological relaxation response and an improvement in scores on the Stroop test of reaction times. In the long-term, meditation showed significant improvements in IQ and scores for cognitive functions, whereas participants' stress levels decreased (Singh, Sharma, & Talwar, 2012).

Another study on focused attention, open monitoring and loving kindness meditation suggest that these meditations have differed, dissociable effects on a wide range of cognitive (control) processes, such as attentional selection, conflict monitoring divergent, and convergent (control) processes, such as attentional selection, conflict monitoring, divergent, and convergent thinking (Lippelt, Hommel, & Colzato, 2014). Consequently, a cross-sectional study on 133 healthy male volunteers (66 meditators and 67 non-meditators) practicing cyclic meditation reported mindfulness awareness scores (MASS) were higher in meditators compared to non-meditators (Vinchurkar, Deepeshwar, & Visweswaraiah, 2014). This suggests, CM can lead to the development of higher levels of mindfulness and may have the ability to positively impact on mental states and attention.

Previous studies on meditation and evoked potentials, event related potentials, autonomic changes, cerebral blood flow, and attention were summarized in the **Table 1-5**, respectively. The above mentioned studies have demonstrated the idea that meditation influences the sensory pathway measured through evoked potentials from the periphery through brainstem evoked potentials (BAEPs), to central areas with long latency auditory evoked potentials (LLAEPs). Evoked potentials have been used in meditation studies, since the correlation between the different components of evoked potentials and the underlying neural generators are fairly well known. Some meditation techniques showed an increase in amplitude and decrease in latency, whereas others showed an increase in latency suggesting delay in information processing. Meditation is also associated with attention.

Focused attention and vigilance are associated with greater or increased sympathetic activity. Some studies showed that meditation practice is associated with reduced sympathetic activity, a few other studies reported increased sympathetic activity.

Meditation reduces sympathetic activity which is considered necessary for alertness, while performance in tasks for alertness was paradoxically better after meditation. There are no reports of simultaneously recording attention (P300 ERPs) and HRV on the traditionally described mental states, i.e., (i) meditation with focused attention leading to (ii) meditation.

Also, earlier studies reported that different meditation practices are associated with different cerebral blood flow pattern in the brain. A possible reason for the differences in results with different meditation techniques, even though they all aim at facilitating spiritual evolution, is that they differ in the methods used. Most of these techniques have evolved in the past 200 years. This is relatively recent compared to the ancient texts (e.g., Patanajli's Yoga *Sutrā*; circa 900 BC). The present study has attempted to overcome the possible cause for differences by assessing the effects of meditation when practiced as described in traditional yoga texts.

Hence the present study was designed to assess the LLAEPs during the 4 mental states i.e., *cañcalatā, ekāgratā, dhāraṇā,* and *dhyāna*, to determine whether the differences in mental states would cause changes in the LLAEP components based on changes in the underlying neural generators. Also, the P300 ERPs, HRV and respiration were simultaneously recorded to determine whether meditation with focusing or meditation without focusing influence the P300 ERPs and the autonomic balance based on the HRV. Also, the present study was attempted to understand the bilateral prefrontal hemodynamic responses in meditation and random thinking related to cognition using stroop color word task. Mindfulness, positive states of mind, executive control, mood, and anxiety was also assessed in the present study to explore the differences in meditators and non-meditators.

REVIEW OF SCIENTIFIC LITERATURE

Table 1: Meditation and Evoked Potentials

Author & Year of Publication	N	Design	Variable studied	Findings
Wenger & Bagchi (1961)	14	Rest vs Meditation	EEG	Resting alpha with increased amplitude and wider distribution after meditation vs. before; Increase in Alpha frequency; Experience of *Samadhi* with increased amplitude - fast beta activity; no alpha blocking to stimuli
Wandhöfer, Kobal, & Plattig (1976)	-	Two groups, Transcendental meditation and control	Slow cortical auditory responses	Latencies for most of the initial peaks during TM as well as during normal consciousness were significantly shorter than in a control group in a dozing state or during normal consciousness.
Barwood, Empson, Lister, & Tilley (1978)	8	Two groups, Meditation, and light sleep	Auditory evoked potentials to tone stimuli	No consistent changes were noted between baseline and meditating AEPs, or between meditating and sleep AEPs.
Corby et al., (1978)	----	Rest vs. meditation	Autonomic & respiratory variables & EEG	Respiratory suspension during meditation; No changes in EEG

Banquet, Bourzeix, & Lesèvre (1979)	20	Two groups, Meditators & matched control group	Visual evoked potentials (N120, P200, P300)	After meditation the reaction time significantly increased with less mistakes, and amplitude of P300 increased significantly.
McEvoy, Frumkin, & Harkins (1980)	5	Two group pre – post design TM group and age matched control group	Brainstem auditory evoked potentials (BAEPs)	At moderate intensities (40-50 dB), latency of the wave V increased following meditation, but at higher stimulus intensities (55-70 dB), latency was slightly decreased.
Goddard (1989)	26	Elderly meditators vs. elderly controls	Auditory and visual oddball	Visual P300 latencies shorter in meditators, no auditory P300 effects
Cranson et al., (1990)	39	Long Term Meditators vs. Short Term Meditators vs. controls	Auditory oddball	P300 latency inversely correlated with length of meditation practice: none>short> long
Liu et al., (1990)	21	Before, during, and after meditation	ABR, MLR, AEP	ABR- increased I - V wave amplitudes; MLR- decreased Na- Pa amplitudes; Decreased P200 amplitude
Goddard (1992)	32	Elderly meditators vs. elderly controls vs. young meditators vs. young controls	Visual oddball	P300 latencies longer in elderly than young; elderly meditators vs. elderly controls had shorter P300 latencies and longer Reaction Times [RT]; Dissociation of P300 latency and RT

Gordeev et al., (1992)	29	Meditators vs. controls	Visual EPs, Somatosensory EP (SEP)	Diminished amplitude of intermediate and late components of visual and somatosensory EPs; SEP early components decreased in amplitude in the hemisphere ipsilateral to stimulation only
Telles, & Desiraju (1993)	14	Two group design Experienced meditators Vs naïve subjects	Middle latency auditory evoked potentials (MLAEPs)	During meditation there was a significant decrease in the latency of Nb wave.
Zhang et al., (1993)	48	3 groups - Long Term vs. Short Term vs. controls	Flash VEP	Increase in VEP amplitude in one form of Qi Gong and decreased in the other
Travis & Miskov (1994)	11	Before vs. after meditation vs. after rest	Auditory oddball task	Decreased latency P300 after TM but not rest; the trend towards higher amplitude P300 after TM
Telles et al., (1994)	18	Self as control design Meditation Vs Non-meditation (OM vs One)	Middle latency auditory evoked potentials (MLAEPs)	When both experienced and naïve meditators repeated 'one' there was a significant decrease in the peak amplitude of the Na wave. The Na wave peak amplitude significantly increased in experienced meditators, but significantly decreased in naïve meditators during mentally repeating *OM*.

Murthy et al., (1997, 1998)	45	Sudarshana Kriya Yoga; Patients: depressed vs. dysthymic vs. controls	Auditory oddball	Improvement in depressive symptoms and increase in P300 amplitude in novice meditators; effect may be due to alleviation of depression
Lyubimov (1999)	----	Experienced meditators	SEP	Decreased amplitude in the later components of the SEPs
Panjwani et al., (2000)	32	Epilepsy patients; 3 groups Sahaja Yoga group, Postural exercises group, Control group	Visual Contrast Sensitivity (VCS), BAEP, and MLAEP	Significant improvement in VCS following meditation and also a significant increase in the Na-Pa amplitude.
Telles & Naveen (2004)	16	Meditation session vs. non-meditation session	AEP-MLR	Decreased peak latency of the Na wave; Decreased latency in Na of AEP-MLRs
Sarang & Telles (2006)	42	Self as control; Cyclic Meditation & Supine Rest	P300	Decrease in the peak latencies and increase in amplitude of P300 after cyclic meditation.
Srinivasan & Baijal (2007)	20	Two groups, Meditators & Non-meditators	The auditory mismatch negativity	The meditators showed significant increase in MMN amplitudes immediately after the practice of meditation, suggesting transient state changes due to meditation.
Subramanya & Telles (2009)	47	Self as control; Cyclic Meditation & Supine Rest	MLAEPs	There was a significant increase in peak latency of Pa wave and Nb wave following CM

				compared to before CM suggesting cortical inhibition following CM
Cahn & Polich (2009)	-	Self as control; Meditation & non-meditation session	P3a event related brain potentials	Reduction in P3a amplitude suggesting decrease in automated reactivity and evaluative processing of task irrelevant attention-demanding stimuli
Kyizom et al., (2010)	60	Two groups; Control & Yoga group	P300 (ERP)	Significant improvement in the latency and the amplitude of N200, P300 in the yoga group as compared to the control group
Kumar et al., (2010)	30	Self as control; *cañcalatā, ekāgratā, dhāraṇā*, and *dhyāna*	Brainstem auditory evoked potentials (BAEPs)	Significant increase in the wave V peak latency in *cañcalatā, ekāgratā, dhāraṇā*, but not during *dhyana* session
Sobolewski et al., (2011)		Two groups; Long-term meditators & Non-meditators	Visual event-related potential (ERP)	The study concluded that, meditators are less affected by stimuli with adverse emotional load, while processing of positive stimuli remained unaltered
Chatterjee et al., (2012)	10	Healthy male volunteers: drawn randomly from the Indian Army went under two months of meditation practice	Middle latency response (MLR), event related potentials P300-	Sleep deprivation impaired cognitive performance to graded extents significantly, but this deterioration could be improved to a significant extent using meditation.

			ERP and contingent negative variation (CNV)	
Telles et al., (2012)	60	4 mental states are random thinking, non-meditative-focused thinking, meditative focusing, and meditation	Mid-latency auditory evoked potentials (MLAEPs)	Prolonged latencies of MLAEPs components, the Na and Pa waves during meditation, suggesting that auditory information transmission at the level of the medial geniculate and primary auditory cortex (i.e., the neural generators corresponding to the Na and Pa waves) was delayed
Delgado-Pastor et al., (2013)	10	Self as control; Vipassana meditation and random thinking	Auditory oddball task with two tones (standard and target),Heart rate variability,	Expert Vipassana meditators showed increased attentional engagement after meditation and increased autonomic regulation during meditation.
Cahn, Delorme, Polich (2013)	18	Long-term Vipassana meditators sat in meditation vs. a control (instructed mind wandering)	Three-stimulus auditory oddball	Vipassana meditation evokes a brain state of enhanced perceptual clarity and decreased automated reactivity

Table 2: Meditation and P300 Event Related Potentials (ERPs)

Author & Year of Publication	N	Design	Variable studied	Findings
Luo, Wei, Weekes (1999)	11 subjects with musical meditation, 12 subjects control	with or without musical meditation training	Auditory mismatch negativity (MMN) and P300 of event-related potentials	MMN amplitudes in the trained children were larger than those in the control group, MMN amplitudes were identical in attend and ignore conditions for both groups,
Sarang, Telles (2006)	42 volunteers	Cyclic meditation (CM)	Peak latency and peak amplitude of P300 auditory event-related potentials	Reduction in the peak latencies of P300 after cyclic meditation at Fz, Cz, and Pz compared to the "pre" values, P300 peak amplitudes after CM were higher at Fz, Cz, and Pz sites compared to the "pre" values
Travis et al., (2009)	16 Vipassana meditators (F=5, M=11)	Meditation (Vipassana)	P3a event-related brain potential	P2 amplitude from both the distracter and oddball stimuli were somewhat reduced during meditation; P3a amplitude from the distracter was reduced during meditation;

				Meditation state can decrease the amplitude of neurophysiologic processes that subserve attentional engagement elicited by unexpected and distracting stimuli
Lakey, Berry, Sellers (2011)	18	Short Mindfulness Meditation Induction (MMI)	P300-based brain-computer interface performance	MMI subjects produced significantly larger P300 amplitudes at Cz and PO7
Chatterjee, Ray, Panjwani, Thakur, Anand (2012)	10	Chanted 'mmmm' of the 'Om' with slow deep breathing	Middle latency response (MLR), event related potentials P300-ERP and contingent negative variation (CNV)	Latency and amplitude of P300 increased after 36 h Sleep deprivation (SD). None of these parameters showed any significant alteration after SD, following meditation practice
Delgado-Pastor, Perakakis, Subramanya, Telles, Vila (2013)	10 males	Vipassana meditation and Random thinking	Event-related potentials to the tones were recorded at the Fz, Cz, and Pz locations. Heart rate variability	Expert Vipassana meditators showed increased attentional engagement after meditation and increased autonomic regulation during meditation

Table 3: Meditation and Psychophysiological Changes

Author & Year of Publication	N	Design	Variable studied	Findings
Telles, Desiraju, (1993)	18 males	Each subject was assessed in three sessions which included a period of meditation, and also in three control (non-mediation) sessions, which included a period of random thinking	Autonomic and respiratory variables during the practice of Brahmakumaris Raja yoga meditation	Heart rate during the meditation period was increased compared to its preceding baseline. Changes which occurred consistently during the three repeat sessions of a subject and Changes which exceeded arbitrarily-chosen cut-off points
Sun, Li DM, Li, (1996)	32 volunteers	Meditation on inspiration and expiration	Spectral analysis of P-R interval, different characteristics of heart rate variability in different form of respiratory exercise	Mind was concentrated at the inspiration, the function of autonomic nerve system was kept in balance, and both the sympathetic and the vagal activities enhanced significantly and while mind concentrated at the expiration could induce a reduction of vagal activity so as to produce a marked change in the sympathovagal balance.

Telles, Nagarathna, Nagendra, (1998)	12 volunteers	Three types of sessions i. mentally repeating a meaningful syllable 'OM' (MOM session) ii. repeating a neutral work, 'one' (COM session) iii. non-targeted thinking (NT session)	Autonomic and Respiratory Variables	MOM and COM sessions the rate of respiration (RR) and heart rate (HR) decreased significantly. Mental repetition of 'OM' (but not 'one') caused a significant decrease in skin resistance level (SRL).
Travis, Wallace (1999)	20 (13 male and 7 female)	Transcendental Meditation I sessions	Autonomic and EEG variables	The rapid shift in physiological functioning within the first minute might be mediated by a "neural switch" in prefrontal areas inhibiting activity in specific and nonspecific thalamocortical circuits. The resulting "restfully alert" state might be sustained by a basal ganglia-corticothalamic threshold regulation mechanism automatically maintaining lower levels of cortical excitability
Murata et al., (2004)	22	Zen Meditation	EEG coherence and autonomic nervous	During meditation, in terms of mean values in all subjects, an increase in slow alpha

			activity using heart rate variability (HRV) as an index	interhemispheric EEG coherence in the frontal region, an increase in high-frequency (HF) power (as a parasympathetic index of HRV), and a decrease in the ratio of low-frequency to HF power (as a sympathetic index of HRV) were observed
Takahashi et al., (2005)	20	Zen meditation	EEG coherence and autonomic nervous activity using heart rate variability (HRV) as an index	During meditation, increases were observed in fast theta power and slow alpha power on EEG predominantly in the frontal area, whereas an increase in the normalized unit of high-frequency (nuHF) power (as a parasympathetic index) and decreases in the normalized unit of low-frequency (nuLF) power and LF/HF (as sympathetic indices) were observed through analyses of heart rate variability.
Hamada et al., (2006)	30 healthy volunteers	Meditation	Autonomic nervous activity using heart rate variability (HRV) and EEG	MA task induced significant increases in normalized LF, LF/HF ratio (as a sympathetic index), and a decrease in

			power during mental arithmetic (MA) tasks	normalized HF (as a parasympathetic index). On the other hand, significant decrease in EEG power (slow theta: 4-6 Hz and fast alpha: 10-13 Hz in the posterior region and fast theta: 6-8 Hz and slow alpha: 8-10 Hz in all the regions) were induced by MA task.
Patra, Telles et al., (2010)	30 males	Cyclic meditation (CM)	Heart rate variability (HRV) during Sleep	CM practice, there were the following changes; a decrease in heart rate, LF power (n.u.), LF/HF ratio, and an increase in the number of pairs of Normal to Normal RR intervals differing by more than 50 ms divided by total number of all NN intervals (pNN50) in all cases, comparing sleep following CM compared with sleep following SR). No change was seen on the night following SR
Mohan, Sharma, Bijlani (2011)	32 healthy adult male students	Practice 20 minutes of guided meditation	Galvanic skin response (GSR), heart rate (HR),	Computer game stress was associated with a significant increase in physiologic (GSR, EMG, HR, QTc/QS2) and psychological

			electromyography (EMG), sympathetic reactivity (QTc/QS2 ratio), cortisol, and acute psychological stress scores	(acute stress questionnaire scores) markers of stress. Meditation was associated with relaxation (significant decrease in GSR, EMG, QTc/QS2, and acute stress questionnaire scores). Meditation, if practiced before the stressful event, reduced the adverse effects of stress. Memory quotient significantly increased, whereas cortisol level decreased after both stress and meditation. VCRT showed no significant change.
Reddy, Kuntamalla (2011)	-	Two forms of meditation i.e., Chi and Kundalini	Heart rate variability analysis	There is a significant change in the nonlinearity and stochastic nature of the signal before and during the meditation (p value > 0.01). During Chi meditation there is a increase in stochastic nature and decrease in nonlinear nature of the signal. There is a significant decrease in the degree of nonlinearity and stochastic nature during Kundalini meditation.

Telles S, Raghavendra BR, Naveen KV, Manjunath NK, Kumar S, Subramanya P. (2012)	30	Four mental states are random thinking (*cañcalatā*), nonmeditative focusing (*ekāgratā*), meditative focusing (*dhāraṇā*), and effortless meditation (*dhyāna*)	Autonomic and Respiratory variables	*dhyāna* increases the skin resistance level and photo-plethysmogram amplitude, whereas decreases heart rate and breath rate. Also, decreases the low frequency (LF) power and increases the high frequency (HF) power, associated with parasympathetic activity.
Sukhsohale ND, Phatak MS. (2012)	100 (33 men and 67 women)	Short-term and long-term Brahmakumaris Raja Yoga meditation	Physiological variables like heart rate (HR), respiratory rate (RR), systolic blood pressure (SBP) and diastolic blood pressure (DBP)	The long-term practice of Raja Yoga meditation improves basic cardio-respiratory functions due to shifting of the autonomic balance in favor of parasympathetic instead of sympathetic system
Fiorentini, Ora, Tubani (2013)	9	Zen meditation	Cardiorespiratory interaction	ZaZen breathing falls within the range of low frequency HR spectral bands. Our data suggest that the modification of HR spectral power remained also in a normal day when the subject have normal breathing.

Table 4: Meditation and Cerebral Blood Flow Changes

Author & Year of Publication	N	Design	Variable studied	Findings
Jevning, Wilson, Smith, Morton (1978)	12	Transcendental Meditation (TM) or ordinary eyes-closed rest-relaxation period	Cardiac output, renal and hepatic blood flows, arterial lactate concentration, and minute volume	Marked declines of renal blood flow, hepatic blood flow, increased cardiac output, decreased arterial lactate, and minute volume were also recorded in the TM-induced rest period.
Jevning, Wallace, Beidebach (1992)	10	Transcendental Meditation (TM)	Cerebral Blood Flow and Cerebrovascular Resistance (CVR)	Increased frontal and occipital CBF in TM determined by the electrical impedance plethysmographic
Jevning R, Anand R, Biedebach M, Fernando G. (1996)	-	Transcendental meditation (TM).	Cerebral blood flow (CBF) measured using electrical impedance plethysmographic methodology known as rheoencephalography (REG),	High correlation between increased CBF and decreased cerebrovascular resistance (CVR) during TM, suggesting that a contributing vascular mechanism to the increased CBF may be decreased CVR.

Lou HC, Kjaer TW, Friberg L, Wildschiodtz G, Holm S, Nowak M. (1999)	9	Relaxation meditation (Yoga Nidra), and during the resting state of normal consciousness	Cerebral blood flow distribution was investigated with the 15O-H20 PET technique	(H2)15O PET method may measure CBF distribution in the meditative state as well as during the resting state of normal consciousness, and that characteristic pattern of neural activity support each state
Newberg, Alavi, Baime, Pourdehnad, Santanna, d'Aquili (2001)	8	Experienced Tibetan Buddhist Meditators	Regional Cerebral Blood Flow (rCBF)	Increased rCBF was observed in the cingulate gyrus, inferior and orbital frontal cortex, dorsolateral prefrontal cortex (DLPFC), and the thalamus. The change in rCBF in the left DLPFC correlated negatively with that in the left superior parietal lobe. Correlation between the DLPFC and the superior parietal lobe may reflect an altered sense of space experienced during meditation.
Litscher, Wenzel, Niederwieser, Schwarz, (2001)	2	QiGong	Transcranial Doppler sonography, EEG, stimulus-induced 40	Increase in mean blood flow velocity (vm) in the posterior cerebral artery, and

			Hz oscillations, and near-infrared spectroscopy	a simultaneous decrease of vm in the middle cerebral artery)
Newberg, Pourdehnad, Alavi, d'Aquili, (2003)	3 Verbal meditators And 8 Buddhist meditators	"Verbal" based meditation by Franciscan nuns involving the internal repetition of a particular phrase compared with eight Buddhist meditators who use a type of "visualization" technique	SPECT: Regional cerebral blood flow	Mean verbal meditation scans showed increased blood flow in the prefrontal cortex, inferior parietal lobes, and inferior frontal lobes. There was a strong inverse correlation between the blood flow, change in the prefrontal cortex and in the ipsilateral superior parietal lobe
Khalsa, Amen, Hanks, Money, Newber (2009)	11 healthy individuals	Chanting Meditation	Single-photon emission computed tomography scans: Cerebral blood flow changes	Significant rCBF increases were observed in the right temporal lobe and posterior cingulate gyrus, and significant rCBF decreases were observed in the left parietotemporal and occipital gyri.
Cohen DL, Wintering N, Tolles V, Townsend RR, Farrar JT, Galantino ML, Newberg AB. (2009)	4 subjects	Cerebral blood flow before and after a 12-week training program in Iyengar yoga (IY) for novice subjects.	Single photon emission computed tomography scan	There were significant decreases between the pre- and post program baseline scans in the right amygdala, dorsal medial cortex, and sensorimotor area. There was

			(pre-program baseline).	a significant difference in the pre- and postprogram percentage change (i.e., activation) in the right dorsal medial frontal lobe, prefrontal cortex, and right sensorimotor cortex.
Newberg, Wintering, Khalsa, Roggenkamp, Waldman, (2010)	14 with memory problems	8-week meditation program	Cognitive Function and Cerebral Blood Flow	Significant increases in baseline CBF ratios in the prefrontal, superior frontal, and superior parietal cortices. Scores on neuropsychological tests of verbal fluency, Trails B, and the logical memory showed improvements after training.
Newberg, Wintering, Waldman, Amen, Khalsa, Alavi, (2010)	12 advanced meditators and 14 non-meditators	Long-term Transcendental meditators	Cerebral blood flow (CBF) SPECT imaging	Significantly higher compared to non-meditators in the prefrontal cortex, parietal cortex, thalamus, putamen, caudate, and midbrain. There was also a significant difference in the thalamic laterality with long-term meditators having greater asymmetry.

Cheng, Borrett, Cheng, Kwan, Cheng, (2010)	15 meditators	Qigong meditation	Deoxyhemoglobin changes were recorded using near-infrared spectroscopy with a dual-wavelength probe	Decrease in Deoxyhemoglobin levels, suggesting an increase in Prefrontal activation during meditation. Decrease in Deoxyhemoglobin and increase in Oxyhemoglobin concentrations were observed in practitioners as compared with non-practitioners.
Wang, Rao, Korczykowski, Wintering, Pluta, Khalsa, Newberg, (2011)	10 experienced meditators	Two types of meditation, a "focused-based" practice and a "breath-based" practice	Pathways of meditation by addressing the cerebral blood flow (CBF) responses associated with two different meditation practices performed	The frontal regions, anterior cingulate, limbic system and parietal lobes were affected during meditation and that there were different patterns of CBF between the two meditation states. Strong correlations between depth of meditation and neural activity in the left inferior forebrain areas including the insula, inferior frontal cortex, and temporal pole.

Bhargav, Nagendra, Gangadhar, Nagarathna, (2014)	schizophrenia (n = 18; 14 males, 4 females) and (n = 18; 14 males, 4 females)	Kapalabhati (KB)	Frontal hemodynamic responses to high frequency yoga breathing technique using functional near-infrared spectroscopy	The increase in bilateral oxyHb and totalHb from the baseline was highly significant in healthy controls during KB. Schizophrenia patients showed significant reduction in deoxyHb in the right pre-frontal cortex.

Table 5: Meditation and Stroop Color Word Task

Author & Year of Publication	N	Design	Variable studied	Findings
Wenk-Sormaz (2005)	120	Meditation, rest, or a cognitive control	Stroop and Word Production (category generation and stem-completion)	Showed a reduction in habitual responding on the Stroop task as compared to controls. Meditation participants showed a reduction in habitual responding to the category production task.
Chan, Woollacott (2007)	50 meditators and 10 controls	Long-term trait effects of meditation	Stroop (measures executive attention) and Global-Local Letters (measures orientational attention) tasks	This suggests that meditation produces long-term increases in the efficiency of the executive attentional network (anterior cingulate/prefrontal cortex) but no effect on the orientation network (parietal systems)
Kozasa et al., (2012)	20 right-handed regular meditators	"Zazen", Mantra Meditation, Mindfulness of Breathing, Regular Meditators and Non-meditators	fMRI adapted Stroop Word-Color Task (SWCT), which requires	Non-meditators showed greater activity than meditators in the right medial frontal, middle temporal, precentral and postcentral

	and 19 non-meditators		attention and impulse control, using a block design paradigm	gyri and the lentiform nucleus during the incongruent conditions. Non-meditators showed an increased pattern of brain activation relative to regular meditators under the same behavioral performance level.
Prakash et al., (2012)	20	Long-term Concentrative Meditation	The tests used were: (i) the Digit Span test, (ii) the Stroop Color Word test, (iii) the Trail making test, (iv) the Letter Cancellation Task, (v) the digit symbol substitution test, and (vi) the Rule Shift Card Test	Vihangam Yogis showed significantly better performances in all these tests of attention except for the digit backward test, where a trend was found in favor of meditators. Long-term Vihangam Yoga meditators have superior cognitive abilities than non-meditators in the old age group.
Moore, Gruber, Derose, Malinowski (2012)	40	Mindfulness-based meditation	Computerized Stroop task while 64-channel EEG	Mindfulness meditation may alter the efficiency of allocating cognitive resources, leading to improved self-regulation of attention.

Teper R1, Inzlicht (2013)	44	Mindfulness Meditation	Error-related negativity (ERN),	Meditators showed greater executive control (i.e. fewer errors), a higher ERN and more emotional acceptance than controls..
Allen (2012)		Mindfulness Training (MT) on self-regulation	Measured behavioral metacognition and whole-brain BOLD signals using functional MRI during an affective Stroop task before and after	MT group displayed greater dorsolateral prefrontal cortex responses during executive processing, consistent with increased recruitment of top-down mechanisms to resolve conflict. MT practice showed improvements in response inhibition and increased recruitment of dorsal anterior cingulate cortex, medial prefrontal cortex, and right anterior insula during negative valence processing.
Bob et al., (2013)	7 healthy persons	Meditation	Bilateral electrodermal activity (EDA) and attentional states (resting state,	The information transference (i.e., transinformation) is able to distinguish those attentional states, and that the highest level of the transinformation has been found during attentional processing related to

			Stroop task, and memory task)	meditation, indicating higher level of connectivity between left and right sides.
Braboszcz, Cahn, Balakrishnan, Maturi, Grandchamp, Delorme (2013)	82 Isha yoga practitioners	Isha Yoga Meditation	Three behavioral psychophysical tests - a Stroop task, an attentional blink task, and a global-local letter task	Increase in correct responses specific to incongruent stimuli in the Stroop task, reduction of the attentional blink. A positive correlation between previous meditation experience and accuracy to incongruent Stroop stimuli was also observed at baseline.
Fan, Tang, Tang, Posner (2014)	43 UG students	Long term meditation practice	EEG and Stroop task	IBMT group showed decreased conflict reaction time (RT), and increased resting mean alpha power. Higher the enhancement of resting alpha power, the stronger the improvement of conflict RT. Short term meditation diffusely enhances alpha and improves the ability to deal with conflict and moreover, these two effects are positively related.

CHAPTER-4

AIMS AND OBJECTIVES

4.0 AIMS AND OBJECTIVES

4.1 AIMS OF THE STUDY

The present study was intended to obtain a greater understanding on measuring indicators of neuronal activity and cerebral blood flow changes in four mental states (*cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*) as defined in traditional yoga texts.

4.2 OBJECTIVES OF THE STUDY

- The objectives of the present study was to review and compile the authentic information on the growth of individual awareness from classical Yogic and Spiritual literature.
- To explore the Indian and Western concept of consciousness or awareness.
- To investigate the effect of four mental states viz. *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* on:

    i. Long latency auditory evoked potentials (LLAEPs),

    ii. Simultaneous recording of P300 Event Related Potentials (ERPs) and Heart Rate variability (HRV),

    iii. Hemodynamic changes in meditation related to cognitive task,

    iv. Mindfulness and state and trait anxiety,

    v. Positive states of mind (POSM) and executive control in meditators and non-meditators,

    vi. Subjective assessment of following the guided instructions for *cañcalatā, ekāgratā*, *dhāraṇā,* and *dhyāna* using visual analog scale (VAS), and also

vii. Correlation of VAS with attention (measured in P300 ERPs) and accuracy (counted clicks during Oddball task).

4.3 JUSTIFICATION OF THE STUDY

Scientific studies on various forms of meditation (such as *OM* meditation, Sahaja Yoga meditation, Brahmakumari Raja Yoga meditation, Vipassana meditation, Transcendental meditation etc.,) have shown psychophysiological, neurophysiological and neurochemical changes. The results are varied across these studies due to different techniques, methods and the underlying principles of each meditation practice. Previous studies on brainstem and midlatency auditory evoked potentials have been recorded during four mental states viz., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* with an encouraging degree of inter-subject consistency. It is believed that the meditation influences subcortical and cortico-efferent connections which would affect neuronal activity of the cortex. The neuronal activity of the cortex is measured through long latency auditory evoked potentials (LLAEPs). There is just one study on LLAEPs during Transcendental Meditation (TM). In that study, LLAEPs were recorded in eight experienced meditators, 'Before', 'During' and 'After' meditation and also during light sleep. No consistent changes were noted between baseline and meditation in long latency auditory evoked potentials or between meditation and sleep.

The long latency auditory evoked potentials (LLAEPs), simultaneous recordings of P300 event related potentials (ERPs) and heart rate variability (HRV) and also, cerebral blood flow have not been studied in these four states (i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*).

In the present study, we have evaluated LLAEPs, simultaneous recordings of P300 ERPs and HRV in meditative and non-meditative states. Subsequently, we assessed cerebral hemoglobin responses in meditation related to attention. And also, the present study was designed to assess the correlations of (i) mindfulness and state-trait anxiety, (ii) Positive states of mind (POSM) and executive control in meditators and non-meditators, (iii) visual analog scale (VAS), accuracy and attention (P300 latency and amplitude).

4.4 HYPOTHESIS AND NULL HYPOTHESIS

The hypothesis of the present study was that, the four mental states i.e., two meditative (*dhāraṇā* and *dhyāna*) and two non-meditative (*cañcalatā* and *ekāgratā*) may:

1. Influence neuronal activity of the brain, especially at the cortical level
2. Affect neuronal network related to attentional processes
3. Enhance cerebral blood flow in the bilateral prefrontal cortex in meditative states related to attentional task
4. Enhance mindfulness and reduce State and Trait anxiety
5. Have a positive correlation of Visual Analogue Scale with accuracy and attention

CHAPTER-5

METHODS

5.0 METHODS

In this thesis, the changes in (i) long latency auditory evoked potentials (LLAEPs), (ii) simultaneous recordings of P300 event related potentials (ERPs) and the autonomic variables based on the HRV and respiration, (iii) cerebral hemodynamic responses in meditation related to cognitive task, (iv) mindfulness and state & trait anxiety (STAI), and (v) positive states of mind and executive control to follow guided instructions were studies in normal healthy male volunteers following two meditative (i.e., *dhāraṇā* and *dhyāna*) and two non-meditative (i.e., *cañcalatā* and *ekāgratā*) states.

Additionally, we have attempted to find the correlations between the visual analog scale (VAS), attention (P300 latency and amplitude) and accuracy of counting clicks in P300 oddball task in four mental states i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*.

The methodology of the research has been described under the following sub-headings:

5.1 PARTICIPANTS

5.2 DESIGN OF THE STUDY

5.3 VARIABLES STUDIED

5.4 INTERVENTIONS

5.5 DATA EXTRACTION

5.6 DATA ANALYSIS

5.1 PARTICIPANTS

5.1.1 Sample size

Sixty males with ages between 18 and 31 years (group means ± S.D., 20.5 ± 3.8 years) were recruited as participants by announcements in the university newsletter and flyers on the notice boards. Statistical calculation of the sample size was not done prior to the experiment. However *post-hoc* analyses showed that for the present study, with the sample size as 46 used for final analysis, in each session, and with the Cohen's *d* = 0.70, the power was 0.95 (Erdfelder, Faul, & Buchner, 1996). The Cohen's *d* was obtained from the P2 component peak latency of long latency auditory evoked potentials (LLAEPs) in the meditation session when during values were compared to pre values. The number of participants varied across the variables studied. The details are as follows:

Table 6: Details of the participants recruited across the variables studied.

Sl. No.	Variable Studied	No. of Subjects	Excluded subjects	No. of recording sessions
1.	Long latency auditory evoked potentials (LLAEPs)	60	12	60 × 4 = 240
2.	P300 Event related potentials (ERPs) and autonomic variables	60	13	60 × 4 = 240
3.	Cerebral blood flow and Stroop Task	25	2	25 × 2 = 50
4.	Mindfulness and STAI	Meditator = 67 Control = 67	1	67 × 2 = 100
5.	Positive states of mind and executive control	Meditator = 30 Control = 30	0	30 × 2 = 60

Note: *The number of participants varied for different variables as it was not always possible for all participants to attend all sessions.*

In LLAEPs recordings, twelve participants and in P300 ERP recordings, 13 participants were excluded from the study because of motion artifact in the signals or because of high electrode impedance during the recordings. Hence, the data from 48 participants for LLAEPs (ranging from 17 to 30 years; group mean age ± S.D., 19.3 ± 2.6 years) and 47 participants in P300 ERPs (ranging from 20 and 32 years; group mean age ± S.D., 21.6 ± 3.4 years) were included for the final analysis. Similarly, 25 adult right handed healthy male participants recruited with age ranged 19 and 30 years (group mean age ± S.D.; 23.4 ± 3.7 years) for cerebral hemodynamic changes at prefrontal cortex measured using functional near infrared spectroscopy (fNIRS) and stroop color word task recordings. Three participants were excluded because of large motion artifacts in the signals due to head movements or because of failure in probe placement due to obstruction by the hair. Thus, only data from 22 participants (group mean age ± S.D., 22.9 ± 4.6 years) were included to measure hemodynamic responses in the final analysis.

5.1.2 Selection and source of participants

Participants were all residential students of Swami Vivekananda Yoga Aunsandhana Samsthana (S-VYASA, a Yoga University) and Veda Vijnana Gurukulam (VVG, a Vedic School), Bangalore, South India. All participants had a minimum of six months experience in the practice of meditation on ‘*OM*’ (with a group average experience ± S.D. of 20.9 ± 14.2 months), and were regular in their practice. They had enrolled in various courses at SVYASA and VVG.

5.1.3 Inclusion criteria

To be included in the trial participants had to meet the following criteria:

(i) have normal health based on a routine clinical examination,

(ii) male participants alone were studied as auditory evoked responses on cognitive abilities and cerebral blood flow (Brackley, Ramsay, Broughton Pipkin, & Rubin, 1999) have been shown to fluctuate with the phases of the menstrual cycle (Yadav, Tandon, & Vaney, 2002) and P300 evoked potentials also varied with gender (Conroy & Polich, 2007),

(iii) have a minimum experience of meditation on the Sanskrit syllable, '*OM*', for 30 minutes each day, for five days in a week,

(iv) the participants had to have a meditation practice for a minimum of three months (with a group average experience ± S.D. of 20.9 ± 14.2 months), and

They were all regular in practice. The regularity of meditation practice was based on self-reporting of the meditators as well as consultations with the meditation teacher (Guru). The further details of each participant enrolled in LLAEPs, P300 ERPs, CBF, mindfulness, POSM, and executive task have been given in the **Table 7**, **Table 8**, **Table 9**, **Table 10**, and **Table 11**, respectively.

5.1.4 Exclusion criteria

The exclusion criteria were used to exclude the volunteers:

(i) persons on any medication or herbal remedy,

(ii) presence of any illness, particularly psychiatric or neurological disorders,

(iii) intake of medication, which is known to influence cognitive functions,

(iv) auditory deficits assessed by checking the auditory thresholds of each ear separately was excluded,

(v) participants who had difficulty in focusing/concentrating, based on interview, and

(vi) smoking or alcoholism which may have influenced the cognitive functions.

None of the participants were excluded based on these criteria.

5.1.5 Ethical consideration

The project was approved by the Institution's Ethics Committee. The study protocol, the nature of the experiments and the operating mode of the instrument was explained to the subjects before providing written signed consent (a sample copy is enclosed in **Appendix-1**). None of them were aware of the hypothesis of the study. They were not compensated for their time and participation in the study.

Table 7: The characteristics of participants in long latency auditory evoked potentials (LLAEPs) recorded in four mental states

Characteristics	
Age (in years) (group mean ± S.D.)	19.3 ± 2.6
Years of education	
17 years and more	17 (35.4%)
Upto 15 years	23 (47.9%)
Upto 12 years	8 (16.7%)
Type of meditation	Meditation on the Sanskrit syllable '*OM*'
Experience of meditation practice (in months)	
6 -12 months	23 (48.9%)
13 - 24 months	9 (19.2%)
25 - 36 months	7 (14.9%)
37 - 48 months	6 (12.8%)
48 - 60 months	2 (04.3%)
Socioeconomic status (Mukherjee & Satija, 2012)	
High income group	9 (18.7%)
Mid income group	33 (68.7%)
Low income group	6 (12.5%)

Table 8: The characteristics of participants in simultaneous P300 event related potentials & autonomic variables recorded in four mental states

Characteristics	
Age (in years) (group mean ± S.D.)	21.6 ± 3.4 years
Years of education	
17 years and more	18 (38.3%)
Upto 15 years	29 (61.7%)
Type of meditation	Meditation on the Sanskrit syllable '*OM*'
Experience of meditation practice (in months)	47.9±23.7 months
6 -24 months	27 (57.5%)
24 - 48 months	12 (25.5%)
48 - 60 months	8 (17.0%)
Socioeconomic status (Mukherjee & Satija, 2012)	
High income group	3 (6.4%)
Mid income group	37 (78.7%)
Low income group	7 (14.9%)

Table 9: The characteristics of participants in functional near infrared spectroscopy (fNIRS) recorded in two mental states (*cañcalatā* and *dhyāna*)

Characteristics	
Age (in years) (group mean ± S.D.)	22.9±4.6 years
Years of education	
17 years and more	6 (27.3%)
Upto 15 years	10 (45.5%)
Upto 12 years	6 (27.3%)
Type of meditation	Meditation on the Sanskrit syllable '*OM*'
Experience of meditation practice (in months)	
6 -12 months	4 (18.2%)
13 - 24 months	3 (13.6%)
25 - 36 months	7 (31.8%)
37 - 48 months	6 (27.3%)
48 - 60 months	2 (9.1%)

Table 10: The characteristics of meditators and non-meditators enrolled for mindfulness and attention task

Characteristics	Mean ± SD
Mean age	
Meditators	23.6±3.25
Non Meditators	21.72±3.44
Years of Education	
Meditators	15.13±1.57
Non Meditators	14.12±1.76
Meditation Experience (years)	
Meditators	7.85±2.37

Table 11: The characteristics of meditators and non-meditators enrolled Positive states of mind (PSOM), executive task and Positive and negative affect (PANAS)

Characteristics	
Age (in years) (group mean ± SD)	25.9 ± 5.0
Education	
Postgraduates	23 (47.92%)
Graduates	8 (16.67%)
Undergraduates	17 (35.41%)
Type of meditation	Meditation on the Sanskrit syllable '*OM*'
Experience of meditation practice (in months)	28 ± 13.6 months

5.2 DESIGN OF THE STUDY

5.2.1 Structure of sessions

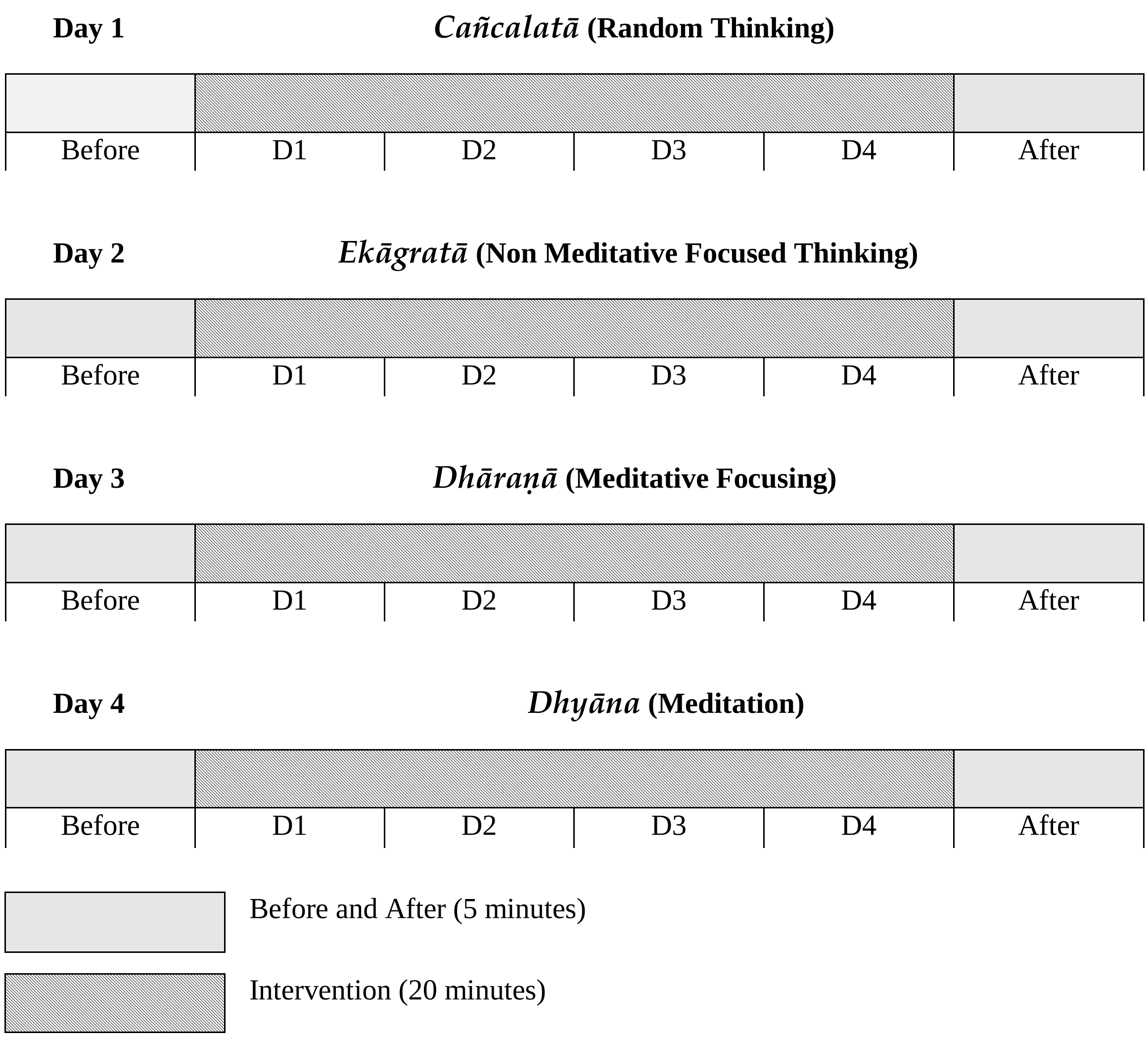
(i) Long latency auditory evoked potentials (LLAEPs)

Each participant was assessed in four sessions, to which they were assigned randomly. The sessions were randomized using a standard random number table. Two of them were meditation sessions. These were (i) *dhāraṇā* (meditative focusing) and (ii) *dhyāna* (meditation without focusing or effortless meditation). The other two sessions were non-meditation sessions. They were (i) *ekāgratā* (non-meditative focused thinking) and (ii) *cañcalatā* (random thinking). All four sessions consisted of three states: 'Before' (5 minutes), 'During' (20 minutes), and 'After' (5 minutes). The design has been presented schematically in **Figure 2.**

(ii) Simultaneous recordings of P300 Event related potentials (ERPs) and autonomic variables

Each participant was assessed in four randomly assigned sessions (*cañcalatā, ekāgratā, dhāraṇā,* and *dhyāna*). Each P300 event related potentials (ERPs) session consisted of two states: 'Before' (5 min), and 'After' (5 min). The heart rate variability (HRV) and respiration consisted of three states: 'Before' (5 minutes), 'During' (20 minutes), and 'After' (5 minutes). The study design has been presented schematically in **Figure 2.**

Figure 2: Schematic representation of the study design of the four sessions; Periods of recording are shown as stippled and periods of intervention are shown as hatched



Note: Sessions were modified for each participant

D1: During 1; D2: During2; D3: During 3; D4: During 4

(i) LLAEPs were recorded 'Before', 'During', and 'After' the intervention.

(ii) The HRV and Respiration were recorded 'Before', 'During', and 'After' the intervention and P300 ERPs were recorded 'Before', and 'After' intervention.

(iii) Hemodynamic changes and Stroop Color Word Task

The protocol utilized in the present study consisted of two Sessions i.e. *cañcalatā* (random Thinking) and *dhyāna* (meditation), and eight States ('Before', 'Stroop_Pre', 'During (D1-D4)', 'Stroop_Post', and 'After'). Each participant underwent both the sessions, separated by consecutive days, after a crossover, randomized, double blind paradigm. The randomization of the sessions was generated online with randomization software (www.randomizer.org). During the experiments, the participants and the researcher who collected the experimental data were masked to both the randomization assignments and to the type of session. The total duration of the each session was 60 min: 'Before' (5 min), 'Stroop_Pre' (15 min), 'During' (20 min), 'Stroop_Post' (15 min), and 'After' (5 min). The design has been presented schematically in **Figure 3**.

Figure 3: Schematic representation of the study design of the two sessions. The fNIRS was recorded 'Before', 'During', and 'After' stroop task and intervention

Day 1 **Random Thinking**

Before	Pre_Stroop	D1	D2	D3	D4	Post_Stroop	After

Day 2 **Meditation**

Before	Pre_Stroop	D1	D2	D3	D4	Post_Stroop	After

Before and After (5 minutes)

Stroop_Pre and Stroop_Post (15 min)

Intervention (20 minutes)

Note: Sessions were modified for each participant

D1: During 1; D2: During2; D3: During 3; D4: During 4

(iv) Mindfulness and Anxiety

This cross-sectional survey aimed to collect data concerning mindfulness, state and trait anxiety using the Freiburg Mindfulness Inventory (FMI) and the State-Trait Anxiety Inventory (STAI), respectively.

The descriptions of the measurements are given below.

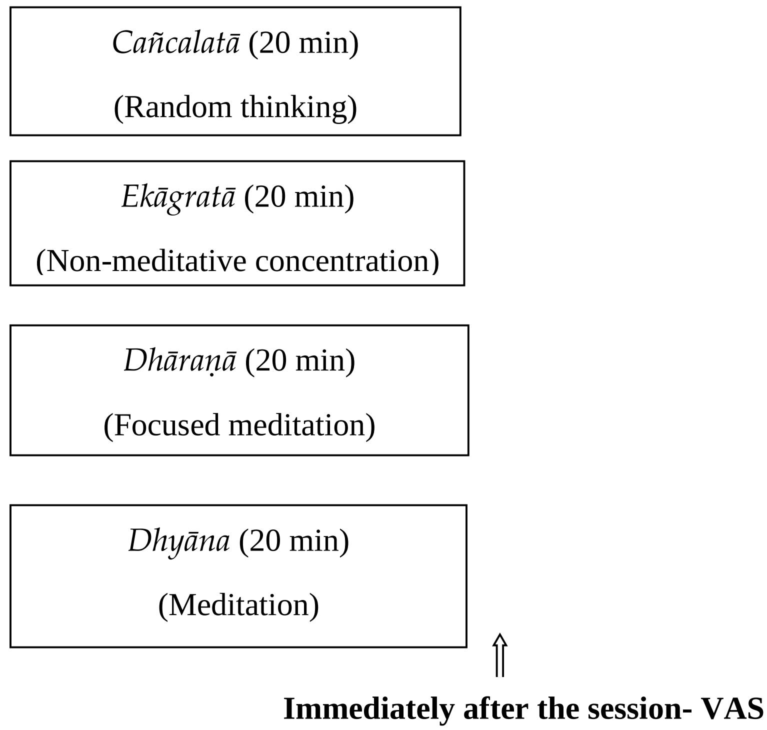
(v) Positive state of mind and executive control

This was a cross sectional study where we compared the data collected from meditators and non-meditators 'Before' and 'After' the meditation practice of one month. Meditators practiced 30 minute meditation on the syllable '*OM*' preceded and followed by 6 minute periods of sitting relaxed, with eyes closed. Non meditators remained seated with closed eyes for the same duration as that of meditation practice, but did not practice any meditation or focusing. Meditation involved mental chanting of '*OM*', while sitting comfortably, with eyes closed. Meditation was practiced for five days in a week.

(vi) Correlation of Subjective assessments with Attention and Accuracy

Each participant was assessed in four sessions. Assessments were made on four different days, which were not necessarily on consecutive days (within one or two day gap), but at the same time of the day. The allocation of participants to the four sessions was random using a standard random number table. The duration of all the four sessions was 20 min. A visual analog scale was given immediately after the practice of *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*.

Figure 4: Schematic representation of the study design in visual analog scale



5.2.2 Order of sessions

The order of the four sessions was randomized for each subject using a random number table. This was done to prevent the influence of being exposed to the laboratory for the first time. The recordings were made on different days, not necessarily on consecutive days, but at the same time of the day. The randomization of the order of four sessions in LLAEPs and P300 ERPs are explained below.

Subject Code	Randomization of session
XXX	1, 3, 2, 4
ABC	3, 1, 2, 4
LKJ	2, 3, 4, 1
….	….

5.3 VARIABLE STUDIED

The word parameter is described as ‘characteristic of distribution or a relationship in the population which are estimated by statistical analysis of a sample of observation’ whereas, the word variable denotes ‘measurement or attribute on which observations are made’ (Altman, Gore, Gardner, & Pocock, 1983). Hence, in this thesis, the term ‘variable’ has been used to describe the assessments studied.

5.3.1 Long Latency Auditory Evoked Potentials (LLAEPs)

5.3.1 A. *Rationale for studying Long latency auditory evoked potentials*

Evoked potentials (EPs) are evoked automatically with repetitive sensory stimulation and also allow changes in a sensory pathway to be understood, from the periphery through brainstem evoked potentials, to central areas with long latency auditory evoked potentials. Long latency auditory evoked potentials (LLAEPs) are generated by thalamo-cortical and cortico-cortical auditory pathways, the primary auditory cortex and the association cortical areas (Ventura, Alvarenga, & Costa Filho, 2009). The auditory modality of stimuli was chosen as it was found to be least disturbing to the meditator during their practice (Telles et al., 1993). Hence, in the present study the long latency auditory evoked potentials were recorded during four mental states i.e., *cañcalatā, ekāgratā, dhāraṇā,* and *dhyāna* using the Nicolet Bravo System (USA). **Plate 1** shows the Nicolet Bravo EP 4 channel amplifier and closed circuit T.V.

5.3.1 B. *Specifications of Nicolet Bravo System*

The Bravo EP (Nicolet, USA) is a 4 channel evoked potential acquisition and review system with options of performing a wide variety of tests such as Auditory Evoked

Potentials (AEP), Somatosensory Evoked Potentials (SEP), Visual Evoked Potentials (VEP) and P300 Event Related Potentials (ERP). The Bravo EP amplifier has 4 acquisition channels, a headbox for electrode connections and an LED electrode impedance panel. To perform AEP tests, acoustically shielded earphone (TDH-39, Amplivox, UK) is used to deliver either ‘tone’ or ‘click’ stimulus. The acoustic stimulus intensity (in dB) has the following options: sound pressure level (SPL), peak sound pressure level (pSPL), peak equivalent sound pressure level (peSPL) and normal hearing level (nHL). The Bravo EP has an optional software package which allows running P300 cognitive response test. The main features of the P300 optional software include 4-channel recording and independent averaging for frequent and rare stimuli (Nicolet Biomedical Inc., 1998).

PLATE 1: Bravo Evoked Potentials System, Nicolet, USA

Nicolet Bravo System (Nicolet Biomedicals, U.S.A.) a 4-channel EP acquisition and analysis system with a closed circuit TV on the

Electrode paste, adhesive tape, electrolyte jelly, skin preparation lotion.

Earphones

A subject seated in a sound attenuated cabin with electrodes at Cz (active) referred to linked ear lobe and a ground electrode (FPz), with acoustically shielded ear phones to deliver binaural clicks during the recording of LLAEPs

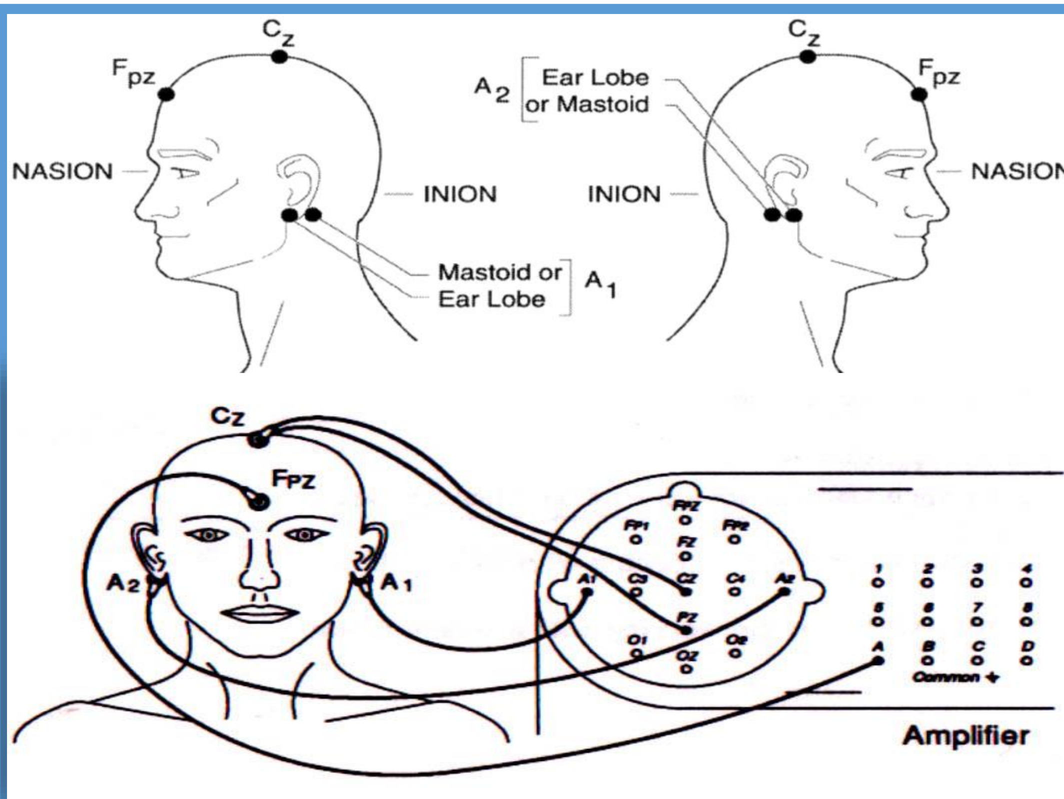
5.3.1 C. *Recording conditions*

LLAEPs were assessed in the four sessions i.e., random thinking (*cañcalatā*), nonmeditative focused thinking (*ekāgratā*), meditative focusing (*dhāraṇā*), and meditation (*dhyāna*). Participants were seated in a sound attenuated, dimly lit cabin with sound level 26 dB normal hearing level and monitored on a closed circuit television to detect if they moved or fell asleep during a session. Instructions were given through a two-way intercom, so that participants could remain undisturbed during a session. The LLAEPs were recorded with eyes closed and participants seated at ease. The temperature in the recording room was maintained at 24.0 ± 1.0 °C. The average humidity was 56 percent of the days the experiments were conducted. LLAEPs were recorded in the 250 ms, a poststimulus time period without any prestimulus delay, using a 4-channel system (Nicolet Biomedical Inc., U.S.A.).

5.3.1 D. *Electrode positions*

Ag/AgCl disk electrodes were fixed with electrode gel (Ten 20 conductive EEG paste, U.S.A.) at the vertex (Cz) with reference electrodes on linked earlobes (A1-A2) and with the ground electrode on the forehead (FPz). Electrode placements were based on the International 10-20 electrode placement system (Jasper, 1958). The electrode impedance was kept below 5 kΩ. The electrode sites (i.e., Fpz, Cz, A1-A2) and schematic illustrations of evoked potentials (BAEPs, MLAEPs, LLAEPs) and event related brain potentials (P300ERPs) from auditory stimuli given in **Figure 5** and **Figure 6**. A typical waveform of long latency auditory evoked potentials are given in **Figure 7 a.**

Figure 5: Electrode sites and schematic of latency and amplitude of LLAEPs and P300 ERPs responses



Common Electrode Site for 2-Channel LLAEPs and P300 ERPs Recordings

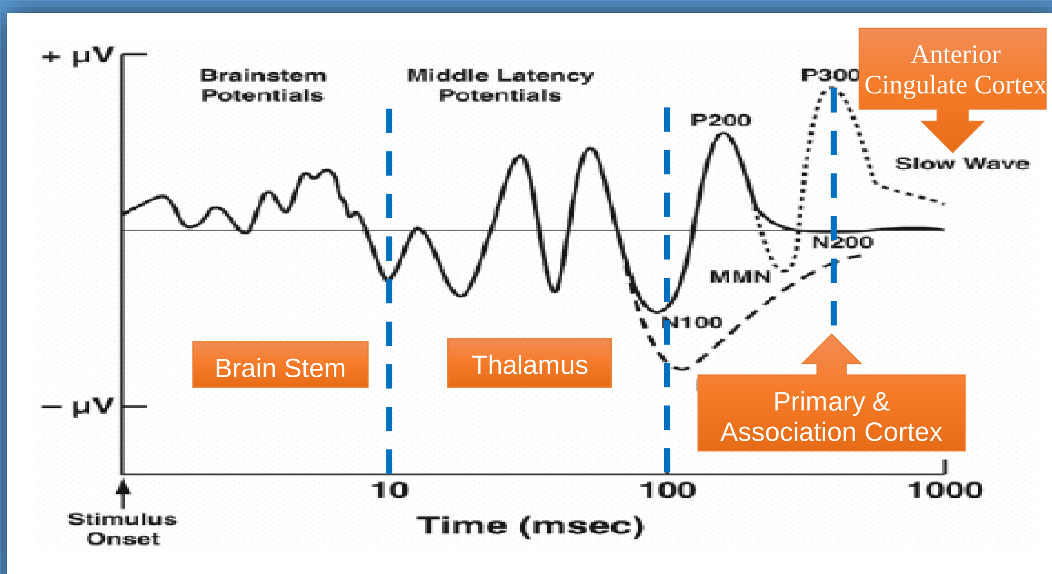
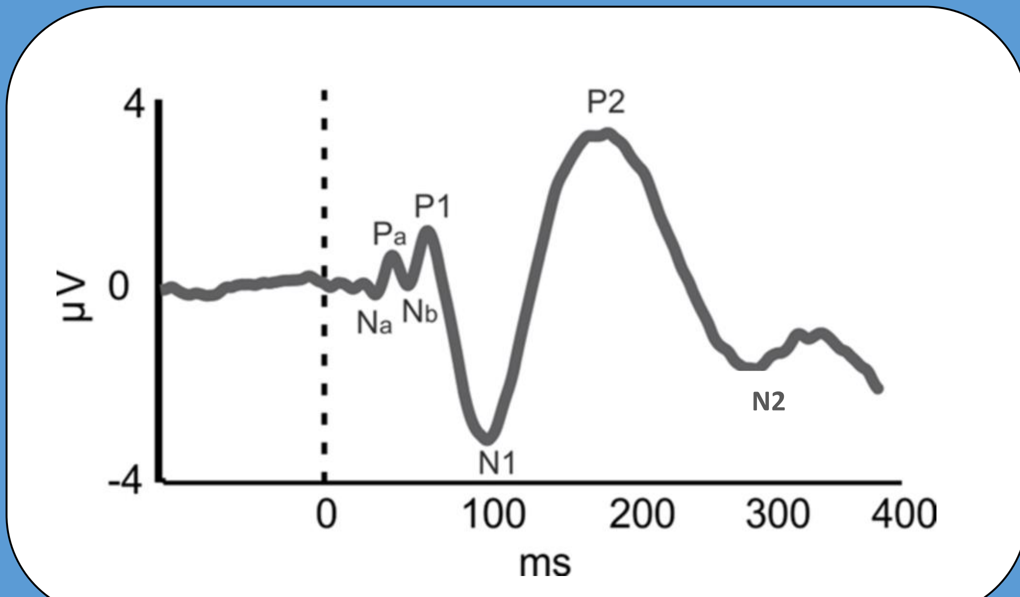
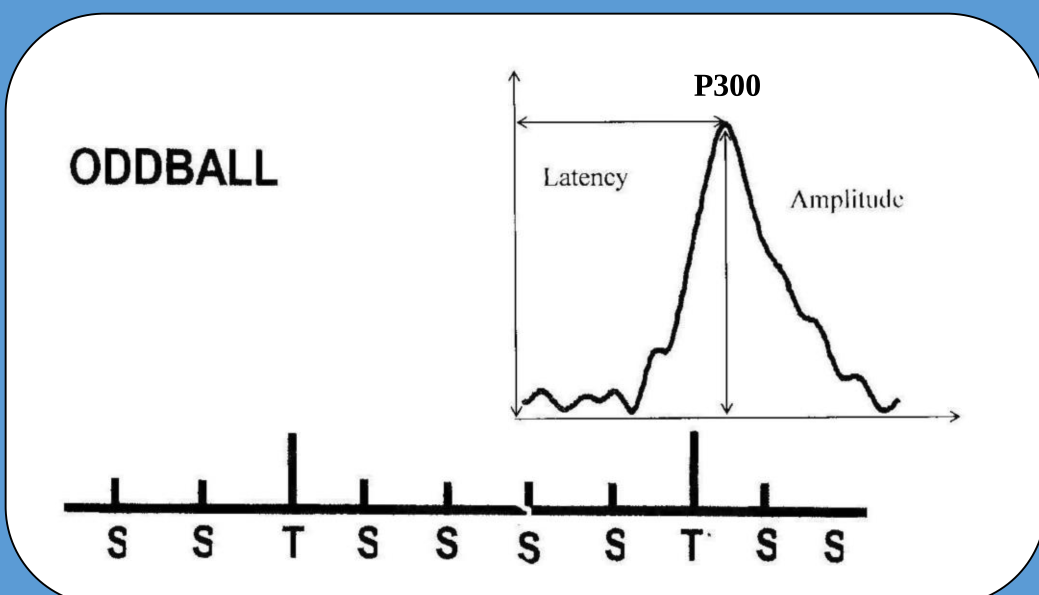


Figure 6: Schematic illustration of evoked and event- related brain potentials from auditory stimuli. Logarithmic scales for amplitude and latency are used for illustrative purposes only (Hillyard & Picton, 1974)

Figure 7: A typical waveform of Long latency auditory evoked potentials and P300 ERPs



a. Typical Trace of LLAEPs with four components (P1, N1, P2, N2)



b. Typical Trace of P300 Event Related Potentials

5.3.1 E. *Amplifier settings*

Standard settings for LLAEP recording were used (Ventura et al., 2009). The electroencephalographic (EEG) activity was amplified with a sensitivity of 100 µV. The low cut filter was 0.1 Hz and the high cut filter was 30.0 Hz. LLAEPs were averaged in 500 trial sweeps in the 0 to 500 ms range. Rejection was set at 90 percent of the full-scale range of the analog-to-digital converter.

5.3.1 F. *Stimulus characteristics*

Binaural click stimuli of 100 µs duration and alternating polarity at the rate of 5.0 Hz were delivered through acoustically shielded earphones (Amplivox, U.K.) (Ventura et al., 2009). The threshold of hearing was noted for each participant to verify that their hearing was normal. The threshold of hearing was checked as follows (i) decreasing the intensity in 5dB steps until the participant could no longer hear the clicks, and (ii) increasing the intensity in 5dB steps until the clicks were audible. The click threshold was taken as the midpoint between the intensities at which the clicks could and could not be heard. This procedure was repeated twice. The thresholds ranged between 15 dB and 25 dB normal hearing level (nHL). The average threshold of hearing was 14.03±2.98 dB nHL. The intensity was kept at 70 dB nHL. Participants' had a 100 percent compliance with the meditation orientation program and for the recordings.

5.3.1 G. Variables measured

The following variables were measured:

1. Peak latencies (ms) of long latency auditory evoked potentials were recorded with 4 components i.e., P1, N1, P2 and N2 waves from Cz position (vertex electrode site).
2. Peak amplitudes (µV) of long latency responses were recorded with 4 components i.e., P1, N1, P2 and N2 waves from Cz position (vertex electrode site).

5.3.2 Simultaneous P300 Event Related Potentials (ERPs) and Autonomic activity

5.3.2 A. *Rationale for studying Computer averaged P300 event related potentials ERPs*

The P300 is a positive ERP recorded widely across the scalp approximately 300 ms after an auditory, visual, or somato-sensory "Oddball" stimulus, which must be random and stand out, and also must be followed by a response from the participants, such as pressing a button or mental Counting. The P300 recorded from the scalp has several components that seem to be independently generated from different brain structures. These components include brain activities involved in selective attention, work update, and short-term memory in response to unexpected changes in the environment (Blackwood, 2000; Donchin & Coles, 2010). The P300 latency is presumed to indicate the time required for task evaluation independent of motor processing and can be used to study the cognitive processing in the disease. The P300 component is often elicited with a simple discrimination task known as the 'oddball' paradigm, since two stimuli are presented in a random series such that one of them occurs relatively infrequently i.e. the odd ball (Polich, 1999). The P300 generation occurs from the interaction between the frontal lobe, hippocampal, and temporoparietal functions (Halgren, Marinkovic, & Chauvel, 1998). The peak latency and peak amplitude of the P300 event related potentials were recorded during four mental states (*cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*) using the Nicolet Bravo System (USA). The P300 component was elicited with a simple discrimination task known as the 'Oddball' paradigm, in which two auditory stimuli are presented in a random series so that one of them occurs infrequently i.e., considered the oddball (Polich, 1999). In our experience meditation practitioners found auditory stimuli less distracting than visual or somatosensory stimuli.

5.3.2 B. *Specifications of Nicolet Bravo System*

The Bravo EP (Nicolet, USA) is a 4 channel evoked potential acquisition and review system with options of performing P300 Event Related Potentials (ERP). The Bravo EP amplifier has 4 acquisition channels, a headbox for electrode connections and an LED electrode impedance panel. The Bravo EP has software package which allows running P300 cognitive response test. The main features of the P300 optional software include 4-channel recording and independent averaging for frequent and rare stimuli (Nicolet Biomedical Inc., 1998). **Plate 1** shows Bravo EP System (Nicolet, USA); The Bravo EP - 4 channels amplifier and subject in sitting position with electrode connections and earphone; and the recording cabin with acoustically shielded earphone (Amplivox, UK) used to deliver the ‘frequent’ and ‘rare’ stimuli, and a head-box for electrode connections to the LED electrode impedance panel. Percent error calculated for Nicolet Bravo System was 0.03 percent.

5.3.2 C. *Recording conditions*

Participants were assessed in four sessions, i.e., random thinking (*cañcalatā*), non-meditative focused thinking (*ekāgratā*), meditative focusing (*dhāraṇā*), and meditation (*dhyāna*) while recording of (i) P300 event related potentials (ERPs), and simultaneously, (ii) heart rate variability (HRV) and respiratory rate. Participants were asked to avoid substances which influence cognitive performance (particularly tea and coffee for the caffeine content) on the day preceding and on the day of the recording. Where this was unavoidable the session was taken on another day.

For assessments, participants were seated in a sound attenuated, dimly lit cabin with sound level 26 dB and monitored on a closed circuit television outside the cabin to detect if they moved or fell asleep during a session. Instructions were given through a two-way intercom, so that participants could remain undisturbed during a session. The temperature in the recording room was maintained at 24.0±1.0 °C. The average humidity was 56 percent of the days the experiments were conducted. The autonomic variables and P300 event related evoked potentials were recorded with eyes closed. A typical waveform of event related potentials is given in **Figure 7 b.**

5.3.2 D. *Electrode positions*

The Ag/AgCl disk electrodes were fixed with electrode gel (Ten 20 conductive EEG paste, U.S.A.) at the vertex (Cz), with reference electrodes on linked earlobes (A1-A2) and with the ground electrode on the forehead (FPz). Electrode placements were based on the International 10-20 electrode placement system (Jasper, 1958). The electrode impedance was kept below 5 kΩ.

5.3.2 E. *Amplifier settings*

Standard settings for P300 event related potentials (ERPs) recording were used (Duarte et al., 2009). The electroencephalographic (EEG) activity was amplified with a sensitivity of 100µV. The low pass cut was kept at 0.01 Hz and the high pass cut was kept at 30 Hz. The P300 ERPs were computer averaged in 300 trial sweeps in the 0 to 750 ms range. The pre-stimulus delay was kept at 75 ms and the level of artifact rejection was set at 90 percent.

5.3.2 F. *Stimulus characteristics*

Binaural tones stimuli of alternating polarity delivered in 0.9s with a frequency of 1 KHz (50 cycles for the plateau, 10 cycles for the ramp) for the standard stimuli and 2 KHz (10 cycles for the plateau, 20 cycles for the ramp) for the target stimuli were used to trigger online averaging of the EEG. The inter stimulus interval was 1.1 s. The stimulus intensity was set at 70dB sound pressure level (SPL).

5.3.2 G. *Variables measured*

The following variables were measured:

i. Peak latencies (ms) of P300 responses at Cz (vertex electrode site)

ii. Peak amplitudes (μV) of P300 responses at Cz (vertex electrode site)

iii. P300 Oddball task: The P300 component was elicited with a simple discrimination task known as the “oddball” paradigm. The oddball task consisted of discrimination between two tones: the standard tone (a 1000 Hz tone presented 240 times, 80%) and the target tone, (a 2000 Hz tone, presented 60 times, 20%), in random order. (Polich 1999). These ‘standard’ and ‘target’ auditory stimuli were delivered through close fitting earphones (TDH-39, Amplivox, U.K.). The participants were asked to distinguish between the two tones and mentally count the “target” stimuli. The equipment gives the number of target stimuli delivered. Only those sessions in which the participants achieved 95 percent accuracy in Counting target stimuli were included. None of the sessions had to be excluded for this reason.

5.3.3 Autonomic variables using Heart rate variability (HRV) and Respiration

5.3.3 A. *Rationale for studying Heart rate variability (HRV) and respiration*

The HRV spectrum is believed to be a useful indicator of sympathetic activity (reflected by low frequency [LF] band power values) and parasympathetic activity (reflected by high frequency [HF] band power values) (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). In the present study, we have used autonomic balance with assessing heart rate variability and respiration to verify sympathetic activation is required for attention task. Separate studies have shown that meditation (i) improves attention and (ii) reduces sympathetic activity.

Heart rate variability (HRV) describes the variations between consecutive heartbeats. The regulatory mechanisms of HRV originate from the sympathetic and parasympathetic nervous systems in addition to other controls and hence, HRV is used as a quantitative marker of the autonomic control over the heart (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, Heart Rate Variability: standards of measurement, physiological interpretation, and clinical use, 1996). The EKG and respiration were assessed throughout a session, which lasted 30 minutes (‘Before’, ‘During’, and ‘After’) using a 16 channel polygraph system (MP 100 BIOPAC, AcqKnowledge software, BIOPAC System Inc., U.S.A.). The EKG was recorded using Ag/AgCl pre–gelled electrodes (Tyco Healthcare, Germany) and recording were made with the standard limb lead I configuration. Data were acquired at the sampling rate of 1024 Hz and were analyzed offline. Noise free data were included for analysis.

Respiration rate: Respiration was concurrently monitored in an attempt to remove the contribution of respiration to the HRV, especially lower frequencies. The respiratory rate was recorded using a volumetric pressure transducer fixed around the trunk about 8 cm below the lower costal margin as the participants sat erect.

5.3.3 B. *Recording conditions*

Participants were assessed in four sessions, i.e., random thinking (*cañcalatā*), non-meditative focused thinking (*ekāgratā*), meditative focusing (*dhāraṇā*), and meditation (*dhyāna*) while recording of (i) P300 event related potentials (ERPs), and simultaneously, (ii) heart rate variability and respiratory rate. Participants were asked to avoid substances which influence cognitive performance (particularly tea and coffee for the caffeine content) on the day preceding and on the day of the recording. Where this was unavoidable the session was taken on another day.

For assessments participants were seated in a sound attenuated, dimly lit cabin with sound level 26 dB and monitored on a closed circuit television outside the cabin to detect if they moved or fell asleep during a session. Instructions were given through a two-way intercom, so that participants could remain undisturbed during a session. The temperature in the recording room was maintained at 24.0±1.0 °C. The average humidity was 56 percent on the days the experiments were conducted. The autonomic variables and P300 event related evoked potentials were recorded with eyes closed.

5.3.3 C. *Specification of Biopac MP 100 system*

The EKG and respiration were assessed throughout a session, which lasted for 30 minutes (Pre, During and Post) using a 16 channel polygraph system (MP 100 BIOPAC, AcqKnowledge software, BIOPAC System Inc., U.S.A.). The ECG100C Electrocardiogram Amplifier records electrical activity generated by the heart and will reliably record ECG from humans and isolated organ preparations. The ECG amplifier output can be switched between normal ECG output and R-wave detection. The R-wave mode outputs a smoothed pulse with the occurrence of each R-wave. The exact timing of the R-wave is detected even under conditions of extreme signal artifact. The amplifier also includes a user-switchable baseline stabilizer.

Use the AcqKnowledge software to provide a complete Lead II ECG analysis. The software automatically scores the data and extracts the measurements of interest on a cycle-by-cycle basis. The results are automatically exported to Excel or pasted in the Journal file. Acq*Knowledge* also includes a fully automated HRV analysis feature. The HRV analysis provides values for VLF, LF, HF, VHF, sympathetic, and vagal, as well as the sympathetic/vagal balance. The EKG were recorded using Ag/AgCl pre–gelled electrodes (Tyco Healthcare, Germany) and recording were made with the standard limb lead I configuration. Data were acquired at the sampling rate of 1024 Hz and were analyzed offline. Noise free data were included for analysis.

Respiration rate: Respiration was concurrently monitored using SS5LB respiratory effort transducer in an attempt to remove the contribution of respiration to the HRV, especially lower frequencies. The respiratory rate was recorded using a volumetric pressure transducer fixed around the trunk about 8 cm below the lower costal margin as the participants sat erect.

5.3.3 D Electrode Position

Electrocardiogram (EKG): An electrocardiogram (ECG) is a graphic recording of the changes occurring in the electrical potentials between different sites on the skin (leads) as a result of cardiac activity. One common placement of the electrodes is based on Einthoven's triangle, which is a theoretical triangle drawn around the area of the heart. Each apex of the triangle represents where the fluids around the heart connect electrically with the limbs. Typically, separate amplifiers would be placed at each of the three points of the triangle, and data from Leads I, II, and III would be acquired. However, Einthoven's law states that if the values for any two points of the triangle are known, the third can be computed. To obtain accurate 3-lead ECG data using the MP150 data acquisition system, set all of the hardware and software parameters as stated below. These have proven to be optimal for ECG testing, although many of the settings can be customized to account for individual testing preferences.

Respiration rate: The SS5LB transducer is used to record respiration via chest or abdomen expansion and contraction. This transducer is useful for determining how deeply someone is breathing and for calculating the person’s breathing rate or respiration rate. The transducer is a strain assembly that measures the change in thoracic or abdominal circumference. The strap presents minimal resistance to movement and is extremely unobtrusive. Due to its novel construction, the SS5LB can measure extremely slow respiration patterns with no loss in signal amplitude while maintaining excellent linearity and minimal hysteresis. The respiratory effort transducer has a two meter flexible lightweight cable. The center plastic housing protects the delicate sensor within. The transducer is attached by a fully adjustable nylon strap, which allows the transducer to fit almost any circumference.

To attach the nylon belt to the transducer, thread the strap through the corresponding slots on the sensor assembly. Place the transducer around the body at the level of maximum respiratory expansion (generally about 5cm below the armpits). At maximum expiration, adjust the strap so there is slight tension to hold the strap around the chest. A 16-channel polygraph [Biopac MP 100 data acquisition system] (Biopac Systems Inc, USA) used for recording of EKG, and Respiration in a sound attenuated cabin, is given in **Plate 2.**

5.3.3 E. *Testing procedure*

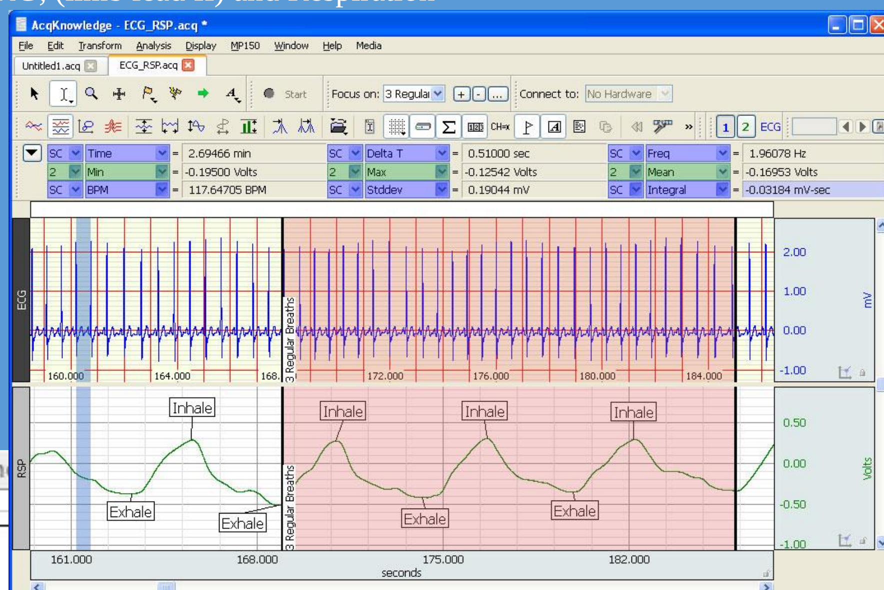
The Ag/AgCl disk electrodes were fixed with electrode gel (Ten 20 conductive EEG paste, U.S.A.) at the vertex (Cz), with reference electrodes on linked earlobes (A1-A2) and with the ground electrode on the forehead (FPz). Electrode placements were based on the International 10-20 electrode placement system (Jasper, 1958). The electrode impedance was kept below 5 kΩ. The data were acquired in five-minute epochs in the pre, during, and post periods. The ECG recording of all volunteers was free of extra systoles. The data recorded were visually inspected off-line and noise free data were included for analysis. The R waves were detected to obtain a point event series of successive R-R intervals, from which the beat-to-beat heart series were computed.

5.3.3 F. *Variables measured*

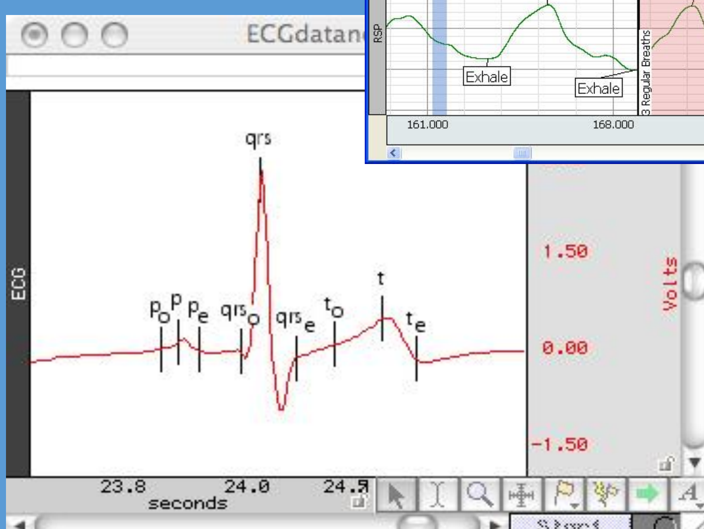
The following variables were measured (i) LF: Low frequency power of HRV spectrum is known to correspond to sympathetic modulation when expressed in normalized units. Low frequency band ranges between 0.05 - 0.15 Hz. (ii) HF: High frequency power (normalized units) of the HRV spectrum ranges between 0.15 – 0.4 Hz. The efferent vagal activity is a major contributor to the HF component. (iii) Ratio of low and high frequency powers (LF/HF ratio) is correlated with the sympathovagal balance. (iv) HR: Heart rate is the number of beats of per minute (b/min). Normally, heart rate ranges between 70 and 80 beats per minute (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, Heart Rate Variability: standards of measurement, physiological interpretation, and clinical use, 1996).

Plate 2: Setup in the Autonomic Function Testing Laboratory

A 4-channel polygraph [Biopac MP 100 data acquisition system] (Biopac Systems Inc, USA) used to record the EKG, and Respiration. A subject seated in a sound attenuated cabin with transducers to record the EKG, (limb lead II) and Respiration

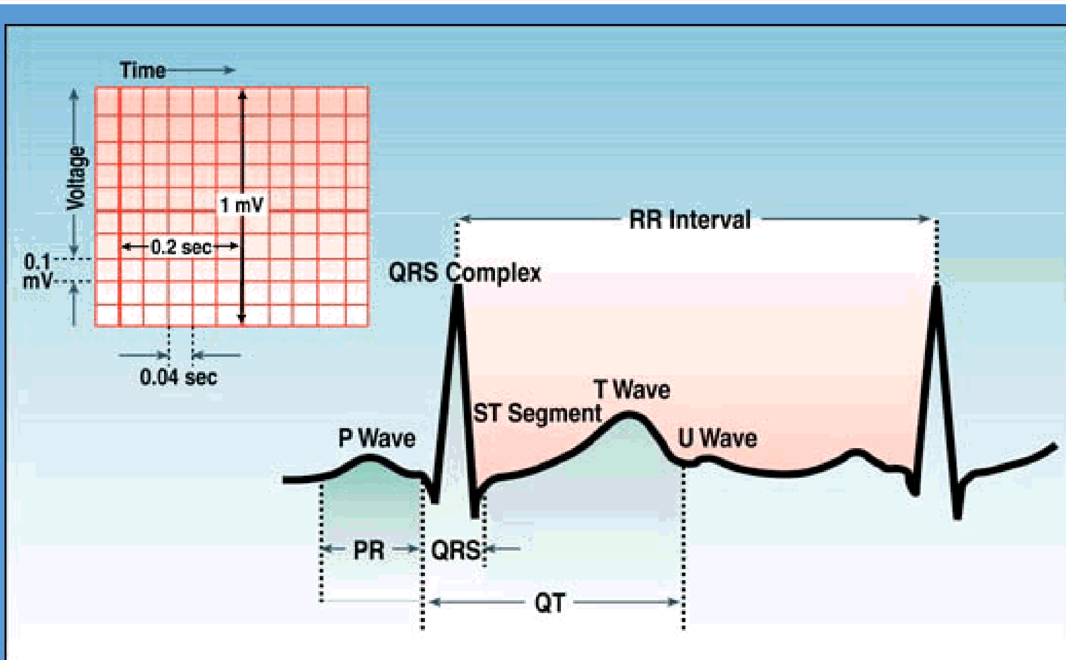


A sample trace of ECG and Respiration

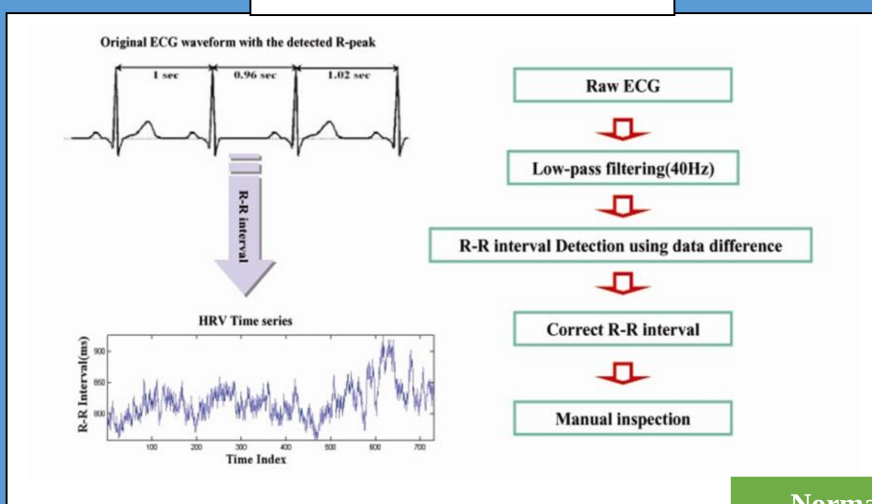


ECG Data extraction (R-R interval)

Plate 3: Schematic representation of ECG and Heart Rate Variability (HRV)



HRV extraction from ECG



Normal ECG

Fast Fourier Transform analysis (FFT)

5.3.4 Cerebral hemodynamic changes and Stroop color word task

5.3.4 A. *Rationale for studying cerebral hemodynamic responses in attention task*

In order to examine neuronal activity and hemodynamic changes in the brain regions during meditation, the application of different neuroimaging techniques (viz., fMRI & MEG) would be beneficial. The neuronal activity during meditation has been reported in several electroencephalography (EEG) and magnetoencephalography (MEG) studies. Experienced meditators showed an increased EEG power in lower frequency bands (theta, delta and alpha) (Kubota et al., 2001; Takahashi et al., 2005) compared to controls. An EEG study on Transcendental Meditation, showed intermittent prominent bursts of frontally dominant theta activity at an average maximal amplitude of 135μV in 21 practitioners (Hebert and Lehmann, 1977). Zen meditators showed fast theta and slow alpha power during meditation (Takahashi et al., 2005) demonstrating enhanced automatic memory and reduction in conceptual thinking following meditation (Faber et al., 2014). In a single MEG study on twelve long term Buddhist meditators were assessed in two distinct types of self-awareness, i.e., “narrative” and “minimal” in mindfulness-induced selflessness awareness (Dor-Ziderman et al., 2013). It was found that there was a reduction in gamma band (60-80 Hz) power in frontal, and medial prefrontal areas, and reduced beta band (13-25 Hz) power in ventral medial prefrontal, medial posterior and lateral parietal regions (Dor-Ziderman et al., 2013) and right inferior parietal lobules. These studies are consistent with fMRI and NIRS findings. Functional magnetic resonance imaging (fMRI) poses several challenges such as high sensitivity to participant’s motion, a loud, restrictive environment, low temporal resolution, and relatively high cost (Cui et al., 2011). Some of these challenges are overcome with new optical imaging technique: NIRS measure's changes in oxy-hemoglobin and deoxy-hemoglobin (ΔHbO and ΔHbR) concentration changes from the cortical surface and less invasive and expensive than fMRI (Bunce et al., 2006). Functional near infrared spectroscopy is a compact and portable optical technique to monitor hemodynamics of the brain in real time (Son, 2006; Lin et al., 2009).

Brain hemodynamic responses during meditation, i.e., oxy-hemoglobin (ΔHbO), deoxy-hemoglobin (ΔHbR) and total hemoglobin changes (ΔTHC) are in its infancy. In fact, there is only one study that assessed deoxyhemoglobin changes with a single wavelength probe placed over the left prefrontal cortex during Qigong meditation (Cheng et al., 2010). Practitioners showed decrease in deoxy-hemoglobin and increase in oxy-hemoglobin concentration that suggest, meditation lead to left prefrontal activation during meditation.

With this background, the present study was designed to assess the bilateral prefrontal hemodynamic responses in meditation and random thinking. Additionally, we investigated the hemodynamic changes and performance during a stroop color word task before and after meditation and random thinking. Since, stroop color word task is known to measure attention, interference, processing speed, and executive attention, we expected that this task to be the most sensitive to the effects of meditation.

5.3.4 B. *Specification of fNIRS 1000 Device*

A 16-channel continuous wave fNIRS imager system (FNIR1000-ACK-W, BIOPAC Systems, Inc., U.S.A) was employed to map changes in Oxy-hemoglobin (ΔHbO), DeOxy-hemoglobin (ΔHbR) and total hemoglobin (ΔTHC) over bilateral prefrontal cortex (PFC). The system consisted of a flexible probe to match contour of the human forehead (see Figure 2). The probe embedded with four LED diodes as light sources (at λ_1 = 730nm, λ_2 = 830nm, λ_3 = 850nm) and ten photodiodes as detectors that were symmetrically arranged in an area of 3.5×14 cm^2, conducing to 16 nearest source – detector (i.e. channels) at 2.5 cm separation displayed in Figure 3. A source-detector distance provides a penetration depth of 1.25 cm (León-Carrion et al., 2008; Kim et al., 2010; Leon-Dominguez et al., 2014). The description of the probe setting is detailed in earlier studies (Izzetoglu et al., 2005; Krawczyk, 2002; Leon-Dominguez et al., 2014). During the experiment, the probe was firmly held with a velcro band on the forehead, and stretched from hairline to eyebrow in a sagittal direction and from ear to ear in axial direction (Tian et al., 2009). The probes were positioned bilaterally on forehead, over the left and right frontal poles, a part of dorsolateral PFC, and a portion of the ventrolateral PFC. Regional cerebral blood flow (rCBF), ΔHbO, ΔHbR, and ΔTHC for each hemisphere were updated every 0.5 sec. The four LEDs flashed in sequence; the reflected light from the brain as detected with the nearest photodiodes of each LED and converted into digital signals using an analog-digital converter (ADC) card in the control box. The digital data were sent to the laptop though a serial port. The sampling rate was 3 Hz across all 16 channels. The principles of measurement were based on the modified Beer-Lambert law for highly scattering media (Plichta et al., 2006) that agrees assessing changes in ΔHbO and ΔHbR at a certain measured point (Hoshi and Tamura, 1993). Increases in ΔHbO and corresponding decrease in ΔHbR can be interpreted as a sign of functional brain activation.

Since, a continuous wave system cannot measure the optical path length and no specific value for the optical path length is adopted from literature, the scale unit is molar concentration multiplied by the unknown path length (micromoles × mm). Increases in ΔHbO and corresponding decrease in ΔHbR can be interpreted as a sign of functional brain activation. Functional near infrared spectroscopy equipment and accessories are given in **Plate 4**.

Plates 4: Functional Near Infrared Spectroscopy Equipment and Accessories

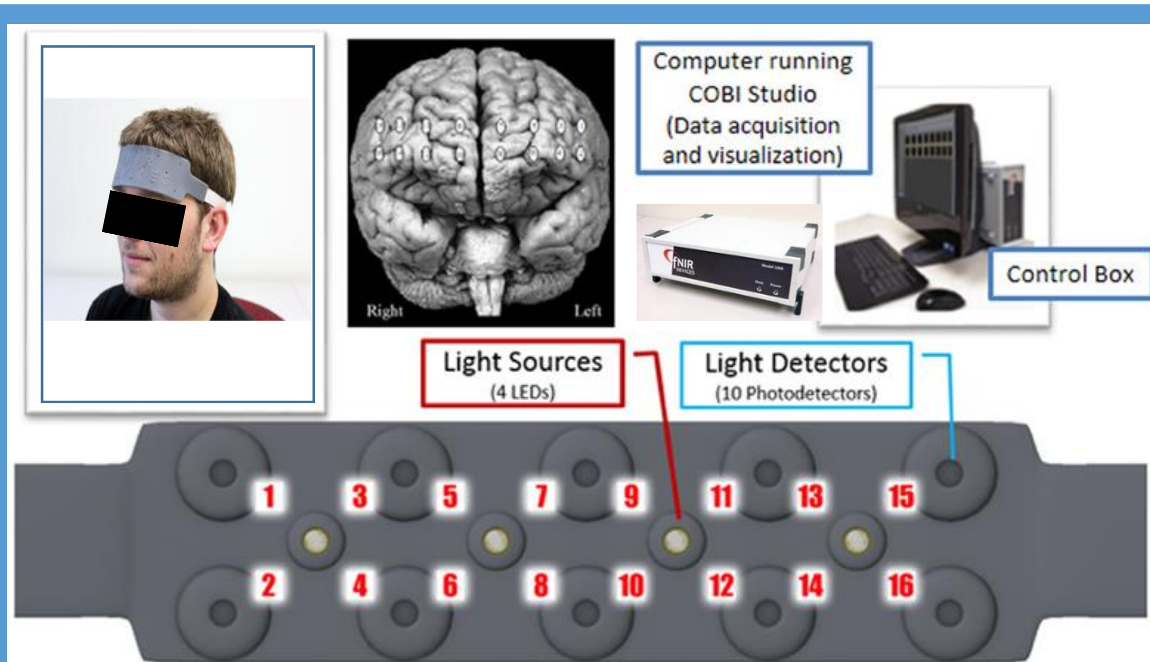
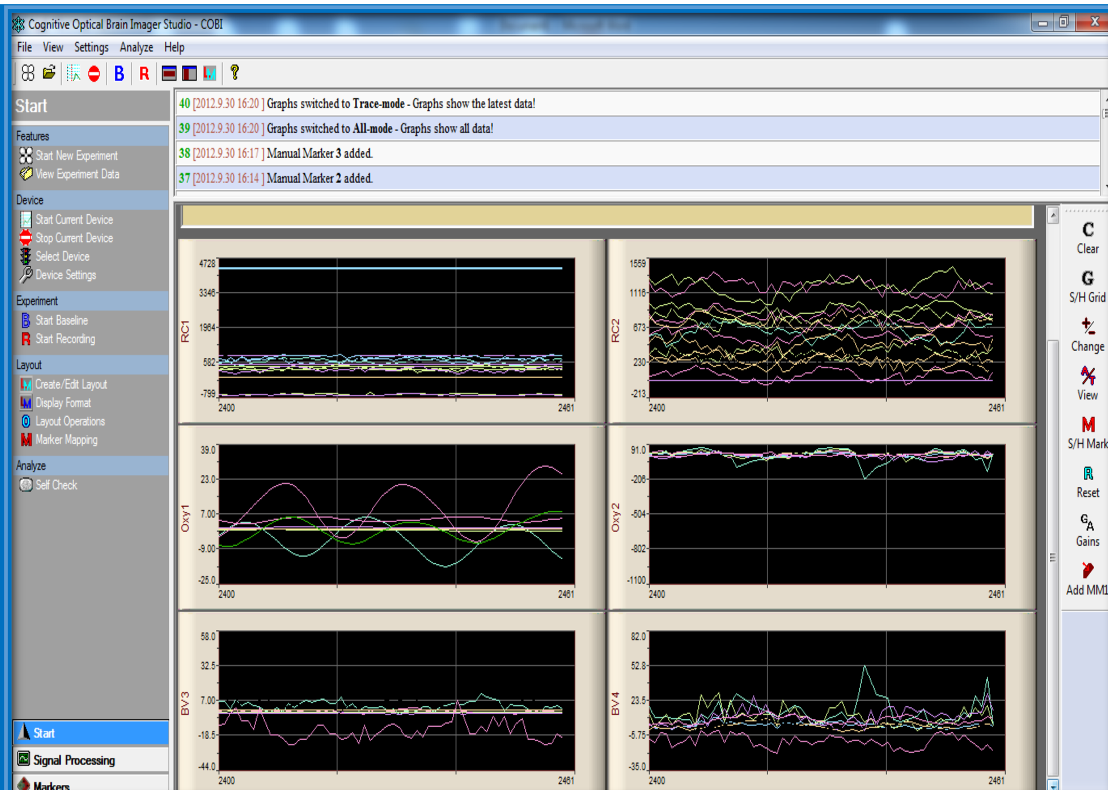


Figure 8: Sample Waveform Display for fNIRS Data Acquisition during *Dhyana*



5.3.4 C. E-Prime Setup for presenting Stroop Color Word Task

Subjects were seated comfortably on a reclining chair in a Faraday cage, facing a 21 inch LCD monitor placed at a distance of 70 cm from their eyes. Participants were required to focus on the center of the screen which was guided by a fixation object "+" followed by stimuli. Participants performed a modified multiple-trial Stroop task and were presented with neutral, congruent, and incongruent stimuli on a black background using E-Prime 2.0.8.90 (Psychological Software Tools, Inc., Pittsburgh, PA, USA). The task consisted of red, blue, and green colored boxes and the corresponding written words "RED", "BLUE" and "GREEN". The color was presented as color square (4.5 x 4.5 cm) boxes with a black background. The duration of the presented square boxes, and written color words was 500 ms each. Congruent trials comprised of square color boxes followed by words describing the color of the box written in the same color (e.g., the BLUE square box and the printed word "BLUE" in blue ink); incongruent trials comprised of words describing the color of the box written in a color other than that of the box (e.g., the RED square box and word RED written in blue ink); neutral trials comprised words written in white (e.g., the BLUE square box and word BLUE printed in white ink).

5.3.4 D. Testing Procedure

The participants reported for the assessment at morning 6:30 am on different days. All recordings were taken empty stomach, in a dark room. The subjects wore a flexible headband over pre-frontal region that contains an array of four photodiodes and ten sensors and covered with a black cloth. The cognitive task was presented using E-prime software in another monitor. Participants were instructed to respond as quickly and accurately as possible to the name of the color word (while ignoring the color itself) corresponding to the color of the Box with a button press of the response key using the thumb of their right hand. To increase the potency of the conflict stimulus, 20% of trials were congruent (approximately 45 trials), 20% were incongruent (approximately 45 trials) and 50% were neutral (90 trials). The duration of the stimulus was 500 ms, with a variable interstimulus interval (ISI) of 1000-2500 ms. The experimental steps are illustrated in **Figure 10.** The raw data was acquired from the probe, which is pre-filtered and processed in the data processing unit. The data was then sent to a laptop computer (with COBI software installed) to be digitized and read by the computer.

5.3.4 D. *Variable measured*

The present study was designed to assess

(i) the bilateral prefrontal hemodynamic responses in meditation and random thinking related to attentional task,

   a. Oxy-hemoglobin changes (ΔHbO),

   b. DeOxy-hemoglobin (ΔHbR), and

   c. Total hemoglobin (ΔTHC)

(ii) the hemodynamic changes and performance while performing a stroop color word task ‘Before’ and ‘After’ meditation and random thinking.

Figure 9: The 16 fNIRS optode (channel) measurement locations registered on the brain surface image are presented

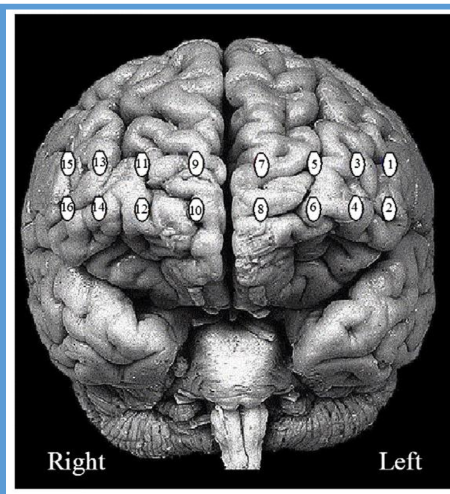
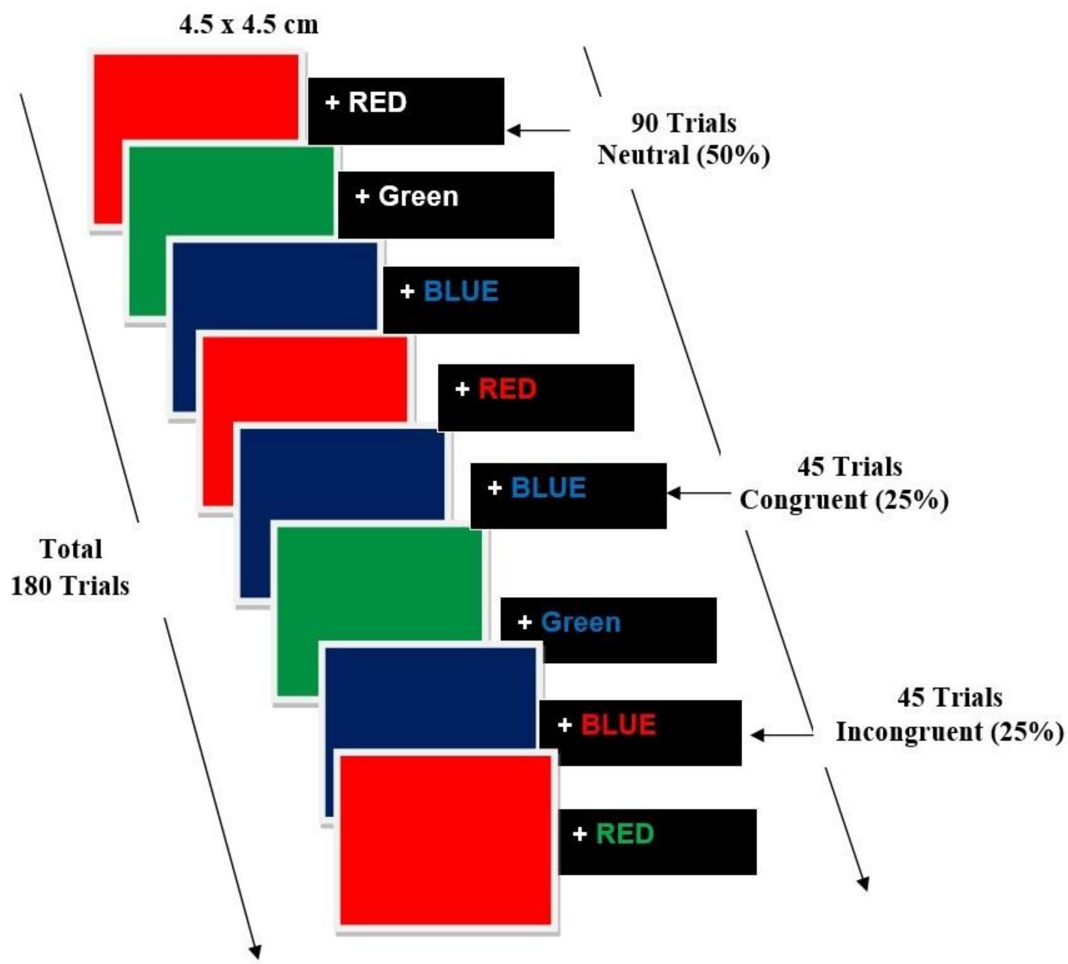


Figure 10: Experimental steps of Color word Stroop Task



5.3.5 MINDFULNESS - *The Freiburg Mindful Inventory [FMI]*

5.3.5 A Rationale for studying mindfulness and anxiety

Meditation is defined as a family of complex emotional and attentional regulatory strategies developed for various ends, including the cultivation of well-being and emotional balance. There are no previous studies reporting mindfulness levels of individuals practicing meditation on the syllable '*OM*'. This cross – sectional survey aimed to collect data concerning mindfulness and state and trait anxiety using *The Freiburg Mindful Inventory [FMI]* and *State and Trait Anxiety Inventory [STAI]* respectively.

5.3.5 B. *Testing procedure*

The description of the measurements and procedure is given below.

We used one dimensional 14-item short version of FMI, which was found to be semantically robust and psychometrically stable (Cronbach's alpha = 0.83) (Baer et al., 2008). All items were scored on a 4-point Likert scale (0: rarely; 1: occasionally; 2: fairly often; 3: almost always). Scores range from 8 to 32, with higher scores indicating higher levels of mindfulness. Furthermore, the scale was able to differentiate between mindfulness practitioners and non-practitioners. The two proposed subfacets of the FMI, presence (items 1,2,3,5,7,10) and acceptance (items 4,6,8,9,11,12,14) was then tested separately. This scale is semantically independent from a Buddhist or meditation context and is applicable to all population groups.

5.3.5 C. *Reliability and validity of the test*

The FMI measures trait mindfulness and has been shown to have good psychometric properties including a high internal consistency (alpha of 0.86 in an initial validation study), and it has been shown to correlate positively with health indicators. (Leigh, Bowen, & Marlatt, 2005).

5.3.6 *State and Trait Anxiety Inventory* (STAI):

5.3.6 A. *Testing procedure*

The anxiety levels were assessed using a questionnaire 'State – Trait Anxiety Inventory' (STAI). This is a self-reported assessment anxiety scale, which includes separate measures of state and trait anxiety. State anxiety (S-Anxiety) is defined as a transitory emotional state characterized by consciously perceived feeling of tension and apprehension. Trait anxiety (T-Anxiety) refers to relatively stable individual differences in anxiety proneness. Depending on the characteristics of the stressful stimulus conditions, individuals experience differential levels of state anxiety as a function of their level of trait anxiety. The STAI consists of two separate subscales that contain 20 items each. The items are in the form of statements people used to describe themselves. The essential qualities evaluated are feelings of apprehension, tension, nervousness, and worry. Both subscales (S-Anxiety and T-Anxiety) use a 4-point Likert scale to allow the subject to show how often or how much each question applies to them in both situations. It has high internal consistency with Cronbach's alpha of 0.73. Also, the test is designed to take only 20 minutes at the maximum to reduce the amount of fluctuations in S-Anxiety that could become apparent if the test was to go for a long period of time.

5.3.6 B. *Reliability and validity of the test*

State Trait Anxiety Inventory (STAI) has been used widely in earlier studies on Indian populations and has a concurrent validity ranging from 0.75 to 0.80 with other tests

(Spielberger, Gorsuch et al., 1970). The scale has shown excellent reliability and validity across populations (Spielberger, Gorsuch, Lushene, R., Vagg, & Jacobs, 1983).

These questionnaires were showing the relations among mindfulness and anxiety in participants of meditator and non-meditator groups.

5.3.7 Positive States of Mind (POSM)

The positive states of mind, paper pencil Stroop color word task and positive and negative affect scale was used to assess mindfulness, executive attention or interference effect and positive and negative mood respectively.

5.3.7 A. *Testing procedure*

The PSOM is a brief self-report tool designed to assess various aspects of positive psychological states (Horowitz, Adler, & Kegeles, 1988). The scale consists of a 4-point rating of seven items probing the dimensions of focused attention, productivity, responsible caretaking, restful repose, sharing, sensuous nonsexual pleasure, and sensuous sexual pleasure. Higher scores on the PSOM indicate higher positive mood states. This scale was used to assess possible differential changes in positive states of mind ‘Before’ and ‘After’ the intervention for both the groups.

5.3.7 B. *Reliability and validity of the test*

The PSOM has been reported to have high internal consistency, with a Cronbach's $\alpha = 0.77$ reported for college students (Williams, Hogan, & Andersen, 1993). This PSOM scale has been consistently found to correlate inversely with measures of anxiety, as well as with response to stressful events (Horowitz et al., 1988).

5.3.8 Stroop Color-word Task (SWT)

5.3.8 A. *Testing procedure*

Research on the Stroop Color and Word Test has established that the test assess psychological processes and functions that affect cognition in normal, neurospcyhological, and psychiatric populations. Stroop scores have been associated with cognitive flexibility, attention deployment, resistance to interference from outside stimuli, creativity, defense structures, and cognitive style and complexity. Participants were administered a standardized three-page paper Stroop test (Golden Stroop Color and Word Test) (Nehemkis & Lewinsohn, 1972; Stroop, 1935). The Stroop interference test is the most well-known test with the ability to inhibit distracters. It measures the ability of an individual to resist the interference created by the actual color of the ink used to spell out the name of a color. The slowing of responses due to incongruent color/name compared to congruent color/name of the task, and the number of errors in the task, are indicators of interference. Each page has 100 items, presented in 5 columns of 20 items. The first page (Word) consists of the words “RED,” “GREEN,” and “BLUE” arranged randomly and printed in black ink on a white 8.5" × 11" sheet of paper. No word is allowed to follow itself within a column. The second page (Color) consists of 100 items, all written as XXXX printed in either green, red, or blue ink. The third page (Color–Word) consists of the words from the Word page printed in the colors from the Color page so that the word is incongruent with the ink color. Administration of the test was done as per the instructions provided in the Catalog No. 30150 of the manual of the Stroop test (Golden & Freshwater, 2002). The items were arranged in a quasirandom fashion with the constraint that the same item did not appear consecutively. All the participants were asked to read the words on the Word page, name the colors on the Color page, and name the colors on the Color–Word page as quickly as possible. The total time to read all the words on each page and the number of errors on each page were recorded as the outcome measures of the tests.

5.3.8 B. *Reliability and validity of the test*

The Stroop is a reliable, efficient and effective clinical test for evaluating psychopathology and brain dysfunction and can be utilized as a screening test or as part of a general test battery for making a differential diagnosis. Jensen (1965) found that test-retest reliabilities of basic and derived scores with intervals of three minutes, one day, and one week showed no appreciable differences. Moreover, the reliability of the Stroop scores is highly consistent across different versions of the test (Golden & Freshwater, 2002). However, Jensen (1965) found that derived scores that utilize differences and ratios have somewhat lower reliabilities of .88, .79, and .71 respectively (N = 436). For the same scores Golden (1978) reported reliabilities of .89, .84, and .73 respectively (N =450) for group administrations; .86, .82, and .73 respectively (N = 30) for individual administration; and .85, .81, and .69 respectively (N = 60) for subjects administered both the individual and group forms.

5.3.9 Positive and Negative Affect Schedule (PANAS)

5.3.9 A. *Testing procedure*

The PANAS consists of two 10-item mood scales and was developed to provide brief measures of Positive affect (PA) and Negative affect (NA) (Watson, Clark, & Tellegen, 1988). Respondents are asked to rate the extent to which they have experienced each particular emotion within a specified time period, with reference to a 5-point scale. The scale points are: 1 'very slightly or not at all', 2 'a little', 3 'moderately', 4 'quite a bit' and 5 'very much'. A number of different time-frames have been used with the PANAS, but in the current study the time-frame adopted was 'during the past week' (Crawford & Henry, 2004).

5.3.9 B. *Reliability and validity of the test*

The PANAS has been extensively employed, and this is reflected in the fact that shortened, elongated, and children's versions have been developed. It is therefore surprising that there have been relatively few studies of other aspects of the instrument's psychometric properties. Watson et al. (1988b) administered the PANAS with time-frames ranging from 'right now' to 'during the last year' to a large, predominantly student, sample. The reliability of the PA scale ranged from .86 to .90, the NA scale from .84 to .87; values similar to those obtained from independent research involving clinical and non-clinical populations (Jolly et al., 1994; Mehrabian, 1998; Roesch, 1998). However, the non-clinical studies that have typically been conducted either employed purely student samples (Roesch, 1998), or participants not broadly representative of the general population (Mehrabian, 1998; Watson et al., 1988b). The nature of these samples means that the generalizability of their results to the normal population is uncertain (Gotlib, 1984; Nezu, Nezu, & Nezu, 1986).

5.3.10 Visual Analogue Scale (VAS)

Participants were assessed in four sessions, i.e., random thinking (*cañcalatā*), non-meditative focused thinking (*ekāgratā*), meditative focusing (*dhāraṇā*), and meditation (*dhyāna*) with – Visual Analogue Scale (VAS)

5.3.10 A. *Testing procedure*

A VAS is an instrument to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured (Wewers and Lowe, 1990). A visual analogue scale is a horizontal line, 10 cm in length, anchored by word descriptors at each end. Immediately after the session, participants were asked to put a mark on the line which represents how much they were able to follow the instructions for the four mental states.

5.3.10 B. *Reliability and validity of the test*

VAS was used to assess the ability to follow the guided instructions for the first time. The visual analogue scale is a common method for rapidly gathering quantifiable subjective rating in both research and clinical settings. This method of rating is thought to provide greater sensitivity for reliable measurement of subjective phenomena, such as various qualities of pain or mood (Pfennings, Cohen, & van der Ploeg, 1995). Reliability of visual analog scale is measuring acute pain was observed to be adequately high (Bijur, Silver & Gallagher, 2001). Another study reports that the reliability of visual analog scale in patient with chronic musculoskeletal pain is at moderate to good level, however, with questionable validity (Boonstra et al., 2008).

5.3.11 Accuracy of Counted Clicks in P300 Oddball task

The accuracy of counted clicks was calculated in a simple discrimination task known as the “Oddball” paradigm.

5.3.11 A Testing procedure

The oddball task consisted of discrimination between two tones: the standard tone, a 1000 Hz tone presented 240 times (80%), and the target tone, a 2000 Hz tone, presented 60 times (20%), in random order (Polich 1999) also known as P300 auditory oddball task. These ‘standard’ and ‘target’ auditory stimuli were delivered through close fitting earphones (TDH-39, Amplivox, U.K.). The participants were asked to distinguish between the two tones and mentally count the “target” stimuli. The equipment gives the number of target stimuli delivered. Only those sessions in which the participants achieved 95 percent accuracy in Counting target stimuli were included. None of the sessions had to be excluded for this reason.

5.4 INTERVENTIONS

Each participant was assessed in four sessions, to which they were assigned randomly. These were (i) *cañcalatā* (random thinking) and (ii) *ekāgratā* (non-meditative focused thinking) as non-meditation sessions. The other two sessions were meditation sessions. They were (i) *dhāraṇā* (meditative focusing) and (ii) *dhyāna* (meditation without focusing or effortless meditation). Throughout the session, participants sat cross legged and kept their eyes closed following pre-recorded instructions. An emphasis was placed on carrying out the practices slowly, with awareness of physical and mental sensations, and relaxation. Participants were given a 3 month meditation orientation program under the guidance of an experienced meditation teacher. For each session the duration was 20 minutes. The sessions were conducted six days a week, between 06:00 to 06:30 hours. On the first day theoretical aspects of the meditation were detailed by the meditation teacher. After this the practice session started with pre-recorded instructions. The evaluation of the participants' practice of meditation was based on their self-report as well as consultations with the meditation teacher.

5.4.1 *Cañcalatā* (Random thinking)

Participants were asked to allow their thoughts to wander freely as they listened to a compiled audio CD consisting of brief periods of conversation, announcements, advertisements and talks on diverse topics recorded from a local radio station transmission. These conversations were not connected, and hence, it was thought that listening to them could induce a state of random thinking.

5.4.2 *Ekāgratā* (Non-meditative focused thinking)

Participants listened to a pre-recorded lecture on the process of meditating and the object of meditation, i.e., the Sanskrit syllable *OM*. This was intended to induce a state of non-meditative focusing.

5.4.3 *Dhāraṇā* (Meditative focusing)

Participants were asked to open their eyes and gaze at the syllable '*OM*' as it is written in Sanskrit. During this time guided instructions required them to direct their thoughts to the physical attributes of the syllable, i.e., the shape and color, and then to close their eyes and continue to visualize the syllable mentally. The main emphasis during meditative focusing was that thoughts are consciously brought back (if they wander) to the single thought of *OM*.

5.4.4 *Dhyāna* (Meditative de-focusing or effortless meditation)

During this session, participants were instructed to keep their eyes closed and dwell on thoughts of *OM*, without any effort, particularly on the subtle (rather than physical) attributes and connotations of the syllable. This would gradually allow the participants to experience brief periods of silence, which they reported after the session.

5.5 DATA EXTRACTION

5.5.1 Long latency auditory evoked potentials (LLAEPs)

LLAEPs were recorded in the 250 ms, post stimulus time period without any pre stimulus delay, using a 4-channel system (Nicolet Biomedical Inc., U.S.A.). LLAEP components, viz., P1, N1, P2 and N2 waves were measured from a zero DC baseline. Peak latency was measured from the time of click delivery. The peak latencies and peak amplitudes of the following components were measured, the P1 wave between 40 and 60 ms, is the maximum positive peak preceding the N1 wave which is a negative component between 80 and 115 ms. The P2 wave is a positive component between 140 and 180 ms. It is also the first maximum positive component preceding the N2 wave component which is between 200 and 280 ms (Ponton, Eggermont, Kwong, & Don, 2000).

The waveforms were visually inspected off-line for artifact, and the peak latency and the peak amplitude were obtained by selection with the cursor. The selection was performed by the experimenter. A sample record of long latency auditory evoked potentials is presented in **Figure 14**.

Neural generators for LLAEPs

Peak latency (ms) is defined as the time from stimulus onset to the point of maximum positive amplitude within the latency window. Peak amplitude (μV) is defined as the voltage difference between a pre-stimulus baseline and the largest positive peak within a given latency window.

Table 12: Components of LLAEPs and their neural generators

LLAEP components	Latency (msec)	Neural Generator
P1	40-60	Secondary auditory cortex in the lateral Heschl's gyrus
N1	80-115	Bilateral Parts of the auditory superior cortex
P2	140-180	Mesencephalic-Reticular Activating System (RAS)
N2	200-280	Anterior Cingulate Cortex

5.5.2 P300 Event Related Potentials (ERPs)

The peak amplitude and the peak latency of the P300 were measured at Cz. The peak amplitude (in μV) was defined as the voltage difference between baseline at stimulus delivery and the largest positive-going peak of the ERP waveform within 250–500 ms latency (Polich 1999). The peak latency (ms) was defined as the time from stimulus onset to the point of maximum positive amplitude within the latency window (i.e., 250-500 ms). The waveforms were visually inspected off-line for artifacts and the latency and the peak amplitude were obtained by selection with the cursor. The selection was performed by the experimenter. A sample record of P300 responses using Nicolet Bravo EP system (USA) in presented in **Figure 16**.

5.5.3 Heart rate variability and Respiration

Recordings of heart rate variability and respiratory rate were taken for 30 minutes for each participant. The 'Before' intervention (5 minutes), 'During' intervention (20 minutes), and 'After' intervention (5 minutes) data were analyzed separately. 'Before' and 'After' sessions had one epoch of 5 min, whereas during had 4 similar epochs viz. D1, D2, D3, D4. The recorded data were visually inspected off-line and only noise free data included for analysis. The HRV power spectrum was obtained using Fast Fourier Transform (FFT) analysis.

The energy in the HRV series in the following specific frequency bands studied viz., low frequency (LF) band (0.05-0.15 Hz) and high frequency (HF) band (0.15-1.50 Hz) and the LF/HF ratio. The low frequency and high frequency band values were expressed as normalized units. The following components of time domain HRV were analyzed: (i) mean RR interval (the mean of the intervals between adjacent QRS complexes or the instantaneous heart rate), (ii) RMSSD (root mean square of successive differences), (iii) NN50 (the number of interval differences of successive NN intervals greater than 50 ms), and (iv) pNN50 (the proportion derived by dividing NN50 by the total number of NN intervals). The mean respiratory rate was calculated 'Before', 'During', and 'After' sessions.

5.5.4 *Hemodynamic responses*

The participants were assessed in two separate sessions i.e. random thinking and meditation while recording hemodynamic activity on the prefrontal cortex (PFC) using 16-channel continuous wave fNIRS system. On the preceding day and on the day of the recording, participants were asked to avoid tea and coffee which are known to influence cognitive performance (Nehlig, 2010) and cerebral blood flow (Addicott et al., 2009). Where this was unavoidable the session was engaged on another day. The participants wore a flexible sensor pad over prefrontal region and covered with a black cloth. The probable artifacts such as heart rate pulsation, respiration and high frequency noise in raw data, which may possibly be induced by autonomic arousal caused during stroop task, was eliminated with pre designed finite impulse response (FIR) filters based on type, order, window function and cut-off frequency. For the present study, raw data were acquired from the probe, which is pre-filtered by two filters and processed in the data processing unit using COBI filter module. The first filter is a 10^{th} order low-pass filter with cutoff frequency of 0.1 Hz with Blackman window. The second filter is a 20^{th} order low-pass, with the normalized cut-off frequency of 0.1 Hz which uses a Hamming window. The filtered data were averaged according to the tasks and conditions for further statistical analysis.

5.5.5 *Mindfulness and State and Trait Anxiety*

Each participant was assessed in two consecutive days at the same time. Participants were requested to use any necessary visual aids (i.e. glasses, contact lenses). On the day 1, participants in each group carried out the FMI first, followed by the State and Trait Anxiety Inventory on the day 2 at a time. To ensure each item was carefully considered and participants were advised they had an unlimited amount of time to complete the questionnaire. Participants received a recording blank with the front page on top and a pencil without an eraser. Participants were instructed as per the instructions stipulated in the manual of the questionnaires. Testing began once participants had confirmed they understood the given instructions. Participants were advised to provide an answer as honestly and spontaneously as possible for every statement. The scoring was done by a person who was unaware when the assessment was made as whether the assessment was meditation group or a control group.

5.5.6 *Positive states of mind and stroop task*

Each participant was assessed on two separate days at the same time. On day 1, participants in each group were administered the PSOM and Positive and PANAS. The Stroop task was administered on the second day at the same time. Participants were requested to use any necessary visual aids (i.e. glasses, contact lenses). There were no time restrictions to complete PANAS and PSOM however the Stroop task was time bound. Participants received a recording blank with the front page on top and a pencil without an eraser. Participants were instructed as per the guidelines stipulated in the manual of the questionnaires. Testing began once participants had confirmed that they understood the given instructions and they were advised to provide an answer as honestly and spontaneously as possible for every statement. On the second day, the Stroop task sheets were distributed to all participants and they were advised to read the instructions carefully. The participants were asked to read the word, name the colors, and finally, name the ink color of the printed word as quickly and as accurately as possible in three subsequent conditions i.e. neutral, congruent and incongruent. The time duration (sec) and errors were recorded after completing three conditions, respectively. Among the three assessments, Stroop task and PSOM were administered at the beginning and end of one month. The assessments were carried out by a person who was blinded to the sessions and groups of the study.

5.5.7 *Visual Analogue Scale (VAS)*

A VAS is an instrument to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured (Wewers and Lowe, 1990). A visual analogue scale is a horizontal line, 10 cm in length, anchored by word descriptors at each end, as illustrated in Fig. 3. Immediately after the session, participants were asked to put a mark on the line which represents how much they were able to follow the instructions for the four mental states. Visual analogue scale for (i) quality of practice,

(ii) quality of sleep during the preceding night of recording, (iii) level of relaxation, and (iv) level of awareness.

5.5.8 *Accuracy of Counted Clicks in P300 Oddball task*

The accuracy of Counted clicks was calculated in a simple discrimination task known as the "oddball" paradigm. The oddball task consisted of discrimination between two tones: the standard tone, a 1000 Hz tone presented 240 times (80%), and the target tone, a 2000 Hz tone, presented 60 times (20%), in random order (Polich 1999) also known as P300 auditory oddball task. These 'standard' and 'target' auditory stimuli were delivered through close fitting earphones (TDH-39, Amplivox, U.K.). The participants were asked to distinguish between the two tones and mentally count the "target" stimuli. The equipment gives the number of target stimuli delivered. Only those sessions in which the participants achieved 95 percent accuracy in counting target stimuli were included. None of the sessions had to be excluded for this reason.

5.6 DATA ANALYSIS

The raw data obtained for each subject in each recording session were tabulated separately. The group mean values ± standard deviation were calculated for all the variables. Statistical analysis was done using Predictive Analytics Software (PASW Statistics 16 or 18; formerly SPSS Statistics) in the following steps.

5.6.1 Long latency auditory evoked potentials (LLAEPs)

(i) The data were tested for variance and normal distribution by F-test and Kolmogorov-Smirnov test respectively.

(ii) Since the same individuals were assessed in repeat sessions on separate days (i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*), repeated measures analysis of variance (ANOVAs) were performed with two 'Within subjects' factors, that is, Factor 1: Sessions such as random thinking (*cañcalatā*), non-meditative focused thinking (*ekāgratā*), meditative focused thinking (*dhāraṇā*), and meditation (*dhyāna*). Factor 2: States that are ‘Before’, ‘During’ (1 to 4), and ‘After’. Repeated measures ANOVAs were carried out for each component of LLAEPs separately, for both peak latencies and peak amplitudes.

(iii) Subsequently, repeated measures ANOVAs was followed by *post-hoc* analyses with Bonferroni adjustment for multiple comparisons between the mean values of different states (‘During’ and ‘After’), and all comparisons were made with the respective ‘Before’ state.

5.6.2 Simultaneous P300 event related potentials and autonomic activity

(i) The data were tested for variance and normal distribution by F-test and Kolmogorov-Smirnov test respectively.

(ii) Since the same individuals were assessed in repeat sessions on separate days (i.e., *cañcalatā* (random thinking), *ekāgratā* (non-meditative focused thinking), *dhāraṇā* (meditative focused thinking), and *dhyāna* (meditation), repeated measures analysis of variance (ANOVAs) were performed with two 'Within subjects' factors, that is, Factor 1: Sessions such as *cañcalatā*, *ekāgratā*, *dhāraṇā* and *dhyāna*, and Factor 2: States that is 'Before', 'During' (1 to 4), and 'After'. There were separate repeated measures ANOVAs for heart rate variability (HRV) components (frequency domain and time domain), respiratory rate and P300 ERPs (peak latency and peak amplitude).

(iii) For P300 ERPs (peak latency and peak amplitude), repeated measures ANOVAs was followed by *post-hoc* analyses with Bonferroni adjustment for multiple comparisons between mean values, for 'Before' – 'After' comparisons. For HRV, *post hoc* analyses with Bonferroni adjustment for multiple comparisons between the mean values of different states ('During' and 'After'), and all comparisons were made with the respective 'Before' state.

5.6.3 Hemodynamic responses and Stroop color word task (SCWT)

(i) The data were tested for normal distribution by Kolmogorov-Smirnov test.

(ii) The hemodynamic responses of bilateral prefrontal cortex (PFC) were recorded and data were averaged according to the task conditions (‘Before’, ‘Stroop_Pre’, ‘During’, ‘Stroop_Post’, and ‘After’). Statistical analyses have been carried out on these differential values. Since, the same individuals were assessed in repeated sessions on two separate days (i.e., random thinking and meditation), repeated measures analysis of variance (ANOVA) was used. Repeated measures analyses of variance (ANOVA) were performed with three 'Within subjects' factors, that is, Factor 1: Sessions such as *cañcalatā* (random thinking) and *dhyāna* (meditation); Factor 2: Prefrontal Cortex (right and left); Factor 3: States that is ‘Before’, ‘Stroop_Pre’, ‘During’ (D1 to D4), ‘Stroop_Post’, and ‘After’). The repeated measures ANOVAs were carried out for concentration changes of oxygenated and deoxygenated hemoglobin and total hemoglobin change (ΔHbO, ΔHbR, ΔTHbC) across the right and left prefrontal cortex (PFC).

(iii) Analysis of Stroop task was compared to the mean reaction time (ms) of neutral, congruent and incongruent conditions and hemodynamic responses of Stroop color word task ‘Before’ and ‘After’ the Sessions (random thinking and meditation). To compare between different conditions, the results were averaged for each position, parameter and subject separately. A repeated measures ANOVA was carried out, followed by again adjusted for multiple comparisons according to Bonferroni.

(iv) This was followed by a *post-hoc* analyses with Bonferroni adjustment for multiple comparisons between the mean values of different states ('During' and 'After') and all comparisons were made with the respective 'Before' state.

(v) For further statistical analysis, we utilized an effect size (*d*). Cohen (1988) defined, effect size (*d*) as the mean change score divided by the standard deviation of change.

5.6.4 Mindfulness and Anxiety

(i) The data were tested for normal distribution by Kolmogorov-Smirnov test.

(ii) The scores were analyzed using one way analysis of variance (ANOVA). One way ANOVA compared mindfulness and state and trait anxiety scores and independent 't' test were used to compare mindfulness and anxiety of the data in '*OM*' meditators and non-meditators.

(iii) Partial Correlation (r) with meditation experience and anxiety and mindfulness is given in **Table 22.** All statistical analyses were computed at $p \leq 0.05$, two tailed.

5.6.5 Positive states of mind and executive control

(i) The data were tested for normal distribution by Kolmogorov-Smirnov test.

(ii) The scores were analyzed using repeated-measures Analyses of Variance (ANOVA) compare the stroop performance and Positive states of mind in meditation and control groups. Repeated measures analysis of variance (ANOVA) was performed with three 'within subjects' factors, i.e., Factor 1: Group; Meditation group and Control group, and Factor 2: Assessments; Word task (Neutral), Color Task (Congruent) and Color-Word Task (Incongruent) and Positive States of Mind (PSOM) and Factor 3: States; 'Before' and 'After'.

(iii) Repeated measures ANOVA was followed by a *post-hoc* analyses with Bonferroni adjustment for multiple comparisons between the mean values of two states ('Before' and 'After') and all comparisons were made with the respective 'Before' state.

(iv) An independent samples t-test was performed for Positive affect and Negative affect between participants in the meditation group and the control group.

5.6.6 Visual analog scale, Accuracy and Attention (P300 latency and amplitude)

(i) Repeated measures analysis of variance (ANOVA) was performed with one 'within subjects' factor, i.e., sessions: *cañcalatā, ekāgratā, dhāraṇā,* and *dhyāna*. This was followed by a *post-hoc* analysis with a Bonferroni adjustment for multiple comparisons between the mean values of different sessions.

(ii) Bivariate correlation (r) with Pearson's correlation was used to compare the visual analogue scale (VAS), accuracy in counting clicks in P300 oddball task and P300 latency and amplitude is given below.

(iii) Cohen's guidelines of correlation coefficients from 0.3 to 0.5 indicated moderate associations; from 0.5 to 0.7, strong association; and above 0.7, excellent association (Streiner & Norman, 2003).

(iv) All statistical analyses were computed at $p \leq .05$ with two tailed.

CHAPTER-6

RESULTS

6.0 RESULTS

The results of the variables studied during four independent sessions, that is, *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* are described below. These studied variables are -

(i) Long latency auditory evoked potentials (LLAEPs) recorded 'Before', 'During' and 'After' the sessions,

(ii) Simultaneous recordings of P300 event related potentials ('Before' and 'After' the sessions) and heart rate variability (HRV) with respiration recorded 'Before', 'During' and 'After' the sessions,

(iii) Relative hemodynamic changes in prefrontal cortex using functional near infrared spectroscopy (fNIRS) during a cognitive task (stroop color word task) and also 'Before', 'During' and 'After'*cañcalatā* and *dhyāna*,

(iv) Mindfulness and anxiety in meditators and non-meditators,

(v) Positive states of mind (PSOM), stroop task and positive and negative affect (PANAS) in meditators and non-meditators,

(vi) Subjective assessment of following the guided instructions for *cañcalatā, ekāgratā, dhāraṇā*, and *dhyāna* using visual analog scale (VAS) and also

(vii) Correlation of VAS with accuracy (counted clicks during Oddball task) and attention (measured in P300 ERPs)

6.1 LONG LATENCY AUDITORY EVOKED POTENTIALS (LLAEPs)

6.1.1 Recapitulation

The long latency auditory evoked potentials were recorded in sixty participants during *cañcalatā* (random thinking), *ekāgratā* (non-meditative focused thinking), *dhāraṇā* (meditative focusing), and *dhyāna* (meditation) sessions. LLAEPs were recorded in the 250 ms, a poststimulus time period without any prestimulus delay, using a 4-channel system (Nicolet Biomedical Inc., U.S.A.). LLAEP components, viz., P1, N1, P2 and N2 waves were measured from a zero DC baseline. Peak latency was measured from the time of click deliver. The peak latencies and peak amplitudes of the following components were measured: (a) The P1 wave, between 40 and 60 ms, is the maximum positive peak preceding, (b) the N1 wave which is a negative component between 80 and 115 ms, (c) the P2 wave is a positive component between 140 and 180 ms. It is also the first maximum positive component preceding (d) the N2 wave component which is between 200 and 280 ms (Ponton, Eggermont, Kwong, & Don, 2000). In each session there were six epochs viz., 'Before', 'During 1', 'During 2', 'During 3', 'During 4', and 'After'. The potentials were recorded from Cz (vertex) site and referenced to linked earlobes (A1-A2). Repeated measures analysis of variance (ANOVA) was performed with two 'Within subjects' factors, i.e., Factor 1: Sessions such as *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* and Factor 2: States that are 'Before', 'During (1 to 4)', and 'After'. Repeated measures ANOVAs were carried out for each wave of LLAEPs separately, for both peak latencies and peak amplitudes. This was followed by a post-hoc analyses with Bonferroni adjustment for multiple comparisons between the mean values of different states ('During' and 'After') and all comparisons were made with the respective 'Before' state. The group mean values

± S.D. for the peak latencies (ms) and peak amplitudes (μV) of P1, N1, P2 and N2 components of LLAEPs in four sessions i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* in 'Before', 'During' and 'After' states are given in **Table 13** (peak latencies) and **Table 14** (peak amplitude). A sample trace of the LLAEPs responses during *dhāraṇā* is given in **Figure 14**. The results of repeated measures analysis of variance (ANOVA) showing in **Table 15**. Peak latencies and peak amplitudes of 'During', and 'After', states are illustrated in **Tables 13 & 14.**

Table 13: Peak latencies of LLAEP components for four Sessions in six States for P1, N1, P2 and N2 components

		Latency Mean ± SD						
		States						
Components	**Sessions**	**Before**	**D1**	**D2**	**D3**	**D4**	**After**	**Cohen's *d***
P1 Component	*Cañcalatā*	46.48±7.92	47.69±9.54	47.52±7.78	46.71±7.53	45.92±7.51	48.48±8.26	0.247
	Ekāgratā	47.33±8.34	47.75±7.76	46.50±7.68	46.04±6.38	46.17±7.33	48.44±8.13	0.135
	Dhāraṇā	48.15±9.70	47.96±8.23	47.71±7.62	47.69±8.25	47.69±8.87	50.44±9.03	0.244
	Dhyāna	48.69±9.46	46.48±7.20	47.13±7.22	46.31±6.91	46.96±7.36	47.79±7.90	0.103
N1 Component	*Cañcalatā*	98.67±14.64	100.65±15.13	97.58±16.34	95.06±15.73	97.25±18.48	100.52±15.81	0.121
	Ekāgratā	97.48±15.22	101.75±15.31	101.98±14.81	99.63±15.61	97.73±15.44	103.33±15.09	0.386
	Dhāraṇā	98.23±15.15	99.98±16.80	98.31±16.19	97.15±15.46	100.94±15.33	101.10±15.11	0.190
	Dhyāna	98.85±14.18	99.71±16.51	100.46±16.82	98.44±16.26	98.52±16.18	100.85±15.71	0.134
P2 Component	*Cañcalatā*	154.88±13.54	158.17±15.05	155.02±14.90	152.85±12.75	153.40±13.85	154.98±12.37	0.008
	Ekāgratā	155.67±10.38	154.90±12.34	154.29±9.85	156.27±14.75	156.58±12.69	156.60±11.50	0.085
	Dhāraṇā	157.73±14.16	154.79±11.18	154.88±12.31	150.81±12.80	157.73±12.03	153.90±11.54	0.296
	Dhyāna	158.23±9.24	151.71±11.83**	153.58±10.36	154.90±10.30	153.15±13.20	151.81±9.06**	0.702
N2 Component	*Cañcalatā*	221.63±3.13	222.48±7.42	222.19±2.76	221.94±2.90	221.92±2.84	222.58±3.74	0.275
	Ekāgratā	222.29±3.72	221.79±3.72	222.88±3.22	222.50±4.78	222.60±3.55	222.31±3.54	0.080
	Dhāraṇā	223.21±6.04	221.33±4.11	222.85±3.37	221.35±4.51	222.13±2.91	222.04±3.40	0.239
	Dhyāna	223.10±5.65	223.42±6.32	223.73±7.09	222.29±4.52	222.88±3.08	223.00±5.58	0.018

**$p < 0.01$; repeated measures of ANOVA with Bonferroni adjustment comparing During and After values with Before values. Values are group means ± S.D. Cohen's *d* is calculated for the maximum difference in the After – Before or During – Before comparisons.

Table 14. Peak amplitudes of LLAEP components for four Sessions in six States for P1, N1, P2 and N2 components

		Amplitude Mean ± SD						
		States						
Component	**Sessions**	**Before**	**D1**	**D2**	**D3**	**D4**	**After**	**Cohen's *d***
P1 Component	*Cañcalatā*	1.19±1.01	0.85±0.62	0.65±0.51**	0.82±0.54	0.74±0.61*	1.04±0.67	0.675
	Ekāgratā	1.05±0.80	0.79±0.59	0.79±0.58*	0.69±0.54**	0.69±0.50***	0.99±0.74	0.540
	Dhāraṇā	1.19±0.97	1.02±0.69	0.97±0.86	0.97±0.60	1.01±0.67	1.06±0.78	0.202
	Dhyāna	0.96±0.66	0.84±0.61	0.90±0.60	0.87±0.72	0.90±0.80	0.97±0.64	0.015
N1 Component	*Cañcalatā*	0.56±0.51	0.44±0.38	0.44±0.40	0.40±0.29	0.41±0.34	0.50±0.38	0.346
	Ekāgratā	0.40±0.31	0.36±0.28	0.38±0.33	0.45±0.38	0.34±0.25	0.42±0.38	0.058
	Dhāraṇā	0.43±0.43	0.46±0.41	0.44±0.47	0.44±0.46	0.44±0.35	0.54±0.46	0.247
	Dhyāna	0.31±0.43	0.37±0.36	0.69±1.84	0.43±0.45	0.46±0.39	0.40±0.36	0.227
P2 Component	*Cañcalatā*	0.95±0.83	0.57±0.42**	0.51±0.46***	0.59±0.51**	0.61±0.40*	0.84±0.57	0.656
	Ekāgratā	0.82±0.47	0.66±0.45	0.58±0.47**	0.56±0.47*	0.56±0.37**	0.78±0.47	0.615
	Dhāraṇā	0.87±0.65	0.71±0.47	0.66±0.62	0.78±0.54	0.72±0.50	0.86±0.60	0.331
	Dhyāna	0.80±0.57	0.69±0.52	0.68±0.47	0.64±0.41	0.70±0.58	0.80±0.47	0.322
N2 Component	*Cañcalatā*	0.39±0.36	0.39±0.33	0.35±0.34	0.31±0.26	0.30±0.26**	0.42±0.40	0.679
	Ekāgratā	0.41±0.30	0.36±0.25	0.36±0.27	0.34±0.31	0.26±0.23*	0.34±0.28	0.561
	Dhāraṇā	0.38±0.36	0.42±0.33	0.40±0.37	0.39±0.38	0.34±0.26	0.43±0.29	0.153
	Dhyāna	0.39±0.33	0.38±0.34	0.35±0.29	0.39±0.35	0.39±0.48	0.28±0.25	0.376

*p < 0.05, **p < 0.01, ***p < 0.001; repeated measures of ANOVA with Bonferroni adjustment comparing During and Post values with Pre values. Values are group means ± S.D. Cohen's *d* is calculated for the maximum difference in the post-pre or during-pre comparisons.

Table 15. Summary of the repeated measures analysis of variance (ANOVA) showing statistically significant results

Component	Factor	F value	df	Hyunh-Feldt ε	Level of significance	η_p^2
P1 wave Amplitude	Session	4.08	(2.52, 118.6)	0.893	$p < 0.05$	0.080
N2 Wave Latency	Session	1.69	(2.19, 102.8)	0.766	$p < 0.05$	0.035
P1 wave Latency	State	3.76	(3.77, 177.04)	0.827	$p < 0.01$	0.074
P1 wave Amplitude	State	10.72	(2.76, 129.57)	0.589	$p < 0.001$	0.186
N1 wave Latency	State	2.86	(4.14, 194.54)	0.918	$p < 0.05$	0.057
P2 Wave Amplitude	State	9.74	(4, 187.98)	0.884	$p <0.001$	0.172
P1 wave Amplitude	Session*State	2.08	(9.59, 450.57)	0.816	$p < 0.05$	0.043
N2 Wave Latency	Session*State	0.83	(7.59, 356.64)	0.613	$p < 0.05$	0.017
P2 Wave Latency	Session*State	1.93	(10.17, 478.16)	0.880	$p <0.05$	0.039
P2 Wave Amplitude	Session*State	4.02	(9.9, 464.54)	0.849	$p <0.001$	0.079

(a)

(b)

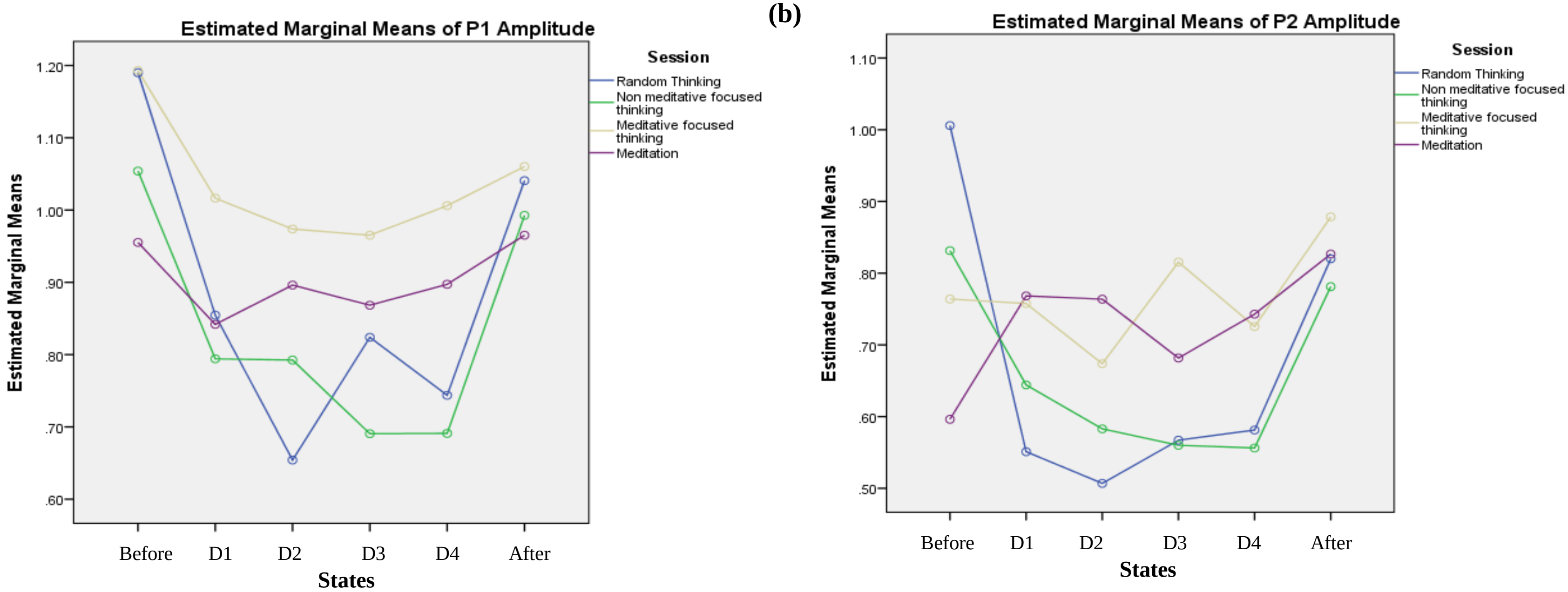


Figure 11: The following graphical representations show the interaction between Sessions × States for the amplitude. The dependent variable (peak amplitude in µV) is displayed on the Y axis and the independent variables (States) on the X axis

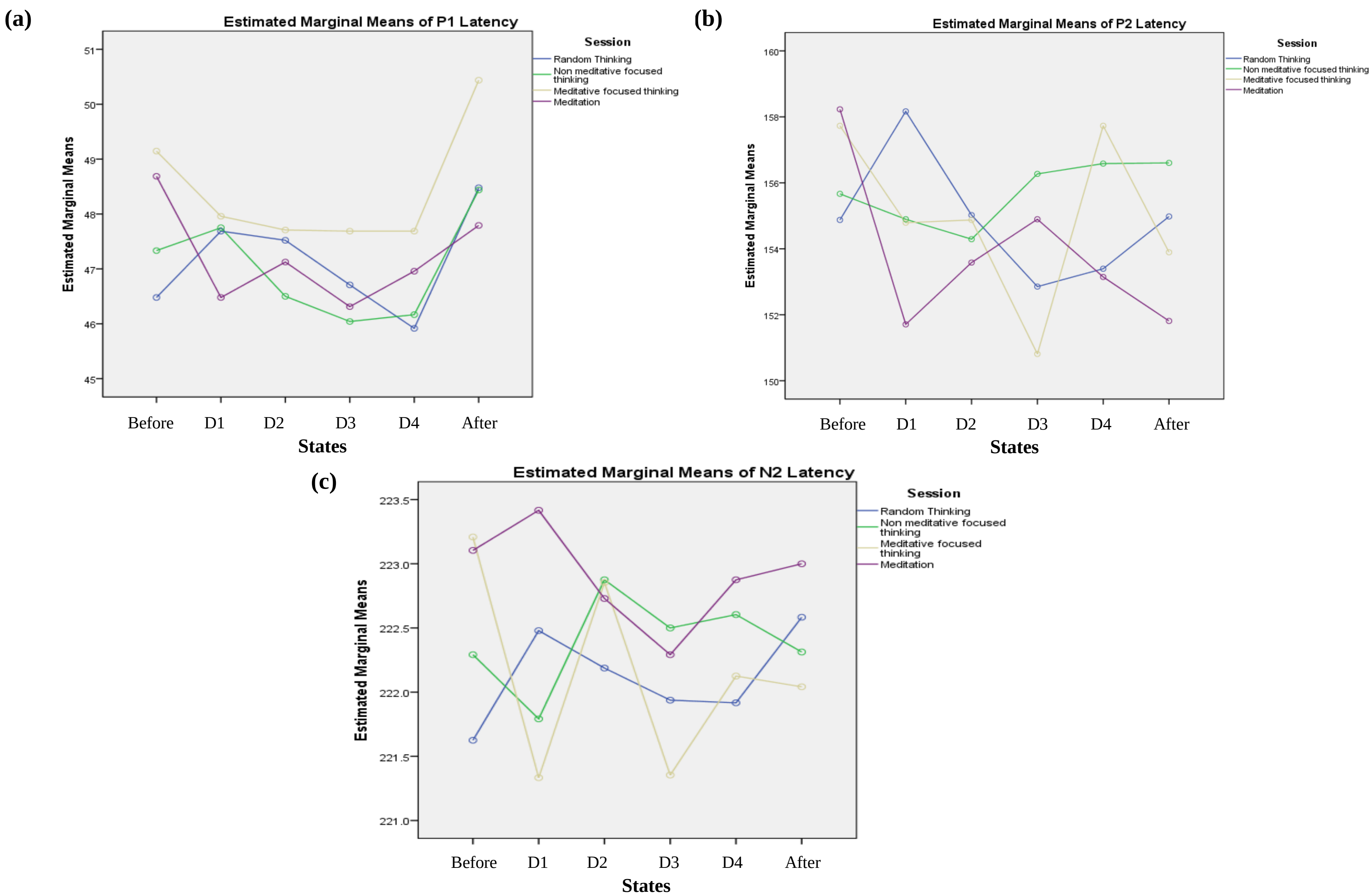


Figure 12: The following graphical representations show the interaction between Session × States for the amplitude. The dependent variable (peak latency in ms) is displayed on the Y axis and the independent variables (States) on the X axis

6.1.2 Peak latency and Peak amplitude of LLAEPs recorded at Cz

The repeated measures ANOVA consisted of two Within-Subjects factors i.e., (i) Sessions (*cañcalatā, ekāgratā, dhāraṇā*, and *dhyāna*) and (ii) States ('Before', 'During 1' to 'During 4', and 'After') for LLAEPs peak latency (ms) and peak amplitude (μV) recorded at Cz. The main effect and the interactions between the two for the different components of LLAEPs are provided in **Table 15.** A significant interaction between Sessions and States for any component suggests that the two are interdependent. Sessions × States interaction were significant for P1 and P2 amplitude; and N1, N2 and P2 latency components of LLAEPs. This significant interaction has been graphically presented in **Figure 11 - 12**.

Post-hoc analyses with Bonferroni adjustment were performed and all comparisons were made with the respective 'Before' states. There was a significant decrease in the amplitude of P1, P2 and N2 waves 'During' *cañcalatā* ($p < 0.01$; $p < 0.001$; $p < 0.01$, respectively) and *ekāgratā* ($p < 0.01$; $p < 0.01$; $p < 0.05$, respectively) and a decrease in the peak latency of the P2 wave 'During' and 'After' *dhyāna* ($p < 0.001$). All comparisons were made with the 'Before' state. The Cohen's *d* values were calculated and are provided in **Table 13** (peak latencies) and **Table 14** (peak amplitude) for the four sessions at Cz. A single sample of a long latency auditory evoked potential waveform before meditation and after meditation is given in **Figure 13**.

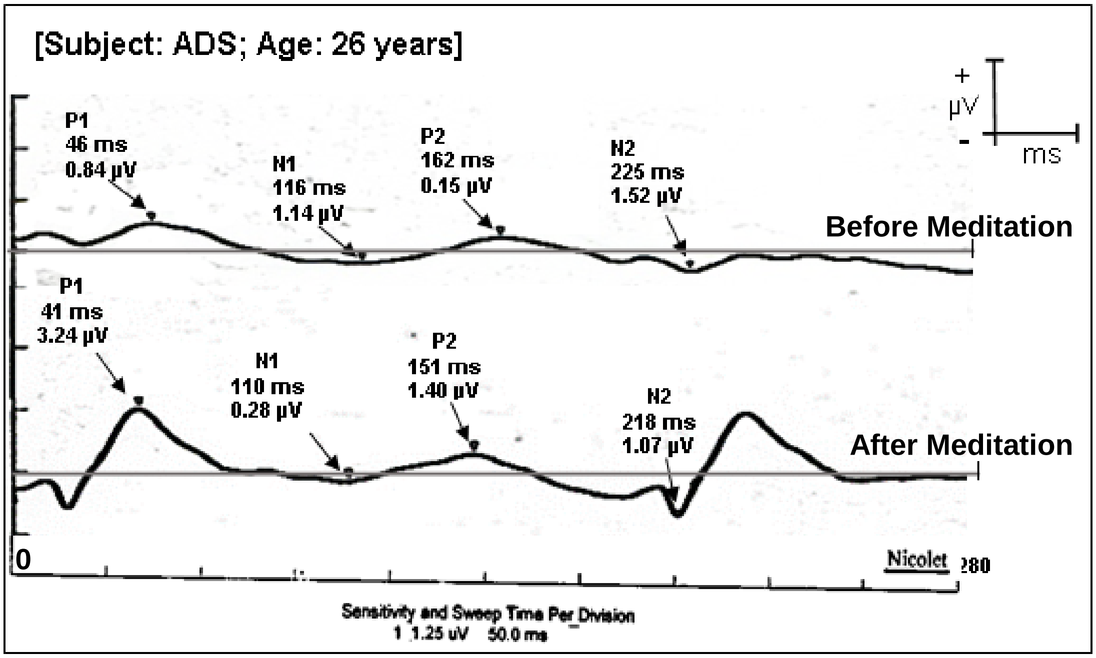


Figure 13: A single sample of a long latency auditory evoked potential waveform before meditation and after meditation

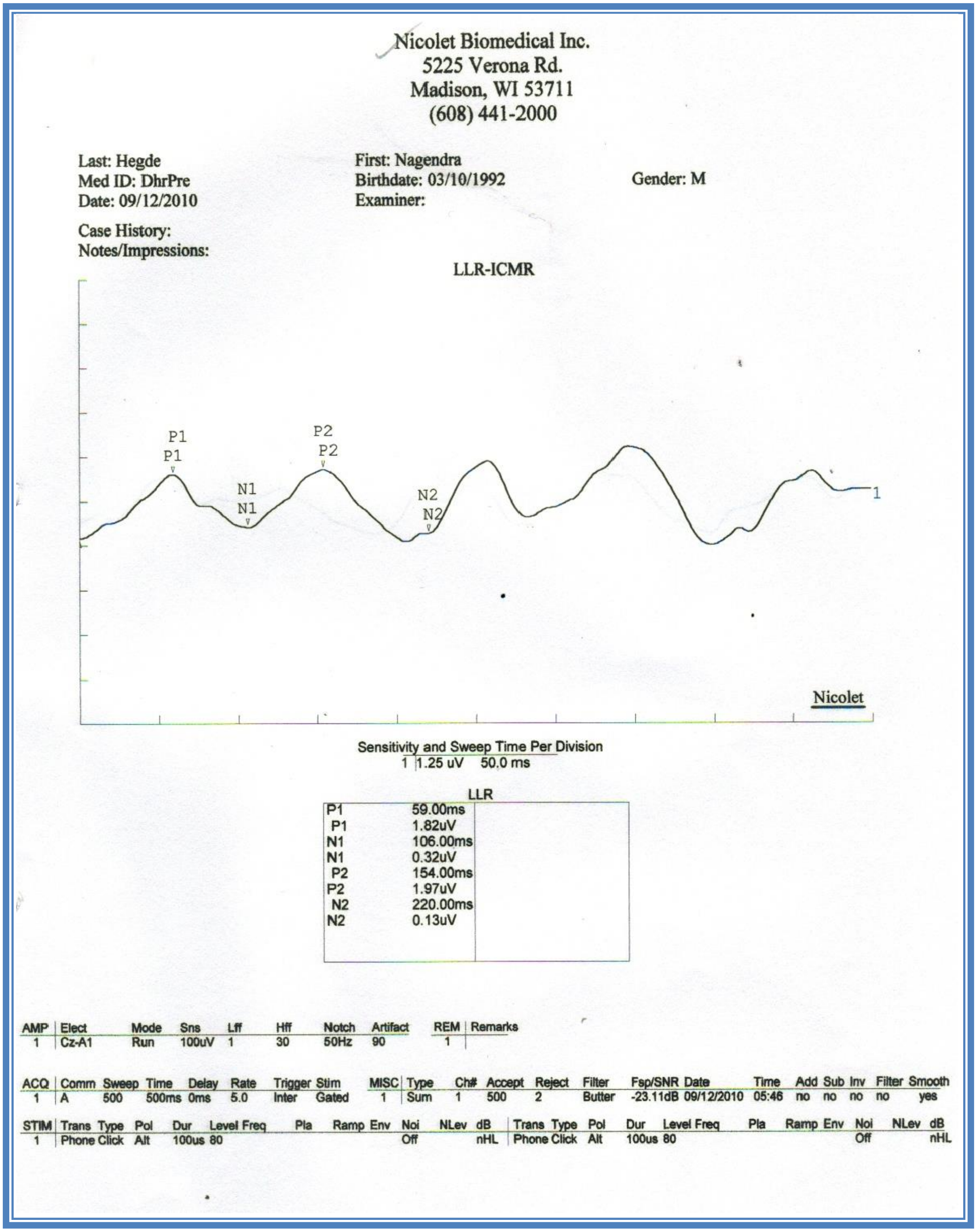


Figure 14: Average trace acquired during *dhāraṇā* with the frequent stimulus whose electrode is referred to Cz

6.2 P300 EVENT RELATED POTENTIALS AND HEART RATE VARIABILITY WITH RESPIRATION

6.2.1 Recapitulation

Simultaneous recordings of P300 ERPs, heart rate variability (HRV) and respiration were recorded in sixty participants during four sessions i.e., *cañcalatā, ekāgratā, dhāraṇā*, and *dhyāna*. The peak amplitude and the peak latency of the P300 ERPs were measured at Cz. The peak amplitude (in μV) was defined as the voltage difference between baseline at stimulus delivery and the largest positive-going peak of the ERP waveform within 250–500 ms latency (Polich 1999). The peak latency (ms) was defined as the time from stimulus onset to the point of maximum positive amplitude within the latency window (i.e., 250-500 ms). Recordings of heart rate variability and respiratory rate were taken for 30 minutes for each participant, before intervention (5 minutes), during the intervention (20 minutes), and after intervention (5 minutes) and the data were analyzed separately. 'Before' and 'After' sessions had one epoch of 5 min, whereas 'During' had 4 similar epochs viz. D1, D2, D3, D4. The recorded data were visually inspected off-line and only noise free data were included for analysis. The HRV power spectrum was obtained using Fast Fourier Transform (FFT) analysis. Repeated measures analyses of variance (ANOVA) followed by *Post-hoc* analyses with Bonferroni adjustment were done to compare data recorded 'During' and 'After' the four interventions with data recorded 'Before' the four interventions. There were two 'Within subjects' factors, i.e., Factor 1: Sessions such as *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* and Factor 2: States that are 'Before', 'During' (1 to 4), and 'After'. Separate repeated measures ANOVAs was performed for HRV components (frequency domain and time domain), respiratory rate, and P300 ERPs (peak latency and peak amplitude).

The group mean values ± SD and Cohen's *d* values for HRV components (frequency domain and time domain) and P300 ERPs (peak amplitude and peak latency) are given in **Table 16 - 17** respectively. A sample trace of the P300 responses is given in **Figure 16**.

Table 16: P300 Auditory Evoked Potentials showing peak latency and peak amplitude for four Sessions in two States ('Before' and 'After') for A1-Cz wave

		Latency (ms)			Amplitude (µV)		
Waves	**Sessions**	**Before**	**After**	**Cohen's *d***	**Before**	**After**	**Cohen's *d***
P3 (A1- Cz)	*Cañcalatā*	331.53±34.39	339.38±32.87	0.23	8.99±3.91	7.71±3.97*	0.33
	Ekāgratā	335.62±35.18	338.68±38.11	0.08	8.97±4.07	9.01±3.98	0.07
	Dhāraṇā	338.55±38.07	335.23±38.31	0.09	8.93±4.24	10.23±3.83*	0.32
	Dhyāna	337.40±37.27	327.47±39.39*	0.31	7.47±4.58	8.56±3.838*	0.34

*$p < 0.05$; repeated measures ANOVA with Bonferroni adjustment comparing 'After' values with 'Before' values. Values are group means ± S.D.

Table 17: Changes in frequency domain and time domain analysis of the heart rate variability components

Sessions	Variables	Before	During D1	During D2	During D3	During D4	After	Cohen's *d*
	Frequency Domain							
Cañcalatā	LF (n.u.)	57.55±22.17	65.41±18.33	65.34±20.06*	69.95±17.62***	66.98±18.53*	63.16±20.76	0.62
	HF (n.u.)	42.45±22.17	34.59±18.33	34.66±20.06*	30.03±17.59***	33.02±18.53*	36.84±20.76	0.62
Ekāgratā	LF/HF ratio (ms^2)	2.42±2.75	3.13±3.43	3.45±4.01	3.57±4.23	4.12±4.22*	2.18±2.80	0.48
Dhāraṇā	LF (n.u.)	55.88±22.46	65.06±19.50*	66.89±18.84***	70.18±17.12***	68.08±20.76**	64.63±20.90*	0.66
	HF (n.u.)	44.12±22.46	34.94±19.50*	33.11±18.84***	29.82±17.12	31.92±20.76***	35.37±20.90*	0.56
	LF/HF ratio (ms^2)	2.37±2.64	4.33±6.81	4.42±5.97*	5.82±10.18	5.27±7.33	3.87±5.67	0.44
Dhyāna	LF (n.u.)	57.11±20.61	44.43±17.82***	48.37±18.24*	51.37±21.09	46.33±17.38**	51.91±17.66	0.66
	HF(n.u.)	42.89±20.61	55.57±17.82***	51.63±18.24*	48.63±21.09***	53.67±17.38***	48.09±17.66	0.57
	LF/HF ratio (ms^2)	2.07±1.80	1.14±1.34*	1.35±1.34	1.81±2.44	1.15±1.07***	1.59±1.65	0.66
	Time Domain							
Dhāraṇā	Mean RR (msec)	781.65±116.35	792.23±121.26	790.34±106.20	808.67±115.27	798.34±124.86	814.48±114.72**	0.28
	Mean HR (bpm)	78.91±11.72	78.33±12.77	77.87±9.97	76.28±10.67	77.53±11.45	82.70±10.29**	0.34
Dhyāna	Mean RR (msec)	770.95±131.26	797.61±135.09	805.12±123.74*	820.49±134.36**	808.39±131.17*	796.56±121.98	0.38
	Mean HR (bpm)	80.44±13.22	77.77±12.03	76.90±11.50**	75.73±11.99**	76.98±11.84*	77.50±11.39*	0.37
	RMSSD (ms)	46.23±34.68	48.14±31.01	56.17±35.22	60.04±38.78*	61.85±39.75*	51.88±30.61	0.42
	pNN50	21.81±20.27	23.01±19.93	26.23±20.05	30.32±22.31*	28.84±21.17	25.82±21.41	0.40

*p < 0.05, **p < 0.01 and ***p < 0.001, Repeated measures analyses of Variance (RMANOVA), with post-hoc analyses comparing During and After. **LF:** low frequency band of the HRV; **HF:** high frequency band of the HRV; **LF/HF:** ratio of low frequency to high frequency; **RR:** the average of time intervals between consecutive R-waves**;** RMSSD, the square root of the mean of the sum of the squares of differences between adjacent NN intervals; pNN50, NN50 count divided by the total number of all NN intervals; NN50, number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording

6.2.2 Peak latency of P300 Event Related Potentials (ERPs)

For peak latency, repeated measures ANOVA values showed no significant difference between:

(i) Sessions [F (3, 138) = 0.52, Huynh-Feldt epsilon = 0.94, $p > 0.05$, $\eta p^2 = 0.011$],

(ii) States [F (1, 46) = 0.18, Huynh-Feldt epsilon = 1, $p > 0.05$, $\eta p^2 = 0.004$], while

(iii) Interaction between Sessions × States [F (3, 138) = 3.10, Huynh-Feldt epsilon = 1, $p > 0.05$, $\eta p^2 = 0.063$] was significant.

6.2.3 Peak amplitude of P300 Event Related Potentials (ERPs)

Also, for the peak amplitude, repeated measures ANOVA values showed no significant difference between:

(i) Sessions [F (3, 138) = 2.55, Huynh-Feldt epsilon = 1, $p > 0.05$, $\eta p^2 = 0.053$],

(ii) States [F (1, 46) = 1.51, Huynh-Feldt epsilon = 1, $p > 0.05$, $\eta p^2 = 0.032$],

(iii) Interaction between Sessions × States [F (3, 138) = 2.32, Huynh-Feldt epsilon = 0.96, $p < 0.01$, $\eta p^2 = 0.048$] was significant.

6.2.4 *Post-hoc* analyses with Bonferroni adjustment for peak latency and peak amplitude of P300 ERP

Post-hoc analyses with Bonferroni adjustment for each session separately showed a significant increase in amplitude of P300 ERPs during *dhāraṇā* (meditative focusing) ('Before' versus 'After'; $p < 0.05$) and *dhyāna* (meditation) ('Before' versus 'After'; $p < 0.05$) with a decrease in latency ($p < 0.05$) whereas there was a significant decrease in the amplitude during the *cañcalatā* (random thinking) ('Before' versus 'After'; $p < 0.05$).

These have been summarized in **Table 16**. Sample P300 waveform showing changes after *dhyāna* (meditation) has been provided in **Figure 15**.

6.2.5 Heart Rate Variability and Respiration

Repeated measures analysis of variance (ANOVA) for HRV components are given below.

6.2.5 A. *Frequency domain analysis*

The LF power showed there was a significant difference between:

(i) Sessions [$F (3, 138) = 27.08$, Huynh-Feldt epsilon = 0.83, $p<0.001$, $\eta p^2 = 0.37$],

(ii) States [$F (5, 230) = 6.98$, Huynh-Feldt epsilon = 0.81, $p<0.001$, $\eta p^2 = 0.13$], and,

(iii) Interaction between Sessions × States [$F (15, 690) = 6.78$, Huynh-Feldt epsilon = 0.78, $p<0.001$, $\eta p^2 = 0.13$].

For the HF power there was a significant difference between:

(i) Sessions [$F (3, 138) = 27.08$, Huynh-Feldt epsilon = 0.84, $p<0.001$, $\eta p^2 = 0.37$],

(ii) States [$F (5, 230) = 6.97$, Huynh-Feldt epsilon = 0.81, $p<0.001$, $\eta p^2 = 0.13$], and

(iii) Interaction between Sessions × States [$F (15, 690) = 6.79$, Huynh-Feldt epsilon = 0.784, $p<0.001$, $\eta p^2 = 0.13$].

For the LF/HF ratio there was a significant difference between:

(i) States [$F (5,230) = 4.10$, Huynh-Feldt epsilon = 0.52, $p<0.001$], and

(ii) Interaction between Sessions × State [$F (15,690) = 1.36$, Huynh-Feldt epsilon = 0.17, $p<0.05$, $\eta p^2 = 0.03$].

Post-hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective ‘Before’ state. ‘During’ and

‘After’ *dhyāna* session there was a significant decrease in LF power ($p < 0.001$) and a significant increase in HF power ($p<0.001$) as well as a decrease in the LF/HF ratio ($p<0.05$) when compared with ‘Before’ intervention. ‘During’ *cañcalatā* and ‘During’ and ‘After’ *ekāgratā*, there was a significant increase in LF power ($p < 0.001$) and a decrease in HF power ($p < 0.001$) when compared to ‘Before’ intervention. There was also a significant increase in the LF/HF ratio ($p<0.05$) ‘During’ *ekāgratā* and *dhāraṇā* when compared with ‘Before’ intervention. These have been summarized in **Table 17**.

6.2.5 B. *Time domain analysis*

The mean RR interval showed a significant difference between:

(i) States [$F(5, 230) = 5.67$, Huynh-Feldt epsilon = 0.48, $p<0.001$, $\eta p^2 = 0.11$] and

(ii) The interaction between Sessions × States [$F(15, 690) = 3.83$, Huynh-Feldt epsilon = 0.60, $p<0.001$, $\eta p^2 = 0.08$].

For the HR, there was a significant difference between:

(i) States [$F(5, 230) = 6.64$, Huynh-Feldt epsilon = 0.64, $p<0.001$, $\eta p^2 = 0.07$], and

(ii) Interaction between Sessions × States [$F(15, 690) = 3.26$, Huynh-Feldt epsilon = 0.64, $p<0.05$, $\eta p^2 = 0.07$].

For the RMSSD, there was a significant difference between:

(i) States [$F(5, 230) = 6.85$, Huynh-Feldt epsilon = 0.64, $p<0.001$, $\eta p^2 = 13$], and

(ii) Interaction between Sessions × States [$F(15, 690) = 1.93$, Huynh-Feldt epsilon = 0.64, $p<0.05$, $\eta p^2 = 0.04$].

For the NN50 count, there was a significant difference between:

(i) Sessions [$F(3, 138) = 0.64$, Huynh-Feldt epsilon = 1, $p<0.05$, $\eta p^2 = 0.02$]

(ii) States [$F (5, 230) = 3.88$, Huynh-Feldt epsilon = 0.55, $p<0.01$, $\eta p^2 = 0.08$], and

(iii) Interaction between Sessions × States [$F (15, 690) = 2.14$, Huynh-Feldt epsilon = 0.56, $p<0.01$, $\eta p^2 = 0.05$].

For the pNN50, there was a significant difference between:

(i) States [$F (5, 230) = 4.92$, Huynh-Feldt epsilon = 0.53, $p<0.001$, $\eta p^2 = 0.10$] and

(ii) Interaction between Sessions × States [$F (15, 690) = 2.78$, Huynh-Feldt epsilon = 0.56, $p<0.001$, $\eta p^2 = 0.06$].

Post-hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective 'Before' state, 'During', and 'After' *dhyāna* session. 'After' *dhāraṇā*, there was a significant increase in mean RR ($p < 0.01$) and mean HR ($p< 0.01$) compared with 'Before' intervention. 'During' and 'After' *dhyana*, there was a significant increase in mean RR ($p<0.01$) and decrease in mean HR ($p < 0.01$), there was also a significant increase in RMSSD ($p<0.05$) and pNN50 ($p<0.05$) when 'During' was compared with 'Before'. These have been summarized in **Table 17.**

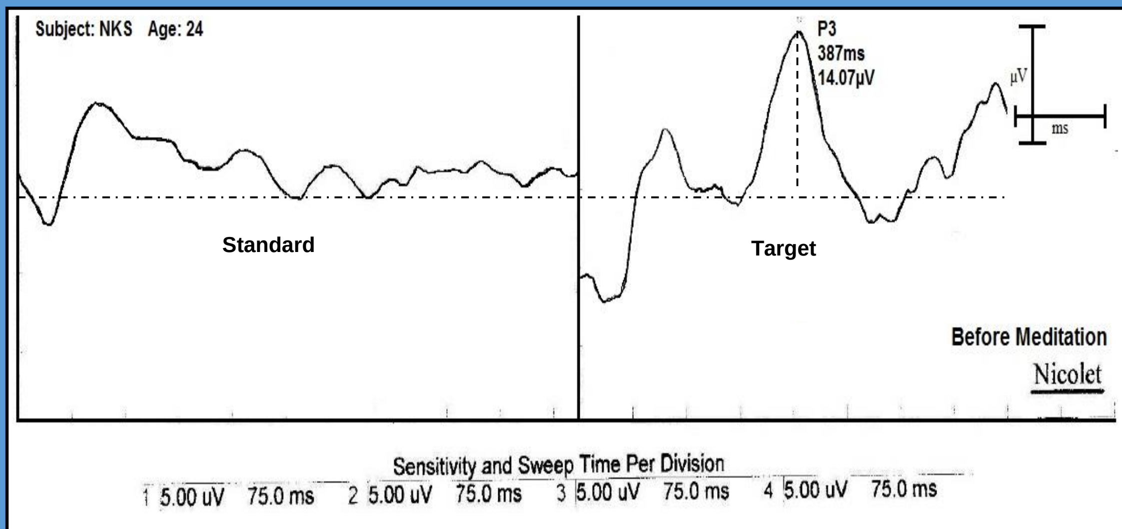
6.2.5 C *Respiratory rate* (RR)

Repeated measures analysis of variance (ANOVA) for respiratory rate (RR) showed a significant difference between States [$F (5, 230) = 5.09$, Huynh-Feldt epsilon = 0.73, $p<0.001$, $\eta p^2 = 0.1$].

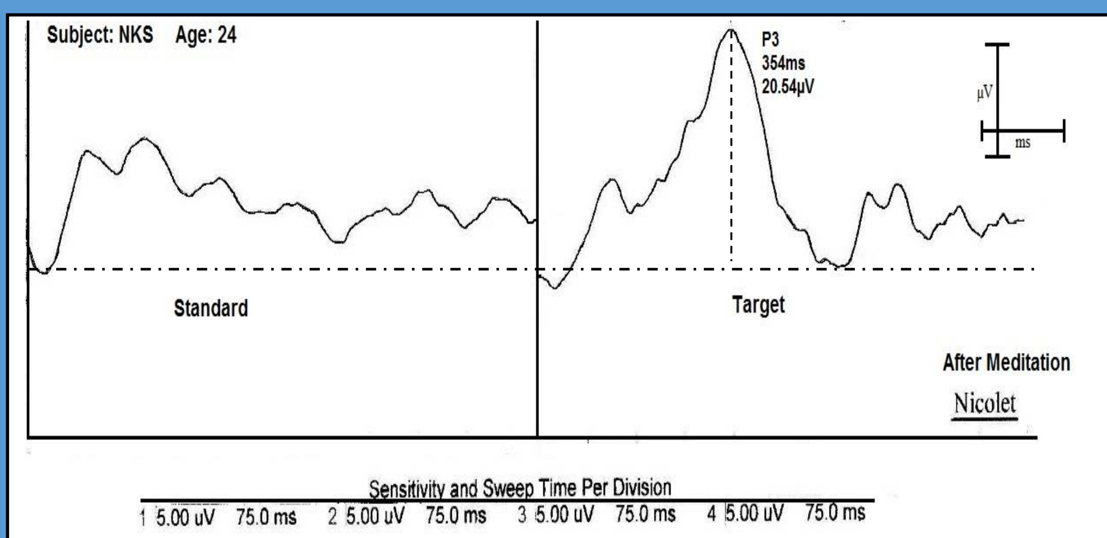
Post-hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective 'Before' state, 'During', and 'After' four sessions. Results showed that there were no significant difference in sessions and states.

Figure 15: Traces of P300 event related potentials 'Before' and 'After' meditation

a. Before Meditation



b. After Meditation (with increase P300 peak Amplitude)



Note: The given figures showed (a) a higher peak latency of the P300 event related potentials (ERPs) 'Before' meditation, whereas (b) 'After' meditation, there was an increase in the peak amplitude and decreased latency.

Figure 16: Averaged trace acquired during *Dhyana* with the rare stimulus whose electrode is referred to Cz sample trace of the P300 responses

Nicolet Biomedical Inc.
5225 Verona Rd.
Madison, WI 53711
(608) 441-2000

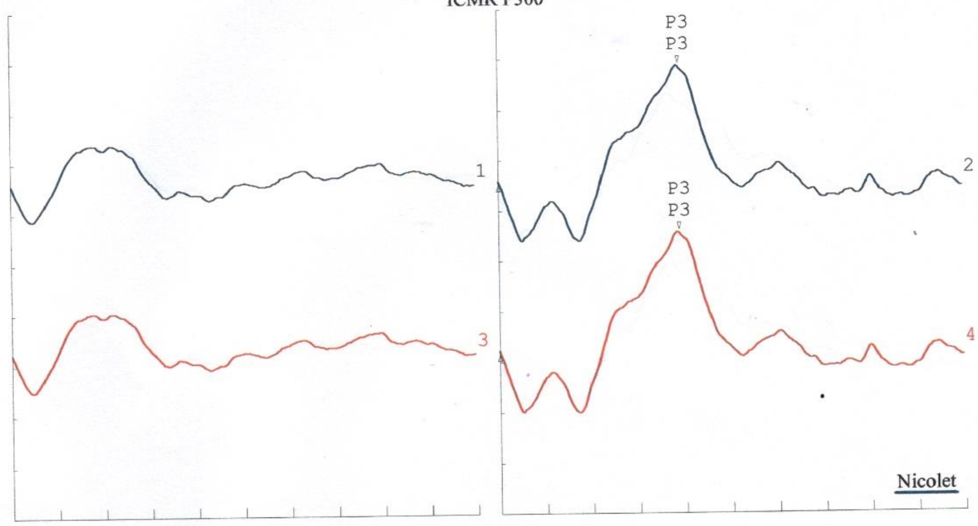
Last: Sharma
Med ID: DhyPre
Date: 08/12/2011

First: Rishikant
Birthdate: 09/12/1991
Examiner: Deepesh

Gender: M

Case History:
Notes/Impressions:

ICMR P300



Sensitivity and Sweep Time Per Division

1 5.00 uV 75.0 ms 2 5.00 uV 75.0 ms 3 5.00 uV 75.0 ms 4 5.00 uV 75.0 ms

P300

P3	366.00ms	P3	366.00ms
P3	11.38uV	P3	11.68uV

AMP	Elect	Mode	Sns	Lff	Hff	Notch	Artifact
1	Cz-A1	Run	100uV	0.01	30	Off	90
2	Cz-A1	Run	100uV	0.01	30	Off	90
3	Cz-A2	Run	100uV	0.01	30	Off	90
4	Cz-A2	Run	100uV	0.01	30	Off	90

REM	Remarks
1	
2	
3	
4	

ACQ	Comm	Sweep	Time	Delay	Rate	Trigger	Stim
1	A	300	750ms	75ms	0.9	Inter	Gated
2	A	300	750ms	75ms	0.9	Inter	Gated
3	A	300	750ms	75ms	0.9	Inter	Gated
4	A	300	750ms	75ms	0.9	Inter	Gated

MISC	Type	Ch#	Accept	Reject	Filter	Fsp/SNR	Date	Time	Add	Sub	Inv	Filter	Smooth
1	Freqnt	1	240	0	Butter	-8.38dB	08/12/2011	05:37	no	no	no	no	no
2	Rare	1	60	0	Butter	-8.38dB	08/12/2011	05:37	no	no	no	no	no
3	Freqnt	2	240	0	Butter	-8.59dB	08/12/2011	05:37	no	no	no	no	no
4	Rare	2	60	0	Butter	-8.59dB	08/12/2011	05:37	no	no	no	no	no

STIM	Trans Type	Pol	Dur	Level	Freq	Pla	Ramp	Env	dB	Ear	Prcnt	Trans Type	Pol	Dur	Level	Freq	Pla	Ramp	Env	dB	Ear	Prcnt
1	Phone Tone	Alt		70	1KHz	50cy	10	Blk	SPL	Both	80	Phone Tone	Alt		70	2KHz	10cy	20	Blk	SPL	Both	20
2	Phone Tone	Alt		70	1KHz	50cy	10	Blk	SPL	Both	80	Phone Tone	Alt		70	2KHz	10cy	20	Blk	SPL	Both	20
3	Phone Tone	Alt		70	1KHz	50cy	10	Blk	SPL	Both	80	Phone Tone	Alt		70	2KHz	10cy	20	Blk	SPL	Both	20
4	Phone Tone	Alt		70	1KHz	50cy	10	Blk	SPL	Both	80	Phone Tone	Alt		70	2KHz	10cy	20	Blk	SPL	Both	20

v 3.2

6.3 HEMODYNAMIC RESPONSES IN MEDITATION AND COGNITIVE TASK

6.3.1 Recapitulation

In this study, we have utilized functional near infrared spectroscopy (fNIRS) to evaluate the relative hemodynamic changes in prefrontal cortex during a cognitive task. Twenty-two healthy male volunteers with ages between 18 and 30 years (group mean age ± SD; 23.4 ± 3.7 years) performed a stroop color-word task before and after 20 minutes of the sessions. The participants were assessed in two separate sessions i.e., *cañcalatā* (random thinking) and *dhyāna* (meditation) while recording hemodynamic changes on the prefrontal cortex (PFC) using 16-channel continuous wave fNIRS system.

Data were tested for normality by Kolmogorov-Smirnov test. Since, the same individuals were assessed in repeated sessions on two separate days i.e., *cañcalatā* (random thinking) and *dhyāna* (meditation), repeated measures analysis of variance (ANOVA) was used. Repeated measures analyses of variance (ANOVA) were performed with three 'Within subjects' factors, i.e., Factor 1: Sessions (*cañcalatā* and *dhyāna*); Factor 2: Prefrontal Cortex (right and left). Factor 3: States ('Before', 'Stroop_Pre', 'During' (D1 to D4), 'Stroop_Post', and 'After'). The repeated measures ANOVAs were carried out for concentration changes of oxygenated and deoxygenated hemoglobin and total hemoglobin change (ΔHbO, ΔHbR, and ΔTHbC) across the right and left prefrontal cortex (PFC). This was followed by a *post-hoc* analyses with Bonferroni adjustment for multiple comparisons between the mean values of different states ('During' and 'After') and all comparisons were made with the respective 'Before' state.

Moreover, for analysis of stroop task we compared the mean reaction time (ms) of neutral, congruent and incongruent conditions and hemodynamic responses of stroop color word task 'Before' and 'After' the sessions (*cañcalatā* and *dhyāna*). To compare between different conditions (neutral, congruent, and incongruent), results were averaged for each position, parameter, and subject separately. The group mean reaction scores (ms) of stroop color word task are given in **Table 18** and hemodynamic responses are given in **Table 19**. The graphical representation (in line diagram) of hemoglobin change at right and left prefrontal cortex in two sessions i.e., *cañcalatā*, and *dhyāna*, and Stroop task are given in **Figure 17-19**.

Table 18: Group mean values ± S.D of the reaction time scores (ms) of Stroop color word task

Sessions	States	Before	After	t-value	P value	% Change
Cañcalatā	Neutral	643.18±130.654	660.00±113.641	-2.274	**0.034***	2.62
	Congruent	783.64±117.333	790.91±119.440	-.876	0.391	0.93
	Incongruent	871.41±136.070	892.73±136.004	-2.920	**0.008****	2.45
Dhyāna	Neutral	638.64±118.615	617.73±121.653	3.533	**0.002****	-3.27
	Congruent	794.55±118.029	764.55±112.238	6.205	**<0.001*****	-3.78
	Incongruent	865.00±137.797	819.09±133.627	3.302	**0.003****	-5.31

*p<0.05; p<**0.01; ***p < 0.001; repeated measures of ANOVA with Bonferroni adjustment comparing Post values with Pre values. Values are group means ± S.D.

RT – Random Thinking; Med – Meditation

Table 19: Group mean values ± S.D of the oxy-hemoglobin (ΔHbO), deoxy-hemoglobin (ΔHbR) and total hemoglobin change (ΔTHC) in Stroop color word task 'Before', 'During' and 'After' *cañcalatā* (random thinking) and *dhyāna* (meditation)

Sessions	Voxels	Before	Stroop_Pre	During				Stroop _Post	After
				D1	D2	D3	D4		
Oxy-hemoglobin (ΔHbO)									
Cañcalatā	**Left PFC**	-0.71±3.71	-0.64±7.39	0.51±7.58	0.15±6.69	0.25±7.16	0.21±7.61	0.83±7.41	0.80±7.22
	Right PFC	-2.65±5.56	0.81±4.59	-2.21±12.47	-1.30±12.45	-1.69±12.67	-1.65±12.49	-1.56±11.90	-1.00±10.02
Dhyāna	**Left PFC**	-0.43±6.53	-0.93±2.55	-1.13±3.17	-0.79±3.22	-0.64±3.54	-0.77±3.98	-0.09±5.15	0.44±5.25
	Right PFC	-2.45±7.18	-1.30±2.64	**-0.71±4.07***	**-0.44±3.84***	**-0.19±3.86****	-0.89±3.70	-0.79±3.89	**0.35±4.41*****
Deoxy-hemoglobin (ΔHbR)									
Cañcalatā	**Left PFC**	-0.20±15.36	-1.70±4.23	-2.03±5.27	-0.98±5.94	-0.73±6.45	-0.73±6.57	-0.32±8.80	-0.91±8.10
	Right PFC	-5.18±10.80	-2.86±3.65	-3.22±6.89	**-1.78±5.75*****	**-0.48±8.08*****	**0.01±8.05*****	**1.22±8.18*****	**0.19±10.25*****
Dhyāna	**Left PFC**	-1.57±6.61	-1.27±8.85	-2.82±18.20	-2.25±18.82	-2.38±19.15	-2.29±18.82	-2.28±19.80	-2.23±17.63
	Right PFC	-3.90±8.22	-3.00±7.93	-7.19±23.46	-8.16±23.09	-8.14±23.43	**-8.15±22.72***	-7.28±23.56	-7.04±19.93
Total hemoglobin change (ΔTHC)									
Cañcalatā	**Left PFC**	-1.70±5.39	-1.83±9.87	-1.58±20.98	-1.39±21.02	-1.73±21.40	-1.66±21.16	-1.71±21.56	-1.02±19.70
	Right PFC	-4.29±6.67	-3.28±9.05	-8.85±28.49	**-9.07±27.55***	**-10.41±26.99*****	**-10.28±26.52*****	**-10.26±26.89****	**-8.41±21.55****
Dhyāna	**Left PFC**	-0.78±17.63	-2.98±7.98	-3.50±9.7	-2.18±10.23	-1.82±10.74	-1.98±11.34	-1.21±14.27	-1.15±13.88
	Right PFC	-5.11±11.97	-4.36±5.29	-4.37±7.48	**-2.83±7.18****	**-1.94±8.48*****	**-2.16±9.14****	**-1.45±10.11****	**-0.57±11.07*****

**p < 0.01; repeated measures of ANOVA with Bonferroni adjustment comparing During and Post values with Pre values. Values are group means ± S.D.

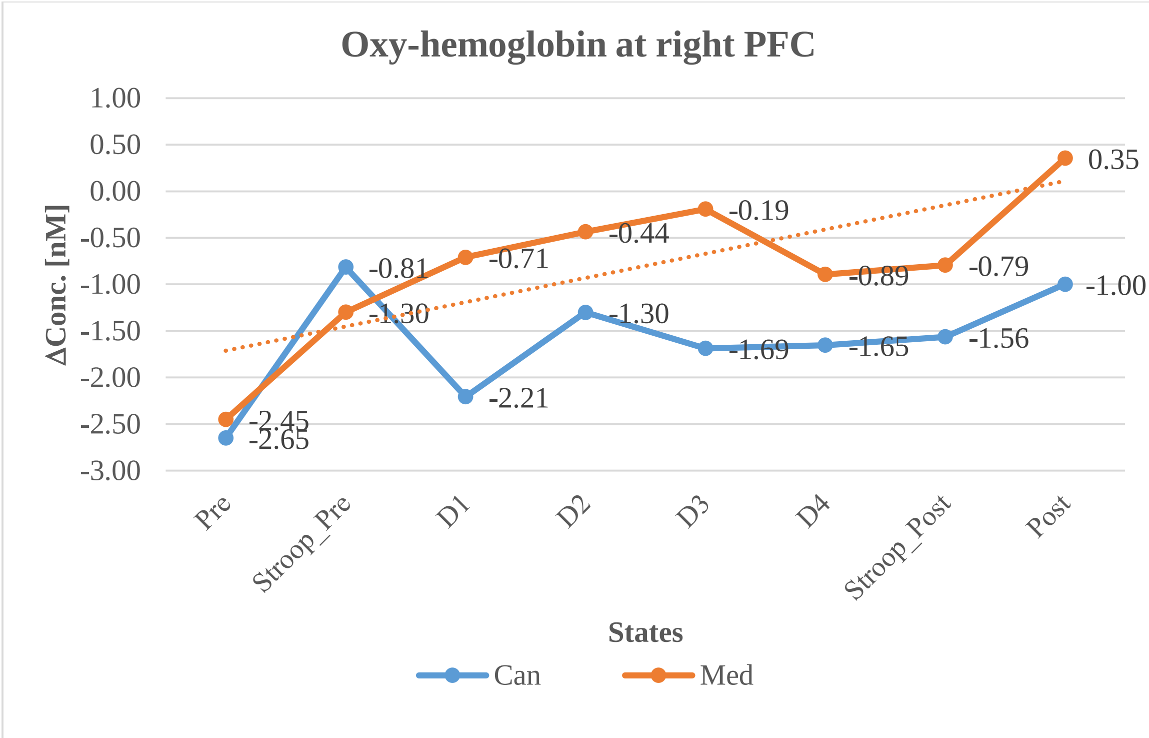


Figure 17: Average of Oxy-hemoglobin change at right prefrontal cortex in two sessions i.e., *cañcalatā*, *dhyāna*, and Stroop task

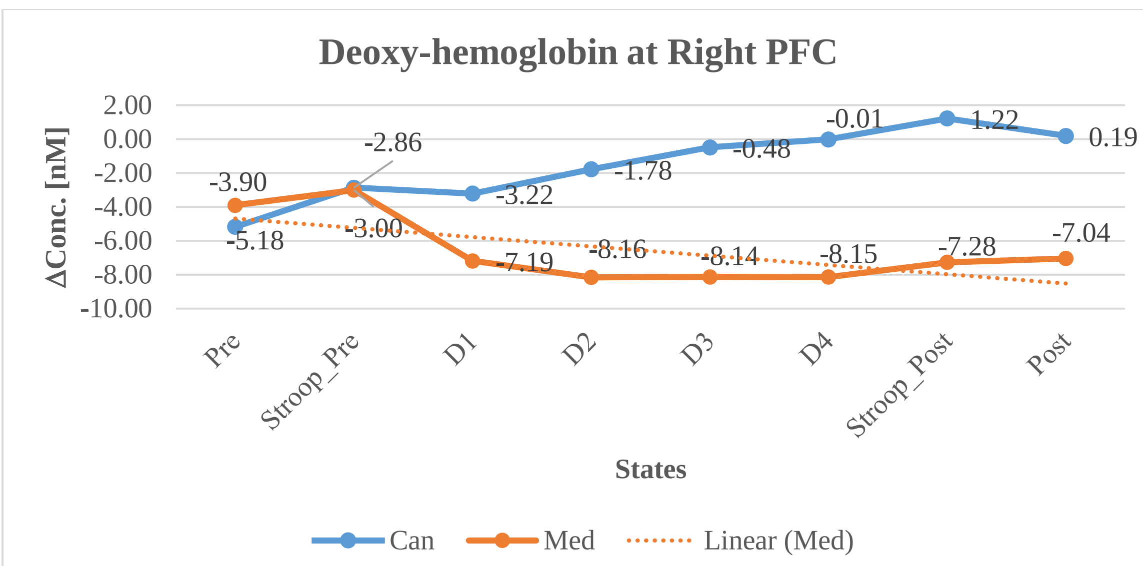


Figure 18: Average of Deoxy-hemoglobin change at right prefrontal cortex in two sessions i.e., *cañcalatā*, *dhyāna*, and Stroop task

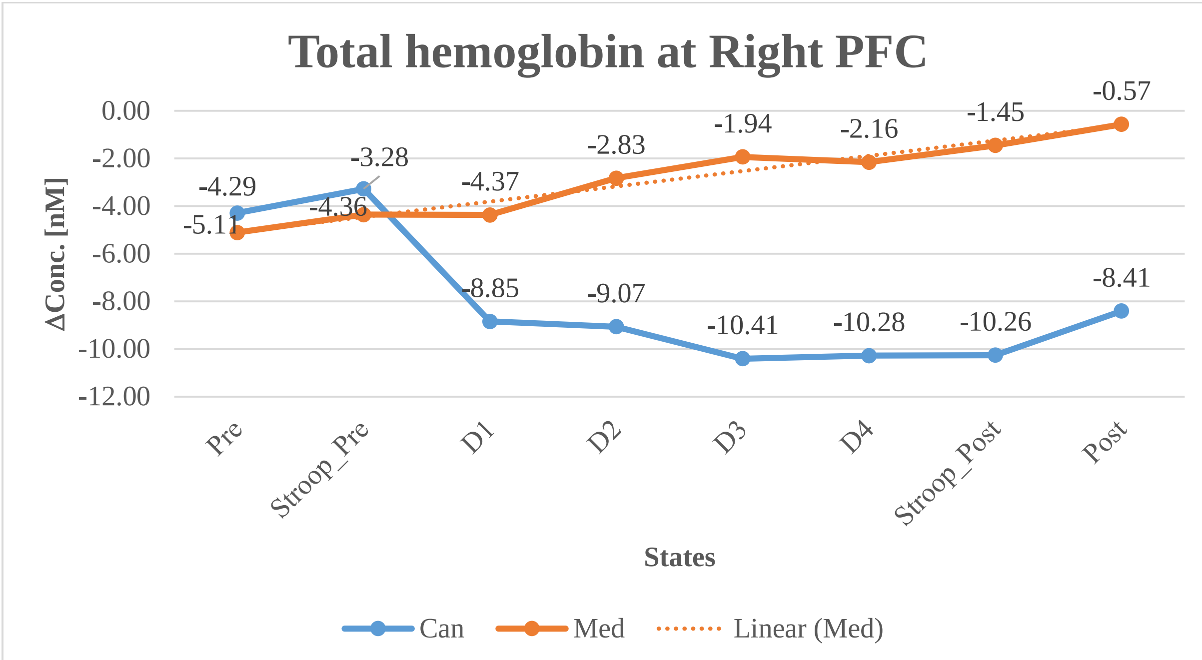


Figure 19: Average of Total hemoglobin change at right prefrontal cortex in two sessions i.e., *cañcalatā*, *dhyāna*, and Stroop task

6.3.2 Behavioral results

Reaction times (RTs) were calculated only from the correctly answered trials. With respect to reaction time, a repeated measures 3 way ANOVA with Sessions (*cañcalatā* and *dhyāna*) × States ('Stroop_Pre', 'Stroop_Post') × Conditions (neutral vs. congruent vs. incongruent) was performed. Repeated measures ANOVA demonstrated a significant main effect for Sessions [$F_{(1, 21)} = 4.862$, p= 0.039, $\eta^2 p = 0.188$]; Conditions [F (2, 42) = 24.12, p<0.001, $\eta^2 p = 0.535$]; States [$F_{(1, 21)} = 6.696$, p<0.023, $\eta^2 p = 0.242$], and significant interaction between Sessions × States [$F_{(1, 21)} = 45.36$, p<0.001, $\eta^2 p = 0.684$].

Post-hoc analysis revealed that there was a significant improvement in cognitive performance after *dhyāna* in all three conditions (neutral, congruent and incongruent) compared to *cañcalatā* session given in **Table 18**. The RTs differed in all the conditions (neutral vs. congruent vs. incongruent) in both the sessions. These findings verify that our attentional manipulation was indeed effective.

Comparing the RTs, two-tailed paired sample t-test revealed significant differences among all three conditions (neutral, congruent and incongruent) in two different sessions (*cañcalatā* and *dhyāna*). In *cañcalatā* session, there were a significant difference in neutral vs. congruent: t (21)= -3.86, p = 0.001; congruent vs. incongruent: t (21)= -2.31, p = 0.031; neutral vs. incongruent: t (21)= -5.92, p< 0.001 whereas in *dhyāna* session, there was a significant difference in neutral - congruent: t (21) = -4.47, p< 0.001; congruent - incongruent: t (21)= -1.85, p > 0.05 (NS); congruent - incongruent: t (21) = -6.148, p< 0.001. The mean RTs were significantly delayed for incongruent stimuli compared with the congruent and neutral conditions for *cañcalatā* and *dhyāna* (p< 0.001; one-tailed paired

Student's t test). Mean RTs were shorter in the neutral ($p = 0.002$), congruent ($p < 001$) and incongruent ($p < 0.003$) conditions after *dhyāna* session, whereas after the *cañcalatā* session, mean reaction times were delayed in the neutral ($p = 0.034$) and incongruent ($p = 0.008$) conditions. The average RTs to neutral, congruent, and incongruent trials of the Stroop color word task are given in **Table 18**. Subjects were made negligible errors during the color word matching stroop task. We did not make any statistical test in terms of error rates, since their distributions are clearly not Gaussian. However, it can be said that the interference effect also manifests itself in error rates. In summary, behavioral results of the Stroop color word task are in accordance with the literature, as demonstrated by a clear interference effect on the participants for *dhyāna* and *cañcalatā* sessions.

6.3.3 Hemodynamic responses in Stroop color word task

In the present study, we have used 16 channel fNIRS device provided a set of time series recorded over the prefrontal cortex (PFC). The locations of the probed regions are shown in **Figure 9.** Note that the ordering of the channels is from left to right, i.e., '1' is on the left and '16' is on the right**.** Analysis of hemoglobin signals, i.e. ΔHbO or ΔHb is still a controversial issue, which hemoglobin signal is more reliably associated with brain activity (Schroeter, Zysset, Kupka, Kruggel, & Yves Von Cramon, 2002). For studying hemodynamic responses, we have utilized three wavelengths (750, 803 and 850 nm). This combination is suitable only for detecting ΔHbO signal. Therefore, we used ΔHbO, ΔHb and ΔTHC signals for statistical analysis. The groups mean values ± S.D. for the ΔHbO, ΔHb and ΔTHC in stroop task and two sessions (*dhyāna* and *cañcalatā*) in 'Before', 'During', and 'After' states are given in **Table 19**.

6.3.3 A. Oxy-hemoglobin change

For oxy-hemoglobin, the repeated measures ANOVA for Sessions (*cañcalatā* and *dhyāna*) × Prefrontal cortex (Left and Right) × States ('Stroop_Pre', 'Stroop_Post') revealed no significant main effect for Sessions, States and Prefrontal cortex. There was a significant interaction between Prefrontal cortex × States [$F_{(1, 175)} = 9.87$, $p < 0.01$, $\eta^2p = 0.053$]; Sessions × Prefrontal cortex × States [$F_{(1, 175)} = 3.17$, $p < 0.01$, $\eta^2p = 0.040$].

6.3.3 B. DeOxy-hemoglobin change

For deoxy-hemoglobin, the repeated measures ANOVA demonstrated significant main effect for Sessions [$F_{(1, 175)} = 9.99$, $p < 0.01$, $\eta^2p = 0.054$]; Prefrontal cortex [$F_{(1, 175)} = 4.57$, $p< 0.05$, $\eta^2p = 0.025$]. Also, there was a significant interaction between Sessions × Prefrontal cortex [$F = 5.11$, $p<0.05$, $\eta^2p = 0.028$]; Sessions × States [$F_{(1, 175)} = 22.13$, $p < 0.001$, $\eta^2p = 0.112$]; Sessions × Prefrontal cortex × States [$F_{(1, 175)} = 9.81$, $p < 0.01$, $\eta^2p = 0.053$].

6.3.3 C. Total hemoglobin change

For total hemoglobin, the repeated measures ANOVA revealed that there was a significant main effect for Prefrontal cortex [$F_{(1, 175)} = 9.71$, $p<0.01$, $\eta^2p = 0.053$], and the significant interaction between Sessions × Prefrontal cortex [$F_{(1, 175)} = 5.33$, $p<0.01$, $\eta^2p = 0.03$]; Sessions × States [$F_{(1, 175)} = 19.87$, $p < 0.001$, $\eta^2p = 0.102$]; Prefrontal cortex × States [$F_{(1, 175)} = 5.96$, $p < 0.05$, $\eta^2p = 0.033$]; Sessions × Prefrontal cortex × States [$F_{(1, 175)} = 14.20$, $p < 0.001$, 0.075].

6.3.3 D. *Post-hoc* analysis of Stroop tasks

The *post-hoc* analysis with Bonferroni corrections showed forehead hemodynamic responses during stroop tasks related to *cañcalatā* and *dhyāna* sessions. The results showed that, 'During' Stroop color word task, a significant decrease in the concentration of ΔHbO in the left Prefrontal cortex (p = 0.016) and in the right Prefrontal cortex (p = 0.032) after *cañcalatā* session, whereas, there was a significant improvement in ΔHbO in the left Prefrontal cortex (p = 0.006) and the right Prefrontal cortex (p = 0.046) after *dhyāna* session. In conclusion, meditation enhances activation bilaterally in the anterior prefrontal cortex and consequently, a stronger increase of oxygenation and cerebral blood flow during stroop task at the right PFC due to interference reduction.

6.3.4 Hemodynamics in random thinking (*cañcalatā*) and meditation (*dhyāna*)

6.3.4 A. Oxy-hemoglobin change

For oxy-hemoglobin, the repeated measures of ANOVA for Sessions (*cañcalatā* and *dhyāna*) × Prefrontal cortex (Left and Right) × States ('Before', 'Stroop_Pre', 'D1-D4', 'Stroop_Post', and 'After') demonstrated a significant main effect for States [$F_{(7,1225)}$ = 5.23, p < 0.001, η^2p = 0.029]. There was a significant interaction between the Prefrontal cortex × States [$F_{(7, 1225)}$ = 2.42, p < 0.001, η^2p = 0.014]; Sessions × Hemispheres × States [$F_{(7, 1225)}$ = 7.32, p < 0.05, η^2p = 0.040].

6.3.4 B. DeOxy-hemoglobin change

For deoxy-hemoglobin, the repeated measures of ANOVA showed, there was a significant main effect for Sessions [$F_{(1,175)}$ =12.20, p < 0.001, η^2p = 0.065]; Prefrontal cortex [$F_{(1,175)}$

= 7.89, p<0.01, $\eta^2p = 0.043$] and States [$F_{(7, 1225)} = 3.55$, $p < 0.001$, $\eta^2p = 0.019$]. There was a significant interaction between the Sessions × Prefrontal cortex [$F_{(1, 175)} = 4.13$, $p < 0.001$, $\eta^2p = 0.023$]; Sessions × States [$F_{(7, 1225)} = 9.99$, $p < 0.001$, $\eta^2p = 0.054$]; Sessions × Prefrontal cortex × States [$F_{(7, 1225)} = 10.37$, $p < 0.001$, $\eta^2p = 0.056$].

6.3.4 C. Total hemoglobin change

For total hemoglobin change, the repeated measures ANOVA showed that, there was a significant main effect for Sessions [$F_{(1, 175)} = 5.07$, $p < 0.05$, $\eta^2p = 0.028$]; Prefrontal cortex [$F_{(1, 175)} = 12.20$, $p<0.001$, $\eta^2p = 0.065$]; and States [$F_{(1, 175)} = 2.79$, $p < 0.01$, $\eta^2p = 0.016$] and a significant interaction between the Sessions × Prefrontal cortex [$F_{(1, 175)} = 6.45$, $p< 0.05$, $\eta^2p = 0.036$]; Sessions × States [$F_{(7, 1225)} = 9.06$, $p < 0.001$, $\eta^2p =0.049$]; Prefrontal cortex × States [$F_{(7, 1225)} = 2.34$, $p < 0.05$, $\eta^2p = 0.036$]; Session × Prefrontal cortex × State [$F_{(7, 1225)} = 14.51$, $p < 0.001$].

6.3.4 D. *Post-hoc* analyses on ΔHbO, ΔHbR and ΔTHC

Post-hoc analyses with Bonferroni adjustment were performed on ΔHbO, ΔHbR and ΔTHC and all comparisons were made with the respective 'Before' state. These have been summarized in **Table 19.** There was a significant increase in ΔHbR at the right Prefrontal cortex (p = 0.005) 'After' *cañcalatā* session, whereas there was a significant increase in the left Prefrontal cortex (p = 0.02) and in the right Prefrontal cortex (p <0.001) 'After' *dhyāna* session. Similarly, in ΔTHC, there was a significant decrease in blood flow change in the right Prefrontal cortex (p < 0.001) 'After' the *cañcalatā* session, whereas there was a significant increase in blood flow change in the left ($p = 0.03$) and in the right Prefrontal cortex ($p < 0.001$) 'After' *dhyāna* session.

In summary, as shown in **Table 19** and in Line diagrams (**Figure 17-19**), there was a positive trend to show a significant increase in the concentration of oxy-hemoglobin change (ΔHbO) 'During' *dhyāna* session at the right prefrontal cortex (as shown in **Figure 17**) and also, there was a significant decrease in the deoxy-hemoglobin change (ΔHbR) (as shown in **Figure 18**) 'During' *dhyāna* session whereas there was a significant increase in the concentration of the deoxy-hemoglobin change 'During' *cañcalatā* session at the right prefrontal cortex. Additionally, there was also a significant increase in the total hemoglobin change (ΔTHC) 'During' and 'After' *dhyāna* session (**Figure 19**) and a decrease in the total hemoglobin change (ΔTHC) 'During' and 'After' *cañcalatā* session.

6.4 MINDFULNESS AND ANXIETY

6.4.1 Recapitulation

Meditation has been shown to be an effective practice of mindfulness and psychological health. This study was to investigate the role of meditation on mindfulness skills and psychological health. Sixty seven long term '*OM*' meditation practitioners and an equal number of normal healthy subjects matched to the meditators were recruited**.** Anxiety and mindfulness were measured by the State-Trait Anxiety Inventory (STAI) and Freiburg Mindfulness Inventory (FMI). One way ANOVA compared mindfulness and state and trait anxiety scores and independent 't' test were used to compare mindfulness and anxiety in '*OM*' meditators and non-meditators. Partial Correlation (r) with meditation experience, anxiety, and mindfulness is given in **Table 20**. The graphical representations of STAI and FMI in meditator and non-meditation are given in **Figure 20-21**.

Table 20: Means and standard deviations, ANOVA, partial correlations (control age and years of education) for FMI and STAI scores for meditator and non-meditator groups

Characteristic		Meditators	Non Meditators	F	Percentage change (%)	Cohen's d (Effect Size)	Partial Correlation (r) With Meditation Experience
State and Trait Anxiety Inventory (STAI)	**S-STAI**	26.24±10.21	32.75±8.29	16.29***	24.81	0.700	-0.329***
	T-STAI	31.12±10.02	33.44±7.36	2.29 (NS)	7.46	0.263	-0.114 (NS)
	Total-STAI	57.36±9.87	65.69±10.57	22.01***	14.52	0.815	-.0363***
Freiburg Mindfulness Scale (FMI)	**Mindfulness**	45.42±5.22	40.34±6.42	25.05***	11.18	0.868	0.355***
	Acceptance	24.53±4.21	20.81±4.75	22.86***	15.17	0.829	0.328***
	Presence	20.89±3.49	19.54±3.94	4.42*	6.46	0.363	0.176*

** p< 0.05; *** p<0.001 significance level*

Figure 20: STAI scores in meditators and non-meditators: values are group means ± S.D.

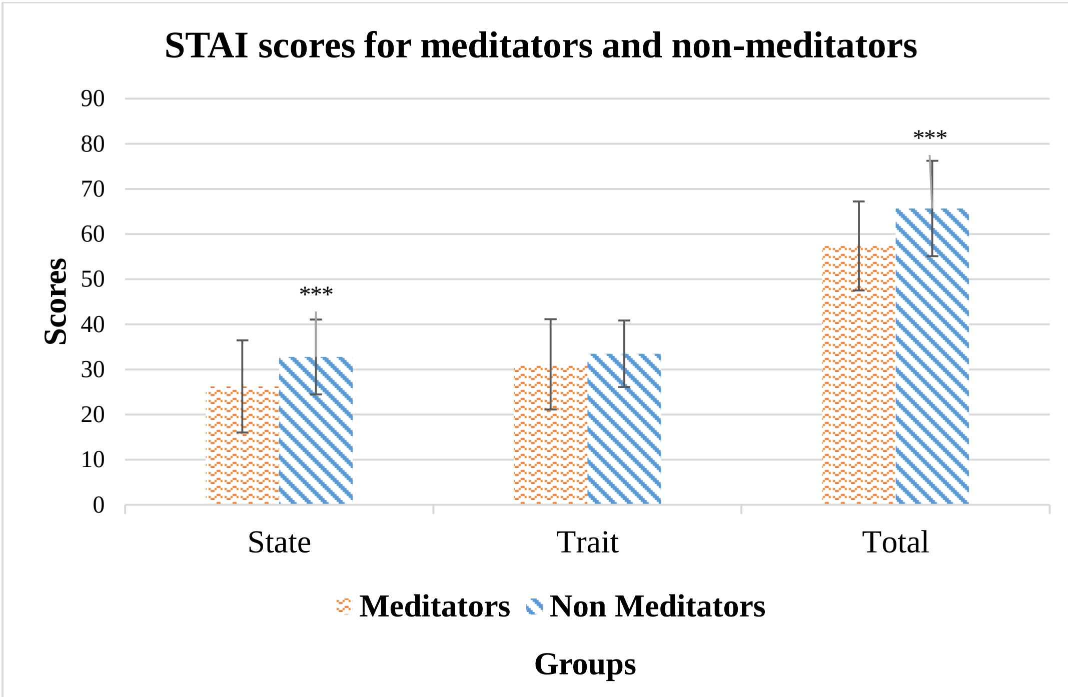
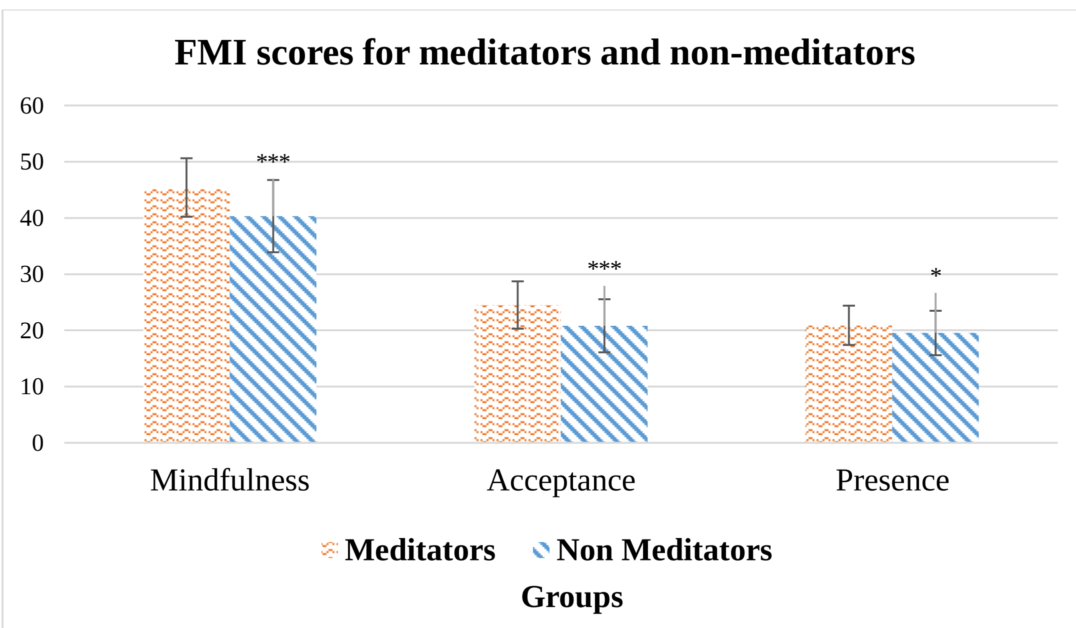


Figure 21: FMI Scores in meditators and non-meditators: values are group means ± S.D.



6.4.2 Freiburg Mindfulness Inventory (FMI) and State-Trait Anxiety Inventory (STAI)

The age and years of education were reported no significant difference in the meditation and non-meditation groups. An independent sample *t*-test and one-way ANOVA were performed to assess the difference in state and trait anxiety, and mindfulness in both the groups. The groups mean values ± SD, Cohen's d (effect size) for age, years of education, FMI mindfulness (mindfulness, acceptance, and presence), and STAI scores (state, trait, and total scores) are given in **Table 20.** STAI and FMI scores in meditators and non-meditators are given in **Figure 20-21**. The analysis of the FMI scores showed that participants in the meditation group reported higher mindfulness scores in all three factors, mindfulness ($F = 3.85$, $P > 0.001$, $t = 5.01$), acceptance ($F= 7.152$, $P < 0.001$, $t = 4.78$), and presence ($F = 1.85$, $P =0.038$, $t = 2.10$) compared to the participants in the non-meditation group. The non-meditation group shows higher anxiety as their state scores of STAI were higher than participants in the meditation group. Results showed that the '*OM*' meditation group has significantly higher mindfulness and less state anxiety compared to the non-meditator group in the age-matched control group.

6.4.3 Partial Correlation (r) with meditation experience, anxiety, and mindfulness

As shown in **Table 20**, the STAI scale and FMI strongly correlated with years of meditation experience. There was negative correlation found between meditation experience and STAI scores (state, trait, and total anxiety), while there was a strong positive correlation between years of meditation practice and FMI mindfulness scores (acceptance and presence). There was also a positive correlation between years of meditation with age and years of education.

6.5 POSITIVE STATES OF MIND AND EXECUTIVE CONTROL

6.5.1 Recapitulation

The present study investigated a specific attentional task to measure the cognitive performance and positive states of mind in meditators and non-meditators. In addition, a possible correlation of meditation experience with the positive and negative affects was also assessed. This was a cross-sectional study comparing the cognitive performance in meditators with age and gender matched non meditators. We selected 30 right-handed meditators and an equal number of non-meditators matched for age, years of education and gender. Participants were administered a Stroop task in which they had to choose the color (red, blue or green) of a single word presented visually in three conditions: congruent, neutral and incongruent as well as Positive states of Mind (PSOM) and Positive and Negative Affect Schedule (PANAS) 'before' and 'after' one month of meditation practice. The scores were analyzed using repeated-measures Analyses of Variance (ANOVA) compare the stroop performance and Positive states of mind in meditation and control groups. Repeated measures analysis of variance (ANOVA) was performed with three 'Within subjects' factors, i.e., Factor 1: Group; Meditation group and Control group, and Factor 2: Assessments; Word task (Neutral), Color Task (Congruent) and Color-Word Task (Incongruent) and Positive States of Mind (PSOM) and Factor 3: States; 'Before' and 'After'.

Table 21: Comparisons of Total Performance Time (sec) and Positive states of mind in meditation and non-meditation groups; Values are group means ± S.D.

S.No.	Variables	Meditation				Non-Meditation			
		Before	After	*P* (Before vs. After)	Cohen's *d*	Before	After	*P* (Before vs. After)	Cohen's *d*
1.	**Word Task (WT; Neutral)**	60.10±13.42	58.13±12.65	0.004	0.83	63.97±11.68	64.50±10.72	0.46	0.19
2.	**Color Task (CT; Congruent)**	89.77±14.73	86.03±12.57	0.000	1.42	101.60±10.27	102.63±8.81	0.30	0.28
3.	**Color Word Task (SCWT; Incongruent)**	150.30±17.07	148.37±14.62	0.043	0.56	163.53±12.66	164.87±11.55	0.19	0.35
4.	**Positive States of Mind (POSM)**	14.33±2.02	19.23±1.41	0.000	2.84	14.03±1.67	14.53±1.74	0.001	0.40

Figure 22: Total Performance Time (sec.) in meditation and non-meditation; values are groups mean ± S.D.

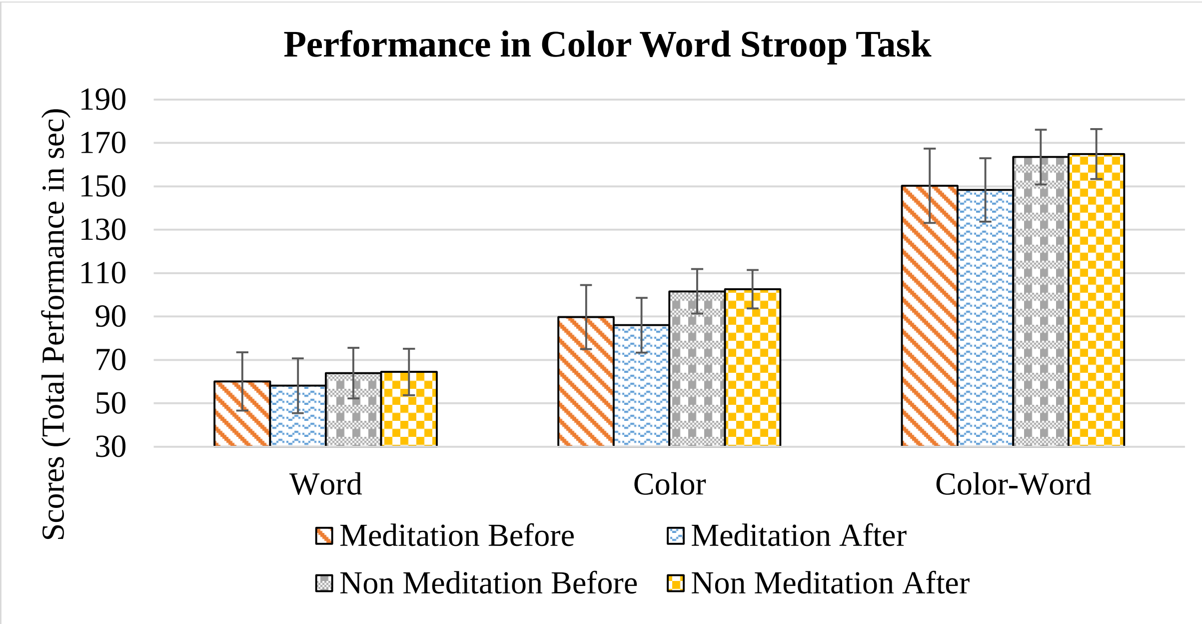


Figure 23: Scores of positive states of mind in meditation and non-meditation; values are groups mean ± S.D.

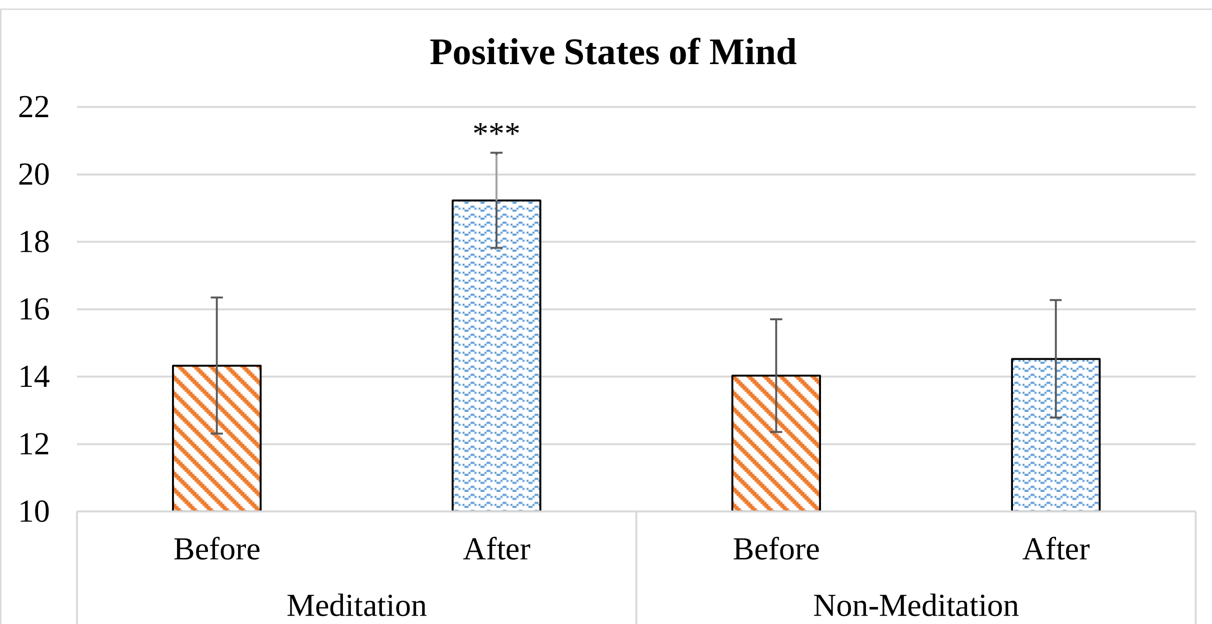


Table 22: Independent t-test between Meditation and Control groups. Values are group means ± S.D.

S.No.	Variables	Meditation Group	Control Group	F – value (df=1, 58)	t-value	P-value	Cohen's *d*
1.	Interested	3.27±1.5	2.39±1.36	0.78	0.88	0.38	0.61
2.	Alert	3.23±1.19	2.90±0.80	1.61	1.27	0.21	0.33
3.	Attentive	3.47±1.33	3.13±1.14	1.09	1.04	0.30	0.27
4.	Excited	3.20±0.92	2.77±1.04	2.91	1.17	0.09	0.44
5.	Enthusiastic	3.90±1.03	3.33±1.24	3.71	1.93	0.06	0.50
6.	Inspired	3.67±0.96	3.40±0.50	1.83	1.35	0.18	0.35
7.	Proud	3.60±1.07	3.20±1.27	1.74	1.32	0.19	0.34
8.	Determined	4.30±0.47	3.77±0.47	15.80	3.97	0.001	1.12
9.	Strong	4.00±0.59	3.40±0.50	18.21	4.27	0.001	1.09
10.	Active	3.93±0.64	3.80±0.61	0.68	0.83	0.41	0.21
11.	**Total Positive Score**	36.57±3.85	32.62±4.55	13.06	3.61	0.001	0.94
12.	Distressed	1.30±0.47	1.90±0.86	11.60	-3.40	0.001	-0.86
13.	Upset	1.60±0.56	1.80±0.71	1.45	-1.20	0.23	-0.31
14.	Guilty	1.30±0.47	1.87±0.63	15.72	-3.97	0.001	-1.02
15.	Ashamed	1.13±0.35	1.53±0.63	9.32	-3.05	0.003	-0.78
16.	Hostile	1.37±0.61	1.60±0.68	1.96	-1.40	0.16	-0.36
17.	Irritable	1.43±0.68	1.93±0.78	6.96	-2.64	0.01	-0.68
18.	Nervous	1.93±1.20	2.03±0.67	0.16	-0.40	0.69	-0.10
19.	Jittery	1.73±0.74	2.10±0.76	3.59	-1.89	0.06	-0.49
20.	Scared	1.97±0.96	2.03±0.89	0.08	0.28	0.78	-0.06
21.	Afraid	1.40±0.56	2.27±0.98	17.63	-4.20	0.001	-1.09
22.	**Total Negative Score**	15.17±4.19	19.07±4.56	11.92	-3.45	0.001	-0.89

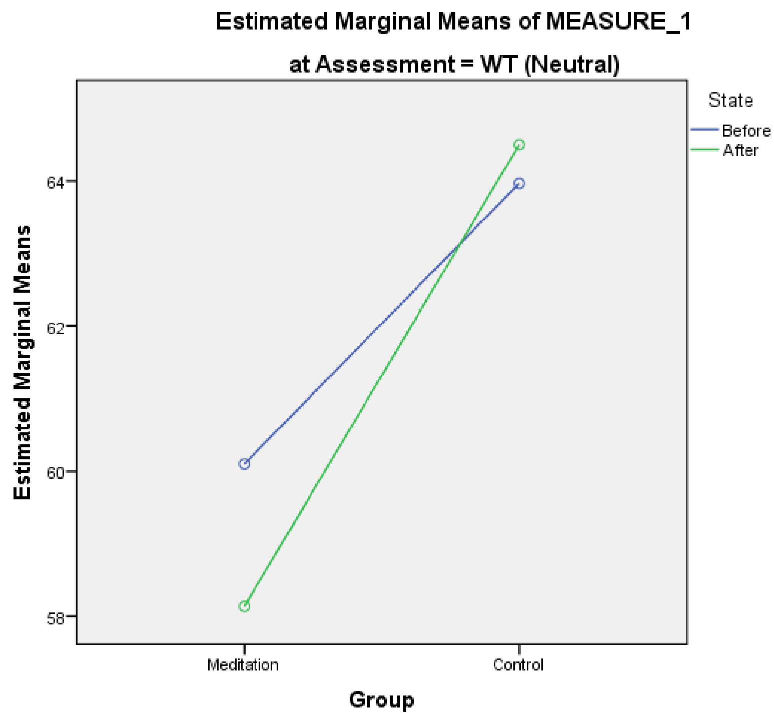


Figure 24: Graphical representation of the Groups × States interaction for the Word Task. Groups are represented on the Y axis and States on the X axis

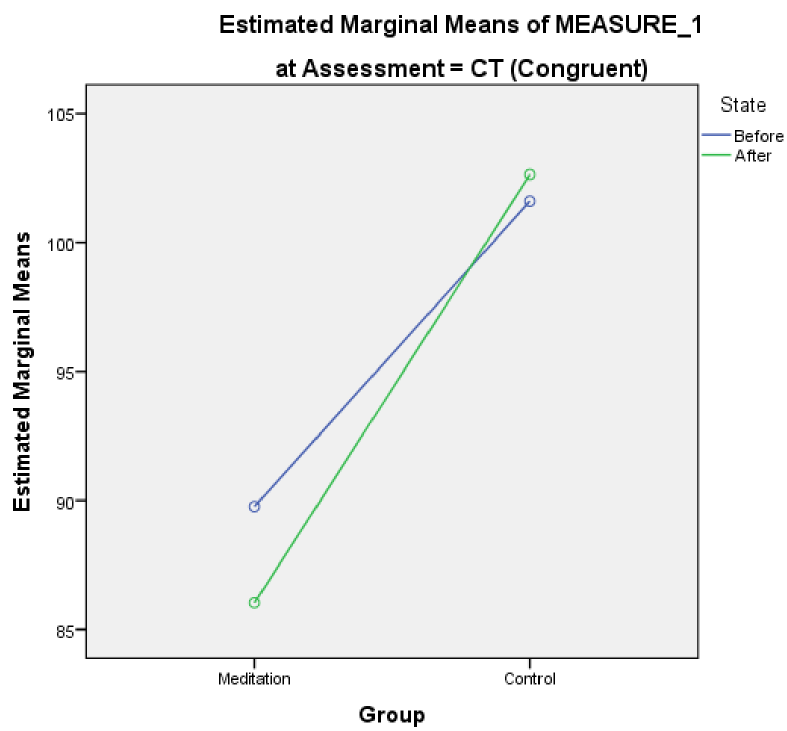


Figure 25: Graphical representation of the Groups × States interaction for the Color Task. Groups are represented on the Y axis and States on the X axis

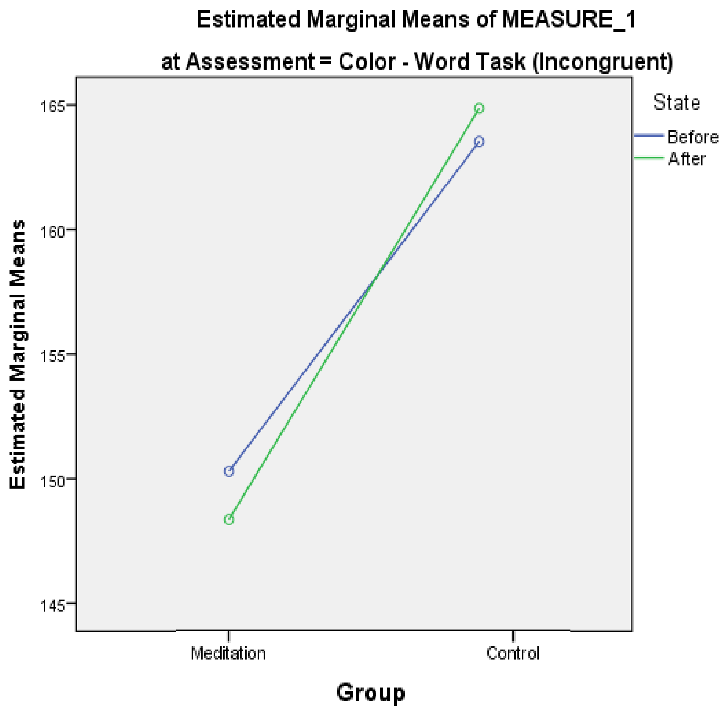


Figure 26. Graphical representation of the Groups × States interaction for the Color-Word Task. Groups are represented on the Y axis and States on the X axis

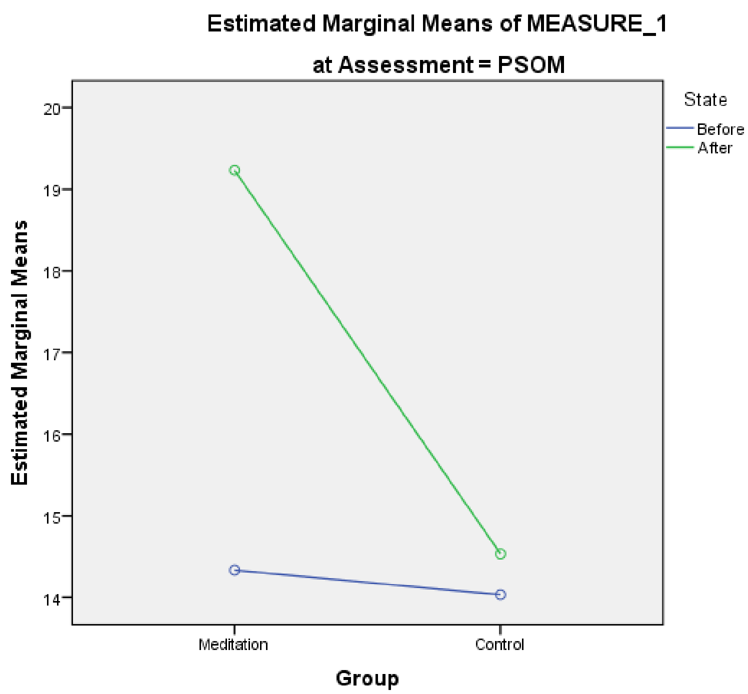


Figure 27. Graphical representation of the Groups × States interaction for the Positive States of Mind (POSM). Groups are represented on the Y axis and States on the X axis

6.5.2 Positive states of mind (PSOM), executive task (Stroop Task) and positive and negative affect (PANAS)

The group mean values ± S.D. for the word task (WT), Color task (CT) and color word task (CWT) and Positive states of mind (PSOM) in participants of meditation and control group 'Before' and 'After' states are given in **Table 21.**

Repeated measures ANOVA consisted of three 'Within-subjects' factors i.e., (i) Groups, (meditation and control); (ii) Assessments [Word task (WT), Color Task (CT) and Color-word task (CWT) tasks] and Positive States of Mind (PSOM), and (iii) States (Before and After). There was a significant difference between Groups [F (1, 29) = 19.201, Huynh Feldt Epsilon ε = 1.0, $p < 0.001$]; Assessments [F (3, 87) = 2369.7, Huynh Feldt Epsilon ε = 0.78, $p < 0.001$]. There were significant interactions between Groups × Assessments [F (3, 87) = 11.14, Huynh Feldt Epsilon ε = 0.78, $p < 0.01$]; Groups × States [F (1, 29) = 7.72, Huynh Feldt Epsilon ε = 1, $p < 0.01$]; and Groups × Assessments × States [F (3, 87) = 17.27, Huynh Feldt Epsilon ε = 0.93, $p < 0.001$]. The interaction graphs of Groups × States of WT, CT, CWT and POSM are given in **Figure 24, Figure 25, Figure 26,** and **Figure 27**, respectively. Paired sample t-test was performed to assess the difference of age and years of education in meditation and control groups. There were no significant differences in the age and years of education between the meditation and control groups.

Post-hoc analyses with Bonferroni adjustment with the effect size (Cohen's *d*) for Stroop (Word, Color, Color-Word task), PSOM are given in **Table 21**. Analysis showed that participants in the meditation group reported superior performance on the SWT, as indicated by significantly higher scores on word task (p<0.001), color task (p<0.001) and color word task (p<0.05) compared to the control group. These results demonstrated that naming the ink color of the color-incongruent color names require control of attention so that the automatic response arising from spontaneously reading the word is inhibited and the color of the ink is named instead. Focused meditation on the symbol '*OM'* may increase the ability of the individual to control visual distraction, which in this case could translate to increased ability for prepotent inhibition.

PSOM scale showed significant improvement in both the groups, however, the magnitude of change was higher in the meditation group compared to the control group. The independent sample t-test between the meditation and control groups showed that there was a significant higher PA ($p<0.001$) and lower NA ($p<0.001$) in the meditation group compared to control group showed in **Table 22.** The effect size was calculated using Cohen's guidelines (Cohen, 2013) given in **Table 21** and **Table 22**.

6.6 VISUAL ANALOG SCALE, ACCURACY AND P300 ERPs

6.6.1 Recapitulation

Visual Analog Scale (VAS), a subjective assessment to follow guided instructions, was studied in sixty participants following *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* after LLAEPs, and P300 ERPs. In the present thesis, we attempted to correlate the accuracy of counted clicks in P300 oddball paradigm, peak latency, and peak amplitude of P300 event related potentials.

Repeated measures analysis of variance (ANOVA) was performed with one 'within subjects' factor, i.e., sessions: *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*. This was followed by a *post-hoc* analysis with a Bonferroni adjustment for multiple comparisons between the mean values of different sessions. Bivariate correlation (r) with Pearson's correlation was used to compare the visual analogue scale (VAS), Accuracy in counted clicks in the P300 oddball task, P300 latency, and the amplitude is given in **Tables 23 & 24.**

Table 23: Scores on visual analog scale in four mental states

Sessions	*Cañcalatā*	*Ekāgratā*	*Dhāraṇā*	*Dhyāna*
Mean ± S.D	6.94±1.37	7.20±1.54	7.74±1.30***	8.00±1.23***

***Comparing *dharana* and *dhyana* sessions with *cancalata* and *ekagrata* sessions shows significant differences in both sessions ($p < 0.001$ for each).

Table 24: Correlation between visual analogue Scale and attention (P300 Latency and Amplitude)

Sessions	Correlation	Can_L	Eka_L	Dhr_L	Dhy_L	Can_A	Eka_A	Dhr_A	Dhy_A
Cañcalatā	Correlation Coefficient	0.070	-	-	-	-0.27*	-	-	-
	Sig. (2-tailed)	0.596	-	-	-	**0.04**	-	-	-
Ekāgratā	Correlation Coefficient	-	0.038	-	-	-	-.04	-	-
	Sig. (2-tailed)	-	0.772	-	-	-	0.76	-	-
Dhāraṇā	Correlation Coefficient	-		-0.010	-	-	-	0.29	
	Sig. (2-tailed)	-	-	0.939	-	-	-	**0.047**	
Dhyāna	Correlation Coefficient	-	-	-	0.286*	-	-	-	0.31*
	Sig. (2-tailed)	-	-	-	**.026**	-	-	-	**0.016**

Can_L = *Cañcalatā* Latency; Eka_L = *Ekāgratā* Latency; Dhr_L = *Dhāraṇā* Latency; Dhy_L = *Dhyāna* Latency;
Can_A = *Cañcalatā* Amplitude; Eka_A = *Ekāgratā* Amplitude; Dhr_A = *Dhāraṇā* Amplitude; Dhy_A = *Dhyāna* Amplitude

Table 25: Correlation between visual analog scale and accuracy (counted clicks)

Sessions	**Correlation**	**Can_ Accuracy**	**Eka_ Accuracy**	**Dhr_ Accuracy**	**Dhy_ Accuracy**
Cañcalatā	Pearson Correlation	0.091	-	-	-
	Sig. (2-tailed)	0.490	-	-	-
Ekāgratā	Pearson Correlation	-	**-0.28***	-	-
	Sig. (2-tailed)	-	**0.03**	-	-
Dhāraṇā	Pearson Correlation	-	-	-0.039	-
	Sig. (2-tailed)	-	-	0.769	-
Dhyāna	Pearson Correlation	-	-	-	**0.27***
	Sig. (2-tailed)	-	-	-	**.036**

Table 26. Correlation between accuracy and attention (P300 latency and amplitude)

Sessions	Correlation	Can_L	Eka_L	Dhr_L	Dhy_L	Can_A	Eka_A	Dhr_A	Dhy_A
Can_Pre_Ac	Pearson Correlation	0.02	-	-	-	.073	-	-	-
	Sig. (2-tailed)	.90		-	-	.582	-	-	-
Eka_Pre_Ac	Pearson Correlation	-	.20	-	-	-	.002	-	-
	Sig. (2-tailed)	-	.12	-	-	-	.989	-	-
Dhr_Pre_Ac	Pearson Correlation	-	-	.170	-	-	-	.102	-
	Sig. (2-tailed)	-	-	.195	-	-		.440	
Dhy_Pre_Ac	Pearson Correlation	-	-	-	-.025	-	-	-	.275*
	Sig. (2-tailed)	-	-	-	.849	-	-	-	**.034**

Can_L = *Cañcalatā* Latency; Eka_L = *Ekāgratā* Latency; Dhr_L = *Dhāraṇā* Latency; Dhy_L = *Dhyāna* Latency;
Can_A = *Cañcalatā* Amplitude; Eka_A = *Ekāgratā* Amplitude; Dhr_A = *Dhāraṇā* Amplitude; Dhy_A = *Dhyāna* Amplitude

6.6.2 Scores in visual analogue scale (VAS)

The group mean values ± SD of visual analogue scale (VAS) for *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* are given in **Table 23**. Repeated measure analysis of variance (ANOVA) performed with one 'Within subjects' factor, i.e., sessions: *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* showed significant differences between sessions [F = 15.34, df = (2.85, 167.91), Huynh-Feldt epsilon = 0.820, p < 0.001].

Post-hoc analyses with a Bonferroni adjustment were performed to see the changes between the sessions. VAS scores of *cañcalatā* and *ekāgratā* were significantly lower compared to those of *dhāraṇā* (p < 0.001), and *dhyana* (p < 0.001).

The raw data of individual participants in *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyana* sessions are presented with group mean ± SD in **Table 117.**

6.6.3 Bivariate correlation analysis

The correlations between the Visual Analogue Scale (VAS), attention (P300 latency and amplitude) and accuracy of counted clicks in P300 oddball task in four mental states i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* are shown in **Table 24, 25** & **26**. Results showed that there was a significant negative correlation found between VAS scores and amplitude of *cañcalatā* session (r = -0.27; p = 0.04) while there was a significant positive correlation in the P300 latency of *dhyāna* session and amplitude of *dhāraṇā* (r = 0.29; p<0.05) and *dhyāna* (r = 0.31; p = 0.016) sessions. The correlation of VAS and attention (P300 latency and amplitude) is given in **Table 24.**

Similarly, the accuracy of counted clicks during auditory P300 oddball task was positively correlated with the VAS score of *dhyāna* (r = 0.27; p = 0.04) session, whereas there was a negative correlation found in the *ekāgratā* session (r = -0.28; p = 0.03) and is shown in **Table 25**. The accuracy of counted clicks and attention (P300 latency and amplitude) showed a significant correlation with P300 amplitude of *dhyāna* session (r = 0.28; p= 0.034) as shown in **Table 26**

CHAPTER-7

DISCUSSIONS

7.0 DISCUSSIONS

The most pertinent results detailed in the previous section are discussed under seven main categories of variables,

(i) Long latency auditory evoked potentials (LLAEPs) measured ‘Before’, ‘During’, and ‘After’ of *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*

(ii) Simultaneous recordings of P300 ERPs measured ‘Before’ and ‘After’ the sessions and heart rate variability (HRV) with respiration recorded ‘Before’, ‘During’, and ‘After’ the four sessions

(iii) Relative hemodynamic changes were shown on prefrontal cortex in *cañcalatā* and *dhyāna* sessions using a functional near infrared spectroscopy (fNIRS) and also during a cognitive task

(iv) Mindfulness and anxiety in meditators and non-meditators

(v) Positive states of mind (PSOM), executive task (stroop task) and positive and negative affect (PANAS) in meditators and non-meditators

(vi) Subjective assessment of following the guided instructions for *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* using visual analog scale (VAS), and also

(vii) Correlation in visual analog scale, accuracy of counted clicks in P300 Oddball task and P300 peak latency and peak amplitude in *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* sessions

7.1 LONG LATENCY AUDITORY EVOKED POTENTIALS (LLAEPs)

Long latency auditory evoked potentials (LLAEPs) are generated by thalamo-cortical and cortico-cortical auditory pathways, the primary auditory cortex and the association cortical areas (Ventura, Alvarenga, & Costa Filho, 2009). The present study assessed LLAEPs during four mental states i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* sessions. During meditation the peak latency of the P2 component significantly reduced. A decrease in peak latency is suggestive of a facilitation of auditory sensory transmission due to increased speed of conduction in the underlying neural generators (Malhotra, 1997).

At present the functional significance of the P2 component is not as clear as that of components generated more peripherally. The P2 wave partly reflects auditory output of the mesencephalic activation system (Picton et al., 1999; Woods, Knight, & Scabini, 1993). MEG studies have attempted to locate the neural generators of the P2 component. Both MEG data and EEG data from depth electrodes implanted in the auditory cortex were collected in the same patients (Hari et al., 1987; Pantev, Hoke, Lütkenhöner, & Lehnertz, 1991; Rif, Hari, Hämäläinen, & Sams, 1991; Sams, Paavilainen, Alho, & Näätänen, 1985). It was found that generators for the P2 component were localized in the *planum temporale* as well as Brodmann area 22 (the auditory association complex). Other reports have speculated that the P2 component may receive contributions from cortical areas in the depth of the Sylvian fissure (Crowley & Colrain, 2004). Hence, it remains possible that the P2 component arises from multiple sources with a center of activity close to Heschl’s gyrus (Crowley & Colrain, 2004). The present results suggest that the practice of meditation improves information transmission in areas concerned with complex processing of auditory stimuli as the auditory association cortices are possibly involved.

During the two mental states which were considered for comparison, that is, random thinking and non-meditative focusing, the peak amplitudes of the P1, P2, and N2 components reduced. A decrease in amplitude suggests that the number of neuronal involvement recruited is less than in the pre-state. The neural generators of the P2 component have been mentioned above. The neuronal sources of the P1 component are difficult to localize due to low signal-to-noise ratio. Also the brain response which generates the P1 component is preceded and followed in time within 10-15 ms by several EP components which arise from sources other than those generating P1 (Korzyukov et al., 2007). Studies on animal models suggested that neuronal activity in the hippocampus might contribute to sensory gating (Freedman et al., 1996), however, this was not proved in human recordings (Grunwald et al., 2003). MEG studies have shown that there may be a temporal lobe generator for P1 especially, located bilaterally in the superior temporal gyrus (Huang et al., 2003). In addition, the frontal lobe is involved in auditory sensory gating and this activity may contribute to the P1 component. However, the maximum contribution to the P1 activity is from the temporal lobe (Weisser et al., 2001). The N2 component of auditory evoked potentials helps to evaluate the cognitive processes involved in stimulus classification (O’Donnell et al., 1993). The amplitude of the N2 component is directly related to changes in the left superior temporal gyrus and bilateral medial temporal lobe areas (Shenton et al., 1992). However, this description does not exclude the involvement of other cortical areas in the genesis of the N2 component. In random thinking and non-meditative focusing sessions a decrease in amplitude of the P1 and N2 components suggests that the overall neuronal activation and number of neurons recruited in the neural generators underlying these components was less. Other studies reported that the P2 and

N2 components decrease in amplitude with a reduction in attention (Hansen & Hillyard, 1980). Since random thinking did not involve focusing of attention, the reduction in amplitude in P2 and N2 components is not surprising. In contrast, the reduction in amplitude in non-meditative focusing is surprising as (i) participants were asked to focus during the session and (ii) the nature of focusing was obviously different from the meditative focusing as meditative focusing did not reduce P2–N2 amplitudes. The P2 amplitude is also sensitive to shifts in consciousness during the stages of sleep (Colrain, Di Parsia, & Gora, 2000). Based on (i) the self-report of the meditators, (ii) observation of the raw EEG recorded, and (iii) observation of the participants on the closed circuit TV. Hence, the reduced amplitude of the three components during random thinking and non-meditative focusing may reflect a decrease in the number of neurons recruited.

The results of this present study are different from the earlier study conducted on practitioners of Transcendental Meditation. This could be due to differences in the method of meditation and sample size. The sample size was 8 with Cohen’s $d = 0.18$ whereas in the present study the sample size was 48 with Cohen’s $d = 0.68$.

Hence, evaluating the effect of meditation based on descriptions in the traditional texts has yielded a significant result for long latency auditory evoked potentials. The most important finding of this study was the reduced latency of the P2 component during meditation.

While the findings are reasonably straightforward, the study has the following limitations:

(i) The evaluation of the quality of practice was based on a self-reported visual analog scale (VAS) and hence was subjective.

(ii) Random thinking and non-meditative focusing were the control conditions. There was no control without any intervention.

(iii) While the participants had been trained to switch between the four states, the possibility that they did get into the meditative state inadvertently cannot be ruled out.

Despite these limitations, the present study results suggest that,

(i) meditation facilitates the processing of auditory information in the auditory association cortex, and

(ii) random thinking and non-meditative focusing resulted in fewer neurons being recruited in auditory association areas.

The summary of evoked potentials findings in four mental states are given in **Figure 28.**

Figure 28: Summary of Evoked Potentials findings in four mental states i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*

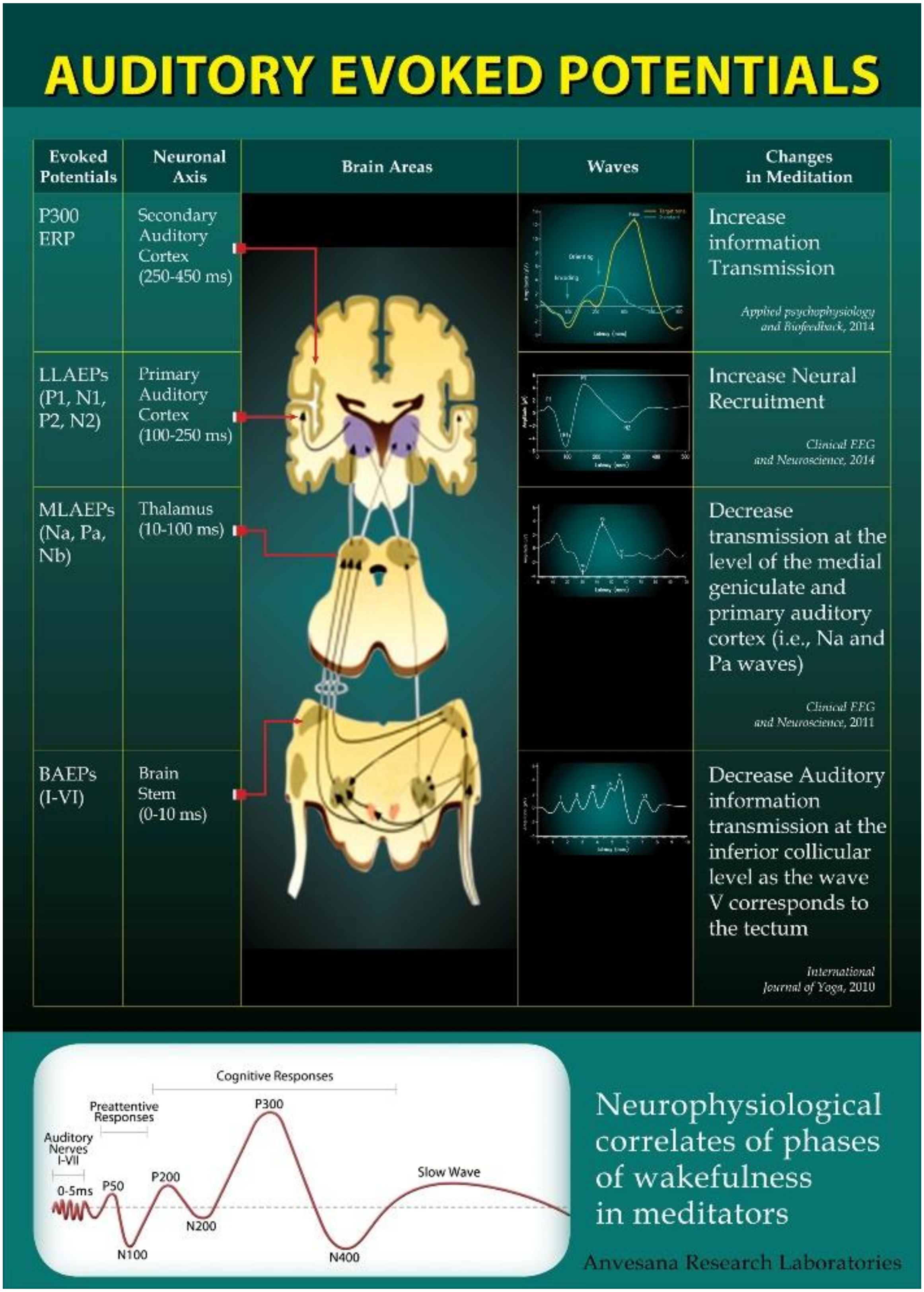


Table 27: Summary of trend of changes in peak latencies of long latency auditory evoked potentials during *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* sessions; Values are percent change

Component	Sessions	During				After
		During 1	During 2	During 3	During 4	
P1	*Cañcalatā*	NS	NS	NS	NS	NS
	Ekāgratā	NS	NS	NS	NS	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	NS	NS	NS	NS	NS
N1	*Cañcalatā*	NS	NS	NS	NS	NS
	Ekāgratā	NS	NS	NS	NS	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	NS	NS	NS	NS	NS
P2	*Cañcalatā*	NS	NS	NS	NS	NS
	Ekāgratā	NS	NS	NS	NS	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	-4.12 % ↓	NS	NS	NS	-4.05 %↓
N2	*Cañcalatā*	NS	NS	NS	NS	NS
	Ekāgratā	NS	NS	NS	NS	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	NS	NS	NS	NS	NS

Note: n = 60; ↑: Increase; ↓: Decrease, which was statistically significant; NS: No significant changes

Table 28: Summary of trend of changes in peak amplitude of long latency auditory evoked potentials during *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyana*; Values are percent change

Component	Sessions	During				After
		During 1	During 2	During 3	During 4	
P1	*Cañcalatā*	NS	-45.38 % ↓	NS	-37.81 % ↓	NS
	Ekāgratā	NS	-24.76 % ↓	-34.29 % ↓	-34.29 % ↓	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	NS	NS	NS	NS	NS
N1	*Cañcalatā*	NS	NS	NS	NS	NS
	Ekāgratā	NS	NS	NS	NS	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	NS	NS	NS	NS	NS
P2	*Cañcalatā*	-40 % ↓	-46.32% ↓	-37.89 % ↓	-35.79 % ↓	NS
	Ekāgratā	NS	-29.27 % ↓	-31.70 % ↓	-31.70 % ↓	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	NS	NS	NS	NS	NS
N2	*Cañcalatā*	NS	NS	NS	-23.08 % ↓	NS
	Ekāgratā	NS	NS	NS	-36.58 % ↓	NS
	Dhāraṇā	NS	NS	NS	NS	NS
	Dhyāna	NS	NS	NS	NS	NS

Note: n = 60; ↑: Increase; ↓: Decrease, which was statistically significant; NS: No significant changes

7.2 P300 EVENT RELATED POTENTIALS AND HEART RATE VARIABILITY WITH RESPIRATION

Autonomic activity during an attention task was measured in four mental states, i.e. *cañcalatā* (random thinking), *ekāgratā* (non-meditative focused thinking), *dhāraṇā* (meditative focusing) and *dhyāna* (meditation). Attention was evaluated using P300 with auditory oddball paradigm while autonomic activity was gained by frequency domain and time domain analysis of the HRV recorded, simultaneously.

Meditation was associated with an increased in the P300 ERPs peak amplitude and decrease in peak latency and a simultaneous increase in HF power with a decrease in the LF/HF ratio. In contrast, in meditative focusing, there was an increase in the P300 amplitude but simultaneously recorded HRV showed decreased HF power.

The P300 peak amplitude is considered to indicate the amount of brain activity related to incoming information processing and is sensitive to the attentive resources engaged in the task (Polich, 2004). The P300 latency reflects the speed of stimulus classification, and is generally not related to the overt response and is independent of behavioral reaction time. Since, the P300 peak latency is an index of information processing rather than response generations, it is used as a measure of motor involvement, to assess cognitive functions. The P300 peak latency is negatively correlated with mental functions in normal subjects; shorter latency being associated with superior cognitive performance in neuropsychological tests of attention and immediate memory. Hence, the present results suggest that meditation with focusing as well as meditation increased attentional resources, stimulus processing speed and efficiency. These results resemble other studies on the P300 ERPs recorded during meditation. An early report demonstrated a reduced P300 peak latency after Transcendental Meditation (TM) practice, whereas no change occurred after the rest condition (Travis & Miskov, 1994).

More recently, the P300 amplitude was found to increase with a decrease in latency at Cz and Pz after a moving meditation (called cyclic meditation) compared to an equal duration of supine rest (Sarang & Telles, 2006). In the study cited, as well as various other assessments of the P300 during meditation (Cahn & Polich, 2009), there was no attempt to simultaneously assess the autonomic status while performing P300 task.

Previous studies have shown that when the mental task load increased, the mean inter beat interval (IBI) of the heart rate traces decreased while the low frequency component of the HRV increased, presumably due to a shift in the autonomic balance towards sympathetic dominance (Lucini et al., 1997; Pagani et al., 1989; Pagani, Mazzuero, et al., 1991; Pagani, Rimoldi, et al., 1991). In general, increased vigilance and attention have associated with higher sympathetic tone (Telles, Naveen, & Balkrishna, 2010). A single study simultaneously monitored the P300 ERPs and heart rate variability (HRV) during a mindfulness "*Vipassana*" meditation (Delgado-Pastor, Perakakis, Subramanya, Telles, & Vila, 2013). The *Vipassana* meditators showed greater P3b amplitude to the target stimuli after meditation compared to before and to the non-meditation session. The simultaneous recordings of the HRV showed a larger LF/HF ratio during *Vipassana* meditation. The author suggested that, expert *Vipassana* meditators showed increased attentional engagement after meditation to increase in the low frequency (LF) of the HRV which did not appear to be associated with the respiratory rhythm. The difference between these results of the Delgado-Pastor et al., and the results of this study are possibly related to the type of meditation. While *Vipassana* meditation is associated with heightened attention and awareness (Delgado-Pastor et al., 2013), the present meditation does not involve increased awareness or focusing, instead a mental state which is devoid of any attempt to focus attention is recommended. This is because the concepts of meditation described in ancient yoga texts are rather different, as meditation is not supposed to be associated with heightened attention or even of being aware of the experience as it happens (Telles & Raghavendra, 2011). In fact, ancient yoga texts categorized meditation as two states, namely meditative focusing (*dhāraṇā*) and meditation (*dhyāna*). Meditative focusing is associated with confining the mind within a limited mental area (Patanjali's Yoga *Sutra*, Chapter III, Verse 1). This description of meditative focusing fits in with contemporary categorizing of meditation as two main categories (Telles, Naveen, Balkrishna, & Kumar, 2010). The categorization is based on how attention is directed (Lutz, Slagter, Dunne, & Davidson, 2008b). One category is focused attention (FA) during which attention is sustained and focused on a specified object. The second category, called open monitor (OM) meditation require the meditator not to react while monitoring the content of ongoing experience. The second stage of meditation (*dhyāna*) description in ancient yoga texts does not exactly fit either category. Meditation more closely approximates the mental activity involved in open monitor meditation. This is because meditation (*dhyāna*) is described as an uninterrupted flow of the mind towards the object chosen for meditation (Patanjali's Yoga *Sutra*, Chapter III, Verse 2).

Apart from the changes during meditation and meditative focusing there were also changes during random thinking (*cañcalatā*) which has been described as one of the possible mental state in an ancient yoga text (*Bhagavad Gita*, Circa 400-600 B.C., Chapter VI, Verse 34). During this condition, there was a decrease in P300 peak amplitude as well as an increase in the LF power and decrease in HF power of heart rate variability (HRV). The HF component of the HRV is mainly contributed by parasympathetic contributions (Wu, Gao, & Han, 1995). The LF component corresponds to both sympathetic and parasympathetic modulation. The LF/HF ratio is an indication of sympathovagal balance (Pal et al., 2012). Based on this, the present results suggest that meditation (*dhyāna*) reduces sympathetic activity, whereas meditative focusing (*dhāraṇā* and random thinking (*cañcalatā*) increased sympathetic activity. The decreased P300 amplitude during random thinking (*cañcalatā*) would suggest that the mental state associated with random ideation does not facilitate performance in the P300 task. The P300 arises from neural activity as a result of interaction between the frontal lobe, the hippocampus and the temporo-parietal lobe. The primary neural generators for P300 ERPs are within the anterior cingulate as new stimuli are processed into working memory. Subsequent to this activation of the hippocampal formation occurs when inter connection between the frontal lobe and the temporal or parietal lobe (Polich & Kok, 1995). Hence, meditation and meditative focusing appear to activate neural connections in these areas associated with focused attention. However an important difference between the two conditions is that meditation is associated with reduced sympathetic activity, whereas in meditative focusing sympathetic activity increased. The latter results are similar to those described in mindfulness (*Vipassana*) meditation (Delgado-Pastor et al., 2013). The suggestion of reduced sympathetic activity based on the frequency domain analysis of the HRV is supported by components of the time domain HRV analysis. The mean RR interval and pNN50 is increased in meditation and these variables are recognized to be strongly dependent on vagal modulation (Doğru, Başar, Yuvanç, Simşek, & Sahin, 2010; Massin, Derkenne, &

von Bernuth, 1999). Concurrent monitoring of respiration and the HRV are considered important, as an acute increase in LF power and total spectrum of HRV and in vagal baroreflex gain occurred with slow breathing during biofeedback (Lehrer et al., 2003). Biofeedback training which may be used to increase the amplitude of respiratory sinus arrhythmia maximally increased the amplitude of heart rate oscillations at approximately 0.1 Hz (Lehrer, Vaschillo, & Vaschillo, 2000). In the present study, the absence of any change in breath rate suggests that changes in respiratory frequency would not have contributed to spectral changes in the HRV.

Hence, the present study has helped to obtain answers for the research questions which were asked that is, out of the four mental states studied, only in meditation (*dhyāna*) there was a simultaneous improved attention along with reduced sympathetic activation characteristics of the classical definition of meditation as a state of alertful rest (Wallace, Benson, & Wilson, 1971).

While the findings are reasonably straightforward, the study may have the following limitations:

(i) The mental state in which participants were based on their self-report, there was no way to verify this objectively

(ii) Carrying out the attention task ‘Before’ and ‘After’ meditation could possibly reduce the quality of meditation, and

(iii) All participants were assessed in four sessions, there may have been an element of adaptation and boredom

Despite these limitations, the present results suggest that meditation practiced as described in the ancient text has desired benefits in improving attention without causing physiological arousal.

Physiological and neurophysiological correlates of meditation

Meditation is a resting but alert state of mind with sustained inward mental attention. Several physiological responses have been studied in relation to the practice of meditation, including that of the brain, cardiovascular, immune and endocrine functions (Davidson, 2003; Ditto, Eclache, & Goldman, 2006; Sudsuang, Chentanez, & Veluvan, 1991). Previous studies on understanding physiological effects of meditation related effect on autonomic arousal from parasympathetic and sympathetic dominance (Sukhsohale & Phatak, 2012; Telles et al., 2013) measured with heart rate, heart rate variability, respiratory rate, oxygen consumption, electrodermal responses etc. (Nesvold et al., 2012; Park & Park, 2012; Sarang & Telles, 2006; Telles, Reddy, & Nagendra, 2000). Some studies showed a decrease in heart rate (HR) and respiration rate (RR) (Ahani et al., 2014; Travis, 2001; Wenger & Bagchi, 1961), whereas others have shown increase or no changes in these measures (Anand, Chhina, & Singh, 1961; Corby, Roth, Zarcone, & Kopell, 1978). Similarly, there are paradoxical data on skin conductance level (SCL); some of which report an increase in skin conductance which imply vagal shift (Guhn et al., 2012; Mohan, Sharma, & Bijlani, 2011; Mohan, Sharma, & Bijlani, 2011; Telles et al., 2012; Wallace, 1970; Wenk-Sormaz, 2005). The summary of these physiological markers are given in **Table 34**. There are several contradictory reports on the effects of meditation techniques due to the differences in the methods used. Also, because experts in yoga meditation are rarely available to researchers the subjects of such inquiries usually have practiced only a few years.

Research studies indicate that there are varying neurophysiological correlates associated with meditation. Some studies show increased alpha or theta electroencephalograph (EEG) activity (Becker & Shapiro, 1981; Hebert & Lehmann, 1977; Park & Park, 2012; Takahashi et al., 2005; Thomas, Jamieson, & Cohen, 2014), whereas other show presence of more beta or even some delta EEG pattern (Braboszcz & Delorme, 2011; Hinterberger, Schmidt, Kamei, & Walach, 2014).

Neuroimaging studies have reported meditation to enhance activity in prefrontal cortex (Chan & Woollacott, 2007a; Farb et al., 2007; Guleria, Kumar, Kishan, & Khetrapal, 2013; Mascaro, Rilling, Tenzin Negi, & Raison, 2013; Newberg et al., 2001), anterior cingulate cortex (attention regulation) (Short et al., 2010; Chan & Woollacott, 2007b; Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010; Manna et al., 2010; Tang et al., 2009; Wang et al., 2011a), Insula (body awareness) (Luders et al., 2012; Mascaro, Rilling, Negi, & Raison, 2013; Thomas et al., 2014), thalamus, corpus callosum, limbic system (includes the basal ganglia, hippocampus, amygdala, hypothalamus, and pituitary gland; central to emotion and regulation) (Newberg & Iversen, 2003; Pickut et al., 2013; Pribram & McGuinness, 1992). Long term practitioners showed thicker cortex in brain regions associated with attention, interoception and sensory processing, including the prefrontal cortex and right anterior insula (Grant et al., 2010; Kang et al., 2013; Lazar et al., 2005). Another longitudinal study on stress reduction following eight week mindfulness based stress reduction program correlates with decrease in amygdala gray matter density (Pickut et al., 2013). Experienced compassion meditators showed high amplitude gamma synchrony (EEG) and enhanced activation of insula, cingulate cortices, amygdala etc. (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004).

These observations support that experience may play a role in the physiological and neurophysiological correlates of yoga meditation. Hence, more research with individuals who are highly experience in meditation is required.

Table 29: Summary of Physiological and Neurophysiological responses of meditation

Physiological responses (↑↓)	**Neurophysiological Responses (↑↓)**
↓ Heart rate slows [1–8]	**Electroencephalogram** [9,10]
↑ Heart rate variability improves [3,4,6,7,12,22–25]	↑ Beta wave enhances [11]
↓ Blood Pressure lowers [26–28]	↑ Alpha-brain wave enhanced [2,9,12–16]
↓ Respiratory rate reduces [3,4,10,13,29]	↓ Delta wave activities reduced[9,17,18]
↑ Respiratory sinus arrhythmia amplitudes higher [13]	↓ Theta wave activity reduced[2,17,19]
↑ Breath volume increase [30]	↑ Gamma wave activity enhanced [11,20,21]
↓ Respiratory exchange ratio (R) [31]	**Auditory evoked potentials**
↓ Oxygen consumption [8,30,43,44]	• Brainstem auditory evoked potentials [32–34]
↓ Carbon dioxide output (VCO)[31,44]	• Midlatency auditory evoked potentials delayed [35–38]
↓ Cardiac output [27]	• Long latency auditory evoked potentials [39–41]
↑ Galvanic skin responses (GSR)/ Skin resistance [3,13,24,29,45–47]	• Event related potentials [40,42]

↑ Photo-plethysmogram amplitude [3,29]	Anterior cingulate cortex and posterior cingulated cortex (attention regulation) [24,48,49]
	Prefrontal cortex (emotion regulation, cognitive re-evaluation, exposure/ extinction/ reconsolidation, flexible self-concept) [48,50,51]
	Insula, Temporoparietal junction (body awareness) [48]
	Putamen, nucleus caudatus and the supplementary motor cortex [52]

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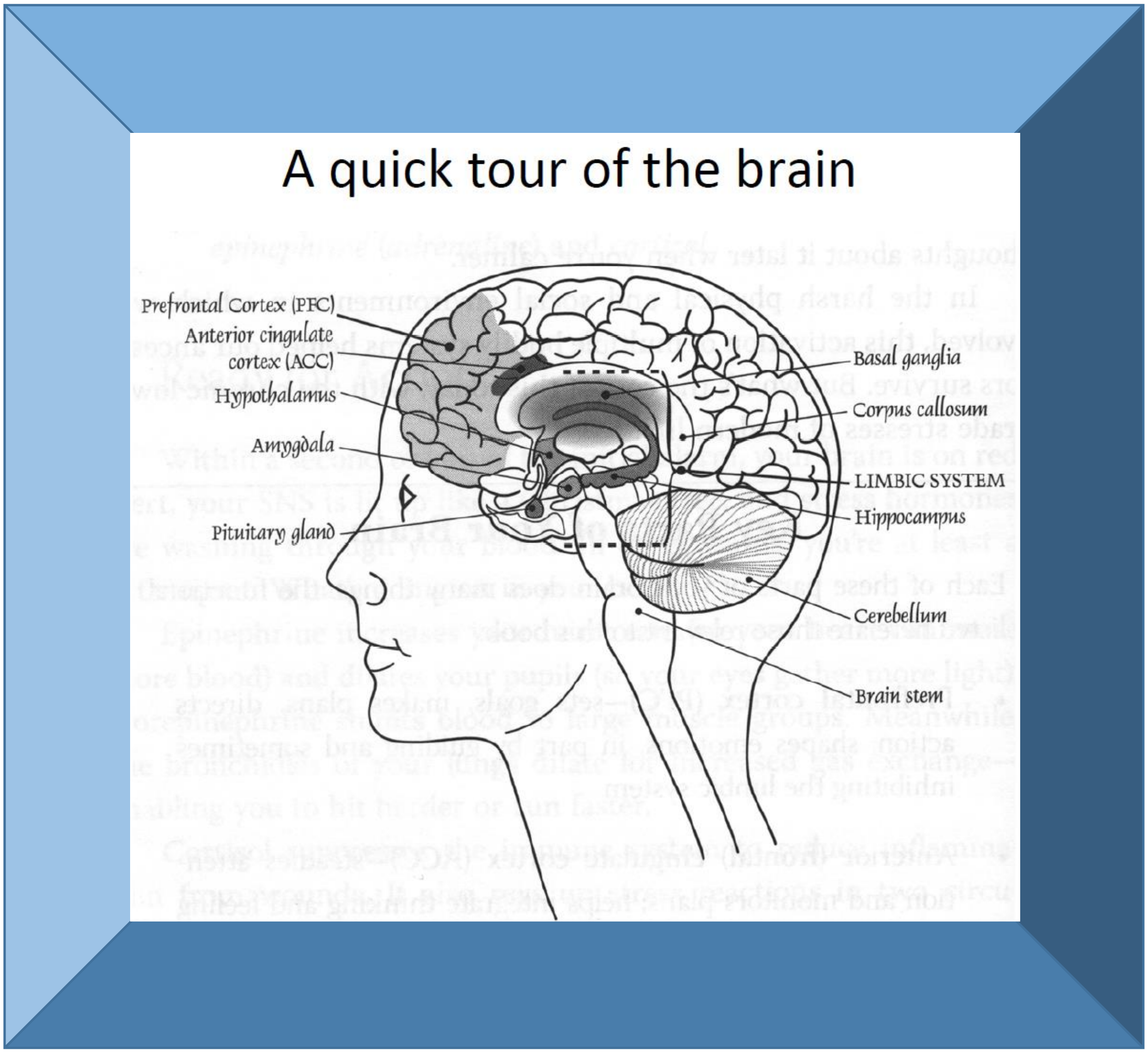
Figure 29: Brain areas involved in meditation



From Rick Hanson (2009) *Buddha's Brain* p. 54 (Hanson, 2009)

Table 30: Summary of trend of changes in peak latency and amplitude of P300 ERPs during *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* sessions; Values are percent change

		Latency (ms)	**Amplitude (µV)**
Waves	**Sessions**	**After**	**After**
P300 ERPs (A1- Cz)	*Cañcalatā*	NS	-14.23 % ↓
	Ekāgratā	NS	NS
	Dhāraṇā	NS	14.56 % ↑
	Dhyana	-2.94 % ↓	14.59 % ↑

Note: n = 60; ↑: Increase; ↓: Decrease, which was statistically significant; NS: No significant changes

Table 31: Summary of trend of changes in frequency domain and time domain during *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* sessions; Values are percent change

Sessions	Variables	During				After
		D1	D2	D3	D4	
	Frequency Domain					
Cañcalatā	LF (n.u.)	NS	13.53 % ↑	21.54 % ↑	16.39 % ↑	NS
	HF (n.u.)	NS	-18.35 % ↓	-29.26 % ↓	-22.21 % ↓	NS
Ekāgratā	LF/HF ratio (ms^2)	NS	NS	NS	70.25 %	NS
Dhāraṇā	LF (n.u.)	16.43 % ↑	19.70 % ↑	25.59 % ↑	21.83 % ↑	15.66 % ↑
	HF (n.u.)	-20.81 %	-24.95 % ↓	NS	-27.65 % ↓	-19.83 % ↓
	LF/HF ratio (ms^2)	NS	86.50 %	NS	NS	NS
Dhyāna	LF (n.u.)	-22.20 % ↓	-15.30 % ↓	NS	-18.87 % ↓	NS
	HF(n.u.)	29.56 % ↑	20.38 % ↑	13.38 ↑	25.13 % ↑	NS
	LF/HF ratio (ms^2)	-44.93 % ↓	NS	NS	-44.44 % ↓	NS
	Time Domain					
Dhāraṇā	Mean RR (msec)	NS	NS	NS	NS	4.20 %
	Mean HR (bpm)	NS	NS	NS	NS	4.80 %
Dhyāna	Mean RR (msec)	NS	4.43 % ↑	6.43 % ↑	4.86 % ↑	3.32 % ↑
	Mean HR (bpm)	NS	-4.40 % ↓	-5.86 % ↓	-4.30 % ↓	-3.66 % ↓
	RMSSD (ms)	NS	NS	29.87 % ↑	33.79 % ↑	NS
	pNN50	NS	NS	39.01 % ↑	NS	NS

Note: n = 60; ↑: Increase; ↓: Decrease, which was statistically significant; NS: No significant changes

7.3 HEMODYNAMIC RESPONSES IN MEDITATION AND COGNITIVE TASK

The primary goal of the present study was to ascertain whether meditation increases regional cerebral blood flow (rCBF) at bilateral prefrontal cortex, measured with fNIRS, compared to random thinking. Our secondary goal was to observe the reaction time scores and relative changes in cerebral blood flow, and to determine if there are persistent effects following meditation session compared to random thinking session. Results as confirmed with recent studies on meditation with spectroscopy (Cheng et al., 2010), SPECT imaging (Cohen et al., 2009; Newberg, Wintering, Khalsa, Roggenkamp, & Waldman, 2010; Newberg, Wintering, Waldman, et al., 2010; Newberg et al., 2001) and fMRI (Short et al., 2010; Guleria et al., 2013; Zeidan et al., 2013) have revealed that meditation program resulted in significant increases in baseline CBF ratios in the prefrontal, superior, inferior and orbital frontal cortex, dorsolateral prefrontal cortex (DLPFC), right dorsal medial frontal lobe, cingulate gyrus and right sensorimotor cortex. In present study, we found that brain activation, measured by changes in oxy-hemoglobin (ΔHbO) and total hemoglobin (ΔTHC) concentration in the right prefrontal area was followed by a strong decrease in deoxy-hemoglobin (ΔHbR) concentration during meditation. Additionally, the rCBF significantly increased in the right frontal lobe during stroop task after meditation, which suggest the improvement in the participant's performance (reaction time) during the task. The total blood oxygenation (ΔTHC) level in the prefrontal cortex (PFC) could rise with increasing task load from neutral to congruent, and then incongruent; this would demonstrate a positive correlation with performance measures. The changes in regional blood flow is mediated by changes in neural activity in a single region or in several selective regions of the brain (Lauritzen, 2001).

Earlier studies have demonstrated that the PFC is activated particularly on the right prefrontal cortex and anterior cingulate cortex (ACC) in willful act and tasks that require intense focused and sustained attention (Frith et al., 1991b; Pardo et al., 1991a; Petersen and Posner, 2012; Vogt et al., 1992). A study on eight Tibetan Buddhist meditators demonstrated improved activity in the PFC bilaterally (though greater on the right hemisphere) and the cingulate gyrus during meditation (Newberg and Iversen, 2003). This suggests that meditation begins with activation of the prefrontal cortex (PFC) and anterior cingulate gyrus associated with the will or intent to clear the mind of thoughts or to focus on an object (Edwards et al., 2012).

Meditation increases CBF and decreases cerebrovascular resistance (CVR) suggesting a contributing vascular mechanism (Jevning et al., 1996) which reflect cerebral activation. The CVR reduction being associated with cognitive improvement which suggests a vascular contribution to cognitive enhancement (Nation et al., 2013). During meditation, the activation of right PFC is theoretically associated with the activity in the reticular nucleus of the thalamus. This activation may be accomplished by the PFC's production and distribution of glutamate, a known excitatory neurotransmission (Cheramy et al., 1987; Finkbeiner, 1987), which communicate with other brain structures such as lateral geniculate and lateral posterior nuclei of the thalamus (Portas et al., 1998). An early study on meditation with single photon emission computed tomography (SPECT) demonstrated a general increase in thalamic activity that was proportional to the activity levels in the PFC (Edwards et al., 2012; Newberg et al., 2001). The activation on the right PFC causes increased activity in the reticular nucleus during meditation, the results may be decreased sensory input entering into the posterior superior parietal lobule which is involved in the analysis and integration of higher order visual, auditory, and somaesthetic information (Adair et al., 1995).

A major strength of the present study was to examine the states of meditation and random thinking related hemodynamic responses in cerebral oxygenation during performance of the stroop color word task. It is a well established phenomenon that executive processes are facilitated by the frontal lobe and due to stroop interference brain activity may depend on increased ability to recruit frontal neural resources (Schroeter et al., 2004b). This allowed us to examine whether there is an increase in oxygenation with meditation corresponding to an ability to recruit appropriate resources for task performance or a decrease in activation corresponding to better optimization and possible reduction in task difficulty with meditation. In a study, fNIRS showed stroop interference is consistently associated with the anterior cingulate cortex (ACC) and the lateral prefrontal cortex (LPFC), especially the dorsolateral prefrontal cortex (DLPFC), where the ACC is considered to be susceptible to conflict, and the DLPFC is purported to implement cognitive control (Carter et al., 2000; Leung et al., 2000). DLPFC may involve attentional maintenance while ACC monitors performance (MacDonald, 2000). Another similar study suggested meditation may enhance specific subcomponents of attention such as conflict monitoring or performance (Jha et al., 2007). Although fNIRS cannot monitor the cortical activation in the ACC because its measurement is limited to lateral cortical surfaces, it has successfully monitored the activation of the LPFC associated with stroop interference (Ehlis et al., 2005; Schroeter et al., 2003, 2002, 2004a, 2004b).

There have been several neuroimaging studies evaluating the cerebral blood flow and performance of different meditation practices using behavioral, EEG and (Carter et al.,

2005) fMRI imaging. Previous studies on meditation and EEG reported, greater midline theta power and slow alpha power in the frontal area during meditation (Chan, Han, & Cheung, 2008; Takahashi et al., 2005). Zazen meditation showed increased alpha-1 and alpha-2 frequency activity of EEG in right prefrontal areas including insula, parts of the somatosensory, motor cortices and temporal areas (Faber et al., 2014). A subsequent study, on Satyananda Yoga meditation practice, showed greater source activity in low frequencies (particularly theta and alpha 1) during mental calculation, body-steadiness and mantra meditation (Thomas et al., 2014). Additionally, body-steadiness and mantra meditation showed greatest activity in right side of superior frontal and precentral gyri, parietal and occipital lobes. Similarly, neuroimaging studies on meditation practice, when compared to the control session showed significantly increased oxy-hemoglobin and CBF in the medial prefrontal cortex which was associated with the intense focus-based component of the practice (Wang et al., 2011). Meditation involves attentional regulation and leads to increased activity in brain regions associated with attention such as DLPFC and ACC. The long-term practitioners had significantly more consistent and sustained activation in the DLPFC and the ACC during meditation versus control in comparison to short-term practitioners (Baron Short et al., 2010). These studies suggest that willful acts and tasks that require sustained attention are initiated via activity in the prefrontal cortex (PFC), particularly in the right hemisphere (Ingvar, 1994; Frith et al., 1991a; Posner and Petersen, 1990; Pardo et al., 1991b). Meditation requires focus of attention on objects which thereby activates PFC, particularly in the right hemisphere (Cohen et al., 2009), as well as the cingulate gyrus (Herzog et al., 1990; Lazar et al., 2000; Newberg et al., 2001b). This demonstrated that during meditation there was an increased activity in the PFC bilaterally (greater on the right) and the cingulate gyrus (Newberg and Iversen, 2003). Therefore, the process of meditation seems to happen by activation of the prefrontal and cingulate cortex which are associated with the will or intent to clear one's mind of thoughts or to focus on an object.

In other imaging studies on meditation, there have been inconsistent results regarding the frontal cortex. A recent study showed decreased frontal activity during externally guided word generation compared to internal or volitional word generation (Crosson et al., 2001). Thus, prefrontal and cingulate activation may be associated with the volitional aspects of meditation. Meditation with fluorodeoxyglucose (FDG) PET in eight subjects undergoing Yoga meditative relaxation (Herzog et al., 1990) reported increased rCBF in the frontal: occipital ratio of cerebral metabolism. Specifically, there was a mild increase in the frontal lobe, but marked decreases in metabolism in the occipital and superior parietal lobes. In addition to these studies, the prefrontal cortex is reported to have a crucial role in social cognitive skills and along with the cingulate gyrus governs social behavior tasks related to Theory of Mind, empathy, moral reasoning, and evaluation of emotional states (Declerck et al., 2006). The prefrontal cortex is essential for flexible behavior because it inhibits the habitual responses that have become inappropriate (Mesulam, 1998). But, an increase in the activity of prefrontal cortex (determined by fNIRS) is not necessarily beneficial always. For example, animal experimentation has shown that the electrical activation of the medial prefrontal cortex prevent the proper sequence of pressing the lever and collecting the reward (a pellet of food) in an operant condition task (Jurado-Parras et al., Learn. Mem., 2012) and also prevent the expression of an already acquired classically conditioned eyelid response (Leal-Campanario et al., 2007, 2013). However, in our study we infer that activation of prefrontal cortices after meditation had beneficial effects on cognition as manifested by improved performance in stroop color word task.

The present study reported increased oxy-hemoglobin concentration because of enhanced neural activity and cerebral blood flow in the prefrontal area during meditation compared to random thinking. In such studies, it is very important to understand the influences of systemic artifacts such as those from the heart, breathing, superficial perfusion, etc. which may be induced by the cognitive tasks related stress and autonomic responses. For example, a recent study performed on peripheral physiological measurements with temporal correlations of fNIRS and fMRI signals concluded that the physiological basis of the systemic artifact is a task-evoked sympathetic arterial vasoconstriction monitored by a decrease in venous volume and these artifacts are fairly common (Kirilina et al., 2012). They also suggested that the separation of fNIRS signals originating from activated brain and from scalp is a necessary precondition for unbiased fNIRS brain activation maps and pre-processing of the raw data using high definition filters is necessary.

In summary, the results of the present study provided first evidence that the oxygenation levels are increased in the PFC during meditation compared with random thinking in the same practitioners. Further event-related NIRS studies may apply well-tested fMRI paradigms in studies with children and patients, utilizing the advantages of the method.

Table 32: Summary of trend of changes in reaction time scores (msec) of Stroop color word Task during *cañcalatā* and *dhyāna* sessions; Values are percent change

Sessions	States	After	% Change
Cañcalatā	Neutral	660.00±113.641	2.62 %
	Congruent	790.91±119.440	0.93 %
	Incongruent	892.73±136.004	2.45 %
Dhyana	Neutral	617.73±121.653	-3.27 %
	Congruent	764.55±112.238	-3.78 %
	Incongruent	819.09±133.627	-5.31 %

Table 33: Summary of trend of changes in reaction time scores (msec) of Stroop color word Task during *cañcalatā* and *dhyāna* sessions; Values are percent change

Sessions	Voxels	During				Stroop _Post	After
		D1	D2	D3	D4		
			Oxyhemoglobin (ΔHbO)				
Cañcalatā	**Left PFC**	NS	NS	NS	NS	NS	NS
	Right PFC	NS	NS	NS	NS	NS	NS
Dhyana	**Left PFC**	NS	NS	NS	NS	NS	NS
	Right PFC	**-0.71±4.07***	**-0.44±3.84***	**-0.19±3.86****	-0.89±3.70	-0.79±3.89	**0.35±4.41*****
			Deoxyhemoglobin (ΔHbR)				
Cañcalatā	**Left PFC**	NS	NS	NS	NS	NS	NS
	Right PFC	NS	**-1.78±5.75*****	**-0.48±8.08*****	**0.01±8.05*****	**1.22±8.18*****	**0.19±10.25*****
Dhyana	**Left PFC**	NS	NS	NS	NS	NS	NS
	Right PFC	NS	NS	NS	**-8.15±22.72***	NS	NS
			Total hemoglobin change (ΔTHC)				
Cañcalatā	**Left PFC**	NS	NS	NS	NS	NS	NS
	Right PFC	NS	**-9.07±27.55***	**-10.41±26.99*****	**-10.28±26.52*****	**-10.26±26.89****	**-8.41±21.55****
Dhyana	**Left PFC**	NS	NS	NS	NS	NS	NS
	Right PFC	NS	**-2.83±7.18****	**-1.94±8.48*****	**-2.16±9.14****	**-1.45±10.11****	**-0.57±11.07*****

Note: n = 47; ↑: Increase; ↓: Decrease, which was statistically significant; NS: No significant changes

7.4 MINDFULNESS AND ANXIETY

Meditation has been shown to be an effective practice of mindfulness and psychological health. This study was designed to measure the levels of mindfulness and correlate the same to state and trait anxiety scores. Long-term meditators reported significantly lower state anxiety and total anxiety scores of STAI and higher level of total mindfulness scores, acceptance, and presence of FMI compared to the non-meditators. There was a strong, positive, partial correlation between the experience of meditation with the total scores of mindfulness, acceptance, and presence; while there was a negative correlation with state and total anxiety. The acceptance component of the mindfulness scale relates to the nonjudgmental acceptance of the situation, while mindfulness presence is related to the experience of the moment and a cognitive reelection of all actions (Kohls, Sauer, & Walach, 2009). Meditation aims to teach more accepting relationship of one's thought rather than emphasizing the creating of more positive or adaptive thoughts. Longer meditation experience reported more frequent meditation with higher mindfulness and lower psychological distress. However, meditation techniques effectively showed, reductions in self-reported state and trait anxiety scores (Shapiro, Schwartz, & Bonner, 1998).

Several studies of meditation to date have reported correlations between self-reported mindfulness and psychological health. Lykins and Baer (2009) reported significantly higher levels of mindfulness, self-compassion, and overall sense of wellbeing; and significantly lower levels of psychological symptoms, rumination, thought suppression, fear of emotion, and difficulties with emotion regulation in meditators compared to non-meditators, and changes in these variables were linearly associated with extent of meditation practice. Linehan (1993) describes the development of mindfulness skills as a central goal of several behavior therapy, a leading mindfulness-based intervention. There was a strong consistency between extent of meditation practice with trait mindfulness as well as and other outcome variables, including fear of emotions, rumination, and behavioral correlations (Josefsson, Larsman, Broberg, & Lundh, 2011). Moreover, participants in the meditation group showed more mindfulness and were also more likely to cope with stress in adaptive ways, particularly using less evident-oriented strategies in stress situations (Chang et al., 2004). Mindfulness meditation has been found to regulate anxiety. In a recent study on mindfulness meditation reported significant reduction in state anxiety scores after a meditation session (Zeidan et al., 2013). In the present study, we reported a strong positive correlation between the experience of meditation and state anxiety and total anxiety; but there was no significant relation with trait anxiety. Our findings are consistent with previous studies that have found an inverse relation between mindfulness, stress, and state anxiety.

The trait anxiety represents a generalized tendency to be fearful, worried, and apprehensive about the future. It also reflects individual differences in the frequency and intensity with which anxiety states have been manifested in the past. The stronger trait anxiety may report more intense elevations in state anxiety in a threatening situation. There was no significant difference in trait anxiety of meditators and non-meditators in the present study because participants in both the groups were young and healthy. The immediate effect of a 30 min practice of a meditation technique called CM on state and trait anxiety was measured in normal healthy volunteers, which showed a significantly better reduction in state anxiety after the CM and improved memory (Subramanya & Telles, 2009).

Feldman *et al*., (2010) compared the immediate effects of mindful breathing to alternative stress management techniques (progressive muscle relaxation and loving-kindness meditation) in novice meditators, demonstrated greater decentering when compared to those receiving the two alternative interventions; there was also reduced frequency of repetitive thoughts and negative reactions to thoughts. These findings provide further evidence that the cognitive aspects of meditation (e.g., mindful breathing) may create changes in cognitive processes (Ramel1, Goldin, Carmona, & McQuaid, 2004) associated with depression and anxiety (e.g., rumination) that are distinct from other validated stress management approaches. Mindfulness meditation is also documented to contribute to better coping in individuals in high stress work environments, such as medical students (Shapiro et al., 1998) or business executives, and community members enrolled in a wellness program.

Studies on neurophysiological changes reported positive impact of meditation training on brain regions responsible for constructs that are often dysregulated in individuals with depression and anxiety disorders. Recently, the majority of functional neuroimaging studies has investigated brain regions like the anterior cingulate cortex (ACC) and the insula were shown to be involved in the development and maintenance of anxiety disorders (Holzschneider & Mulert, 2011). Meditation-related anxiety relief was associated with activation of the ACC, ventromedial prefrontal cortex, and anterior insula. Meditation-related activation in these regions exhibited a strong relationship to anxiety relief. During meditation, those who exhibited greater default-related activity [i.e., posterior cingulate cortex (PCC)] reported greater anxiety, possibly reflecting an inability to control self-referential thoughts. Meditation showed changes in activation of the prefrontal cortex (PFC) and the ACC, as well as significant increases in alpha and theta activity (Cahn & Polich, 2006). In addition, theta activity was found to be more common in experienced meditators, suggesting that greater meditation expertise may result in an improved ability to self-regulate a state of deep relaxation (Chiesa & Serretti, 2011). These findings are important to demonstrate a neurobiological impact of meditation on brain structures and regions (i.e., PFC, hippocampus, and limbic system) that are well-known to be affected in individuals with anxiety and depression. Earlier studies have shown that meditation can reverse some abnormalities, like depression, anxiety, attention deficit, and posttraumatic stress disorder; producing salutary functional and structural changes in the brain. The mindfulness programs reported a positive impact on symptoms of anxiety and depression, (Baer, 2003) as well as improvements in sleep patterns and sustained attention (Jha et al., 2007). After several researches on meditation and mindfulness; however, clear mechanisms of change have yet to be identified. There are different behavioral, psychological, and biological pathways which have suggested how enhanced mindfulness may displace stress and anxiety-related illness and enhancing adaptive coping processes.

In summary, the present study suggests that, the intense practice of meditation on the symbol ‘*OM*’ may enhance mindfulness and reduce anxiety. Meditation techniques have been used to regulate the mind, emotions, and the responses in adverse psychological conditions. Therefore, meditation would be a mind body medicine which helps in the modulation of expectations, inner engagement, anxiety, and self-awareness.

In conclusion, the results suggest that a mindful person may be less prone to anxiety-related problem. Mindfulness practice will help to increase awareness and problem solving strategies of the present moment which would facilitate effective processing as a means to enhance mental health and well-being. Further study of meditation and mindfulness may help to better disclose how the quality and depth of meditation influences mindfulness and enhancing adaptive strategies for anxiety and its related problems. Also, additional research is needed to clarify the mechanisms of change that are responsible for the beneficial effects of meditation on both psychological and physical health.

Table 34: Summary of trend of changes in meditators and non-meditators; Values are percent change

Characteristic		Meditators	Non-meditators	Percentage change (%)
State-Trait Anxiety Inventory (STAI)	S-STAI	26.24 ± 10.21	32.75 ± 8.29	24.81
	T-STAI	31.12 ± 10.02	33.44 ± 7.36	7.46
	Total-STAI	57.36 ± 9.87	65.69 ± 10.57	14.52
Freiburg Mindfulness Inventory (FMI)	Mindfulness	45.42 ± 5.22	40.34 ± 6.42	11.18
	Acceptance	24.53 ± 4.21	20.81 ± 4.75	15.17
	Presence	20.89 ± 3.49	19.54 ± 3.94	6.46

Note: n = 22; ↑: Increase; ↓: Decrease, which was statistically significant; NS: No significant changes

7.5 POSITIVE STATES OF MIND AND EXECUTIVE CONTROL

The present study investigated a specific attentional task to measure the cognitive performance and positive states of mind in meditators and non-meditators. In addition the present study also assessed the possible correlation of meditation experience with the positive and negative affects. The results of the present study suggest that one-month practice of meditation is positively associated with states of mind and attentional performance. Meditators showed significantly less NA (especially after meditation) and higher PA compared to non-meditators. This suggests that meditation may reduce the intensity of negative feelings with enhanced attentional abilities, which may have reduced their stress by increasing their sense of competence.

The positive and negative affect suggests two opposite mood factors. The high PA reflects enthusiasm, active, full concentration and pleasurable engagement whereas low PA is characterized by sadness and lethargy. Similarly, high NA shows subjective distress, aversive mood states (including anger, contempt, disgust, guilt, fear), and unpleasable engagement whereas low NA reflects a state of calmness and serenity (Watson & Clark, 1984; Watson & Tellegen, 1985). Meditation practitioners scored slightly higher on the PA and lower on the NA compared to non-meditators. Previous studies reported that meditation significantly reduces anxiety and NA and heightens PA (Jung et al., 2010) with increased hope (Sears & Kraus, 2009). The experience of meditation is also associated with lower levels of NA and higher levels of PA (Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010).

The PSOM reflects focused attention, productivity, responsible caretaking, restful repose, sharing, sensuous nonsexual pleasure, and sensuous sexual pleasure. In the present study, both meditation group and control group showed improved POSM but the magnitude of change was higher in the meditation group compared to control group. An early study of meditation also reported improved positive state of mind in meditators compared to the relaxation group (Chang et al., 2004). Both these results demonstrate that the consistent changes may be related to the greater practice of cultivating present-moment awareness (and thus being more aware of positive states as they occur). The significant increase in PSOM scores in the relaxation group also indicates that increase in positive states of mind are not necessarily specific to mindfulness practice, but may also be due to more general relaxation effects (Jain et al., 2007). A recent cross sectional study compared cognitive skills in long term meditative and control group seniors showed a positive effect on the extent of attention, the speed of processing, the ability to attentional shift, and performance (Prakash et al., 2012a). Another similar study on 15 practitioners of Vihangam Yoga (> 10 years experience) reported a meditation improved attention span, processing speed, attention alternation ability, and performance in interference tests (Prakash et al., 2010).

The regular practice of meditation helps to maintain focus on a particular object with greater executive control. In cognitive psychological studies, the SWT is most widely used as a cognitive task. The most critical finding is that color naming is much slower in the incongruent condition (e.g., saying “red” because of the red ink in which the word GREEN is written) than in a control condition where there is no color word but, typically, a string of colored Xs (MacLeod, 1998) or when the word is congruent with the color in which it is written, color naming is much quicker (Dalrymple-Alford, 1972). Previous studies reported that meditation is associated with high processing speed, good attentional and inhibitory control, and a good coordination of speed with concurrent accurate performance. In addition, the reduced errors suggest greater attentional control, accuracy of visual scanning, inhibitory control, carefulness, cognitive flexibility and quality of performance (Moore & Malinowski, 2009). The present results supported the existing evidence, that meditators performed significantly better than non-meditators in SWT. Meditators showed reduced interference which suggests automatisation of cognitive processes which can be brought back under cognitive control (Wenk-Sormaz, 2005). Studies have shown that meditators have reported superior cognitive abilities (Prakash et al., 2012b) and sustained attention (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010) than non-meditators. These effects of meditation practice, improve one's ability to have focused attention and demonstrated an involvement of several neural networks responsible for different aspects of attentional function (Malinowski, 2013).

Neuroimaging studies showed that, a rapid visual presentation task (e.g., Stroop task) is linked to cerebral gray matter volume in Buddhist meditators (Pagnoni & Cekic, 2007). The experience of meditation practice is associated with an improvement in response inhibition and increased recruitment of dorsal anterior cingulate cortex, medial prefrontal cortex, and right anterior insula (Allen et al., 2012). Meditation is accompanied by a relatively increased perfusion in the sensory imagery system (i.e., hippocampus and sensory and higher order association regions), with decreased perfusion in the executing system (i.e. Dorsolateral prefrontal cortex, anterior cingulate gyrus, striatum, thalamus, Pons, and cerebellum) (Lou, Nowak, & Kjaer, 2005). On the contrary, another study reported greater activity in the right medial frontal, middle temporal, precentral and postcentral gyri and the lentiform nucleus during the incongruent conditions in non-meditators. The anterior cingulate cortex (ACC), is implicated in conflict monitoring in the engagement of cognitive control, promoting adjustments in behavior (Kerns et al., 2004) such as the inhibition of motor actions during a task (Sharp et al., 2010). In this case, the medial frontal region is involved in the conflict monitoring of the SWT conditions and adjustments when choosing one of the buttons during the task (which represents the selection of one of the colors). The middle temporal gyrus is associated with planning volitional movement (Caffarra, Gardini, Vezzadini, Bromiley, & Venner, 2010). Motor control includes the ability to inhibit a planned movement if it is identified as incorrect or inappropriate. The lentiform nucleus is part of the gateway to the basal ganglia and is related to the motor control and the activity of the primary motor cortex (the precentral gyrus) (Kreitzer & Malenka, 2008). The regular meditators tend to have “higher” activation levels, compared to non-meditators, for congruent stimuli, and lower activation levels of incongruent stimuli. It seems that regular meditators, unlike non-meditators, tend to process incongruent and congruent stimuli quite similarly (and this is partially supported by the lack of a congruency effect for the number of errors in the task). Meditators can develop the ability of sustained attention during meditation practice. Meditation can have sustained effects in brain circuitry and behavior related to attention abilities. This observation may support that meditation training develops the ability of keeping attention to execute an attention task with less interference from distracters (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). Non-meditators showed an increased pattern of brain activation relative to regular meditators under the same behavioral performance level, which suggest meditation improves efficiency of the executive attentional network (anterior cingulate/prefrontal cortex) but no effect on the orientation network (parietal systems) (Chan & Woollacott, 2007a), possibly via improved sustained attention and impulse control (Kozasa et al., 2012).

In summary, the findings of the present study suggest meditation enhances Positive affect and positive state of mind with lower Negative affect. In stroop task meditators scored significantly higher than non-meditators suggesting superior cognitive abilities, greater executive control, improved efficiency of sustained attention with impulse control. It also suggests improvements in attention span, processing speed, attention alternation ability, and performance in interference tests.

7.6 VISUAL ANALOG SCALE, ACCURACY, AND P300 ERPs

The present study was conducted to assess the self-rated ability to follow the instructions to achieve the four mental states viz., *cañcalatā* (random thinking), *ekāgratā* (non-meditative focused thinking), *dhāraṇā* (meditative focusing), and *dhyāna* (meditation) using visual analog scale. Additionally, we have also attempted to correlate the visual analog scale with an accuracy of counted clicks during P300 Oddball task and peak latency and amplitude of P300 event related potentials (ERPs). The result showed that following *dhāraṇā* and *dhyāna* scores on visual analog scale were significantly higher compared to *cañcalatā* and *ekāgratā*. This suggests that during focused meditation and meditation sessions participants were more involved to follow the instructions without many distractions. Additionally, correlated with accuracy in counted clicks and attention (P300 ERPs latency and amplitude) were higher after *dhyana* session, which suggest after meditation more brain areas are involved in mental counting and improve the practitioner's ability to sustain attention for prolonged periods.

A study on 62 college students reported mantra meditation and yogic relaxation increases self-actualization in self-reported scales (Personal Orientation Inventory and the Behavioral Relaxation Scale) (Janowiak & Hackman, 1994). Results suggest meditation was associated with larger gains in scores on measures of systematic relaxed behavior than of the relaxation training. Another study on brain areas involved in focused attention (FA) and open monitoring (OM) meditations are distinct and different (Lutz, Slagter, Dunne, & Davidson, 2008a). FA meditation improves sustained attention on a particular object for a prolonged period. During FA meditation, functional magnetic resonance imaging (fMRI) has shown activation in the brain regions involved in monitoring, engaging attention and attentional orientation. In contrast, *OM* meditation has shown activation in the brain regions implicated in monitoring vigilance and disengaging attention from stimuli which could distract attention from the experience at the moment. In a recent study on sixty meditators assessed the ability to follow instructions using visual analog scale (VAS) for four mental states i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyana*. The results showed that following *dhāraṇā* score on the visual analog scale were significantly lower compared to those related to *cañcalatā*, *ekāgratā*, and *dhyana.* In contrast, the present study showed that following *dhāraṇā* and *dhyāna* scores on a visual analog scale were significantly higher compared to *cañcalatā* and *ekāgratā*.

Dhāraṇā (meditative focusing) is defined as confining the mind within a limited area. In the present study it is involved mental visualization, and intense focusing on the Sanskrit syllable *OM* (described in the Patanjali Yoga *Sutra*, 3-1). The next stage is *dhyāna* (effortless meditation or defocused meditation) (described in the Patanjali Yoga *Sutra*, 3-2) which is characterized by the uninterrupted flow of the mind towards the object chosen for meditation. *Dhāraṇā* and *dhyāna* may be considered as the last two of four stages, which form a continuum in the process and practice of meditation.

CHAPTER-8

APPRAISAL

8.0 APPRAISAL

To understand the limitations of the present study as well as to get insight into new ideas for future research, a critical review of the work done has been done. The appraisal of the research work in this thesis is presented under the following headings:

1. Summary of the findings
2. Conclusion
3. Implications and applications of the study
4. Application of the study
5. Strength of the study
6. Limitations of the study
7. Suggestions for future studies

8.1 SUMMARY OF THE FINDINGS

The present study was conducted on sixty healthy male participants with ages ranging from 18 to 38 years (group average age ± S.D., 20.5 ± 3.8 years). They were studied in four sessions viz., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna*. Each session consisted of ‘Before’ (5 minutes), ‘During’ (20 minutes) and ‘After’ (5 minutes) states. Long latency auditory evoked potentials (LLAEPs), autonomic changes and hemodynamic responses were recorded in the before, during and after sessions, whereas P300 Event related potentials (ERPs) and stroop color word task were studied before and after the sessions. Mindfulness, Positive states of mind, anxiety, and executive control were studied as correlational studies in meditators and non-meditators. A Visual analog scale (VAS), to measure the ability to follow guided instructions was given immediately after the practice of all four sessions. Also we attempted to correlate VAS results in four sessions with an accuracy of counted clicks in P300 Oddball task and peak latency and peak amplitude of P300 event related potentials (ERPs).

For each of the variables the data were analyzed separately using IBM SPSS (Version 20). The repeated measure ANOVA followed by *post-hoc* analysis was used to analyze the long latency auditory evoked potentials (LLAEPs), P300 event related potentials (ERPs), heart rate variability (HRV), respiratory rate (RR), hemodynamic responses and stroop color word task. Also, two cross sectional studies on mindfulness, anxiety, positive states of mind, and executive control were done in meditators and non-meditators. In the present thesis we additionally, attempted to correlate the accuracy of counted clicks in P300 oddball paradigm and peak latency and peak amplitude of P300 event related potentials.

LLAEPs results suggest that the decrease in the peak latency of the P2 component during and after meditation. The P1, P2, and N2 components showed a significant decrease in peak amplitudes during random thinking and non-meditative focused thinking. The HRV there was a significant decrease in LF power, LF/HF ratio, and the mean HR and increased HF power, mean RR, RMSSD, and PNN50 ‘during’ and ‘after’ meditation, compared to ‘before’ values. There was a significant increase in the P300 peak amplitude after meditative focusing and meditation, with a reduction in peak latency after meditation.

The non-meditation group showed higher anxiety as their state scores of STAI were higher than participants in the meditation group. PSOM scale showed significant improvement in both the groups, however, the magnitude of change was higher in the meditation group compared to the control group. The correlations between the Visual Analogue Scale (VAS), attention (P300 latency and amplitude) and accuracy of counted clicks in P300 oddball task in four mental states i.e., *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* showed that there was a significant negative correlation found between VAS scores and amplitude of the *cañcalatā* session while there was a significant positive correlation in the P300 latency of *dhyāna* session and amplitude of *dhāraṇā* and *dhyāna* sessions.

8.2 CONCLUSIONS

The results suggest that meditation facilitates the processing of auditory information in the auditory association cortex, whereas the number of neurons recruited was less in random thinking and non-meditative focused thinking at the level of the secondary auditory cortex, auditory association cortex and anterior cingulate cortex respectively. Simultaneous recordings of P300 ERPs and HRV showed that following meditation (both with and without focusing), there was reduced sympathetic activity along with an improvement in the ability to perform the P300 auditory oddball task. A cross-sectional study on two groups showed '*OM*' meditation has a significantly higher mindfulness and less state anxiety compared to non-meditator group. Also, meditation improved the positive states of mind and positive affect as well as reduced the interference on the Stroop task with enhanced executive control. Subjective assessment about the ability to follow the guided instructions showed that participants were more involved in *dhāraṇā* and *dhyāna* compared to *cañcalatā* and *ekāgratā* on the visual analog scale.

8.3 IMPLICATIONS OF THE STUDY

The present study demonstrated that there was a significant decrease in the peak latency during and after meditation and also, decrease in peak amplitudes during random thinking and non-meditative focused thinking. This suggests that meditation facilitates the processing of auditory information in the auditory association cortex, whereas the number of neurons recruited was less in random thinking and non-meditative focused thinking at the level of the secondary auditory cortex, auditory association cortex and anterior cingulate cortex respectively. Another study has helped to obtain answers for the research questions which were asked that is, out of the four mental states studied, only in meditation (*dhyana*) there was a simultaneous improved attention measured through P300 event related potentials (ERPs) along with reduced sympathetic activation characteristics of the classical definition of meditation as a state of alertful rest. Meditation and meditative focusing appear to activate neural connections in these areas associated with focused attention. However, an important difference between the two conditions is that meditation is associated with reduced sympathetic activity, whereas in meditative focusing sympathetic activity increased.

The introduction of functional near-infrared spectroscopy (fNIRS) into the field of neuroscience created new opportunities for investigating neural processes within the human cerebral cortex. In this study we assessed, hemodynamic responses measured through functional near infrared spectroscopy (fNIRS), a new method to measure executive function, workload related to meditation that offers several advantages. First, it uses a device that is only slightly intrusive: a lightweight headband. Second, the executive function and workload related to meditation is measured in real-time. Third, the setup is cheap compared to the very expensive fMRI technology. The results of the present study provided the first evidence that the oxygenation levels are increased in the prefrontal cortex (PFC) during meditation compared with random thinking in the same practitioners. Furthermore, applications to various areas of cognitive neuroscience, such as attention, sensory and working memory, executive and preparatory, and language are beginning to appear in the last few years, as well as applications involving not only young adults but also older adults.

Two cross-sectional studies have shown that meditation was associated with higher levels of mindfulness, positive states of mind and lower levels of psychological anxiety. Meditation techniques have been used to regulate the mind, emotions, and the responses in adverse psychological conditions. Therefore, meditation would be a mind body medicine which helps in the modulation of expectations, inner engagement, anxiety, and self-awareness.

8.4 APPLICATIONS OF THE STUDY

Neuro-electric responses to sensory stimuli can be readily and non-invasively recorded using averaging techniques first employed by Dawson in 1947. Long (late) latency evoked potentials application has been conducted in individuals diagnosed with Asperger syndrome to confirm changes in attention and concentration tasks and solution of problems, support the diagnostic method and give focus to the encoding process of the sound characteristic. Additionally, clinical uses of P1, N1, and P2 responses of auditory evoked potentials include threshold estimation and their use as an electrophysiological index of auditory system development, auditory discrimination and speech perception, and the benefits from cochlear implantation, auditory training, or amplification.

Long latency auditory evoked potentials attained in passively alert adults have a remarkably high correspondence with perceptual threshold. Acoustic features of complex sounds may be reflected in the waveform and latency of these potentials and so might be used to determine the integrity of neural encoding for such features and thus contribute to speech perception assessment. P300 even related potentials have been used to discern discrimination abilities among groups of normal-hearing and hearing-impaired individuals; however, their sensitivity and specificity for testing an individual's abilities has not yet been established. Cortical auditory potentials are affected by listening experience and attention and so could be used to gauge the effects of aural habilitation. The presence of cortical potentials in children with auditory neuropathy appears to indicate residual hearing abilities. Parametric and developmental research is needed to further establish these applications in audiology.

The functional near infrared spectroscopy, used in the present study, might be a useful tool to conduct functional activation studies in different neuropsychiatric disorders, most prominently schizophrenic illnesses, affective disorders and developmental syndromes, such as attention-deficit/hyperactivity disorder as well as normal and pathologic aging. fNIRS is a valid addition to the range of neuroscientific methods available to assess neural mechanisms underlying neuropsychiatric disorder.

8.5 STRENGTH OF THE STUDY

The present study evaluated the electrophysiological, psychophysiological and hemodynamic changes following *cañcalatā*, *ekāgratā*, *dhāraṇā*, and *dhyāna* using long latency auditory evoked potentials, event related potentials with autonomic balance and cerebral blood flow related to attentional task in meditators. In this study meditation has been studied in two separate meditative states based on the descriptions from the yoga texts. The findings revealed that *dhāraṇā* and *dhyāna* are different and distinct meditative states, hence they produce different results. This may explain the differences found in earlier meditation studies and shows the importance in taking descriptions from traditional texts.

8.6 LIMITATIONS OF THE STUDY

While the findings are reasonably straightforward, the study may have the following limitations:

(i) The evaluation of the quality of practice was based on a self-reported visual analog scale (VAS) and hence was subjective.

(ii) *Cañcalatā* (Random thinking) and *ekāgratā* (non-meditative focusing) were the control conditions. There was no control without any intervention.

(iii) Carrying out the attention task before and after meditation could possibly reduce the quality of meditation.

(iv) While the participants have been trained to switch between the four states, the possibility that they did get into the meditative state inadvertently cannot be ruled out.

(v) Hemodynamic changes were studied only in *cañcalatā* and *dhyāna* which could be a limitation of the study.

8.7 SUGGESTIONS FOR FUTURE STUDIES

The limitations of the present study may be corrected in future studies if,

1. A neurophysiological marker for the depth of meditation or four mental states could be established.
2. Get better understanding of P1-N1-P2 complex signals and the cortical detection of an auditory event that can be used reliably to diagnose the disorders affecting the central processing of sound.
3. EEG could be recorded throughout, along with the eye movements and muscle tone to assess the electrical activity of the brain and to rule out sleep episodes.
4. Further studies can include dense array EEG and functional magnetic resonance imaging (fMRI) to study cortical areas of the brain involved in different stages of meditation
5. Cerebral blood flow during four mental states (*caïcalatä*, *ekägratä*, *dhäraëä*, and *dhyäna*) related to attention task could give more information about cortical hemodynamics of the brain.
6. Further event-related NIRS studies may be tested in fMRI setup with children and patients, utilizing the advantages of the NIRS methods.
7. Future research particularly focus on expanding the presently used activation paradigms and cortical regions of interest, while additionally fostering technical and methodological advances particularly concerning the identification and removal of extracranial influences on fNIRS data as well as systematic artifact correction.

8. EEG-fNIRS could be used to get a convincing idea about the cortical activity and cerebral hemodynamic changes during four mental states.

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APPENDICES

APPENDIX – 1

INFORMED CONSENT FORM

Title of the project : **NEURONAL ACTIVITY AND CEREBRAL BLOOD FLOW CHANGES IN MEDITATIVE STATES AS DEFINED IN YOGA TEXTS**

Investigator : Deepeshwar Singh, M.Sc., Ph.D. Scholar

Name of the guides : Naveen K.V., B.N.Y.S, Ph.D.

Nagendra H. R., M.E., Ph.D.

Ramachandra G. Bhat., Ph.D., D.Lit.

Name of the Participant : ____

Date and Time : __________________and ___________________

The purpose of the study : To understand the neurophysiological, psychophysiological and cerebral blood flow changes following *cañcalatā* (random thinking), *ekāgratā* (non-meditative focused thinking), *dhāraṇā* (meditative focusing) and *dhyāna* (meditation).

Procedure for measurement:

In order to understand the neuronal activity, cognitive and autonomic functions, hemodynamic responses before, during and after four sessions viz., *cañcalatā*, *ekāgratā*, *dhāraṇā* and *dhyāna* will be recorded in long latency auditory evoked potentials (LLAEPs), P300 event related potentials (ERPs) using the Nicolet Bravo System (USA). The autonomic variables such as heart rate variability and respiration will be recorded using BIOPAC MP 100. The cerebral blood flow changes in the prefrontal cortex will be assessed in meditation and attention task using functional near infrared spectroscopy (fNIRS). The mindfulness, positive states of mind, executive control and subjective assessment on visual analog scale will be obtained using various questionnaires.

Please note:

- All information obtained during the study will be kept confidential and individual report of the test will be given.
- You can withdraw from the study at any point of time unconditionally.
- In case the study does cause any adverse effects, the institution is not liable.

I have understood the all above and consent voluntarily to participate in the study.

Place_______

Date________ **Signature of the Participant**

APPENDIX – 2

INSTRUCTIONS FOR *DHĀRAṆĀ* AND *DHYĀNA*

INSTRUCTIONS FOR *DHĀRAṆĀ* WAS AS FOLLOWS:

General: Sit comfortably. Close your eyes. Observe your breathing. Slow down your breathing. Calm down your mind. Relax the whole body.

***Dhāraṇā*:**

- Open your eyes gently with few blinks. Slowly bring your awareness on the picture of OM in front of you.
- Allow the random thoughts to flow freely as you are observing the picture of OM.
- Now gradually replace these random thoughts with the thoughts related to OM.
- Let us start this process by observing the attributes of OM.
- From the gross awareness, observe the first attribute, the shape of the symbol OM.
- Scan through the symbol OM from the upper part and move slowly downwards. As you reach the bottom, move your attention again to the upper part and start moving down. Let this process continue.
- Now slowly shift your awareness to the center of the symbol OM. Move your concentration to the extension of OM on the right. Observe slowly and come back to the center. Now gradually move your attention to the upper right corner of the picture and focus on the crescent and the dot. Now slowly observe the complete picture.
- Gently close your eyes and try to visualize the picture of OM mentally.
- Open your eyes with few blinks. Now gradually shift your concentration from the shape to the color of OM. Observe the orange color.
- Slowly expand your vision and observe the blue color surrounding the orange OM. Slowly combine the awareness of the shape and color and have a complete picture of OM.
- Try not to blink in between, focus your attention on the picture of OM.
- Experience the process of dharana. *Deśabandhaścittasya dhāraṇā*. *Dhāraṇā* is the process of fixing the mind on a single object in a given space and time. Hold on to it as long as you can without any distractions.

- Now slowly close your eyes. Visualize the symbol OM in between your eyebrows and fix it there.
- Continue internal focusing on OM between the two eyebrows. As the symbol starts fading away, slowly open your eyes and observe the same in front of you again. Continue the process of focusing.
- Let your mind be fixed on the symbol OM.
- No other thoughts in the mind. Mind is filled with the thoughts of OM and no other distractions.
- Slow down your thoughts and gradually reach at one single thought. But no compromise on the intensity of focusing.
- Once again slowly close your eyes and visualize the Symbol of OM in between your eyebrows.
- Gradually increase the duration of internal focusing and try to remain there as long as you can.
- Your attention is focused on the single object OM. Make it as one pointed awareness and enjoy being with OM and your mind is totally engrossed in this process.
- From full size OM, reduce the size of OM in the mind to smaller and smaller size. As small as rice seed. But with full clarity of OM in all its vividness. Let the mind get fixed on this smallest picture.
- Let it come back quickly to full size OM. Again focus the mind by making the OM smaller and smaller, focusing deeper and deeper. Bringing the full power of attention on OM as small as a rice seed, retain the same for as long as you can with full clarity for at least 10 seconds. Suddenly take it back to full size OM.
- Retain the full OM at least for 20 seconds (This process has to be repeated).
- Now slowly try to come out of this state of intense focusing.
- Allow your mind to remember the attributes of symbol OM. Visualize the orange OM surrounded by the blue color, visualize the shape of OM.
- **General:** Gently rub your palms (palming) and make a cup of your palms and place them on the eyes. Relax your eyes by the warmth produced by palming. Gently massage your face and release slowly. Open your eyes with few blinks.

INSTRUCTIONS FOR *DHYĀNA* WAS AS FOLLOWS:

General: Sit comfortably. Close your eyes. Observe your breathing. Slow down your breathing Calm down your mind. Relax the whole body.

***Dhyāna*:**

- Prepare yourself for the practice of meditation.
- Observe different thoughts passing through your mind. Be a witness to your thoughts and observe them without any judgment.
- Gradually replace these different thoughts by the thoughts related to OM.
- Slowly start dwelling upon the thoughts of OM. Slowly observe and listen to the background chanting. You will start hearing the chanting OM.
- Enjoy listening to the repetition of OM. As the sound starts fading away slowly start chanting OM mentally.
- Increase the speed of mental chanting if there are any distractions.
- Now gradually slow down the mental repetition of OM.
- Try to observe the gap between two OMkaras as you continue this process. Make an attempt to observe the silence between two OMkaras.
- Mentally chant OM observe the silence. Chant OM again. Observe the silence
- Chant OM and observe the fine resonance of OMkara in the end taking you to deeper levels of silence each time. Merge yourself with OM.
- Remain there with complete awareness. Now gradually try to expand the gap featured by silence.
- Try to remain in that state of silence as long as you can enjoy the silence and expand yourself.
- Feel the expansion. The mind is filled with happiness and bliss. Enjoy the silence. You are merging with expanded space of OM.
- Enjoy being there with complete awareness and relaxation. Slowly come back from the state of expansion. Observe the slow and repeated chanting of OM in the background.
- **General:** Gently rub your palms (palming) and make a cup of your palms and place them on the eyes. Relax your eyes by the warmth produced by palming. Gently massage your face and release slowly. Open your eyes with few blinks.

APPENDIX – 3

Freiburg Mindfulness Inventory

The purpose of this inventory is to characterize your experience of mindfulness. Please use the last ___ days as the time-frame to consider each item. Provide an answer the for every statement as best you can. Please answer as honestly and spontaneously as possible. There are neither 'right' nor 'wrong' answers, nor 'good' or 'bad' responses.

What is important to us is your own personal experience.

1	2	3	4
Rarely	Occasionally	Fairly often	Almost always

1. I am open to the experience of the present moment.	1	2	3	4
2. I sense my body, whether eating, cooking, cleaning or talking.	1	2	3	4
3. When I notice an absence of mind, I gently return to the experience of the here and now.	1	2	3	4
4. I am able to appreciate myself.	1	2	3	4
5. I pay attention to what's behind my actions.	1	2	3	4
6. I see my mistakes and difficulties without judging them.	1	2	3	4
7. I feel connected to my experience in the here-and-now.	1	2	3	4
8. I accept unpleasant experiences.	1	2	3	4
9. I am friendly to myself when things go wrong.	1	2	3	4
10. I watch my feelings without getting lost in them.	1	2	3	4
11. In difficult situations, I can pause without immediately reacting.	1	2	3	4
12. I experience moments of inner peace and ease, even when things get hectic and stressful.	1	2	3	4
13. I am impatient with myself and with others.	1	2	3	4
14. I am able to smile when I notice how I sometimes make life difficult.	1	2	3	4

Appendix – 4

SWAMI VIVEKANANDA YOGA RESEARCH FOUNDATION

BANGALORE

<u>SPIELBERGERS STATE TRAIT ANXIETY INVENTORY (STAI)</u>

<u>STAI FORM</u>

Date: **Age:**
Name: **Gender:**

Directions: A number of statements which people have used to describe themselves are given below. Read each statement and then fill the appropriate number in the box to the right of the statement to indicate how you feel at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

Choose the answers from the choice given below:

1. Not At All.
2. Somewhat.
3. Moderately So.
4. Very Much So.

1.	I feel calm	1	2	3	4	☐
2.	I feel secure	1	2	3	4	☐
3.	I am tense	1	2	3	4	☐
4.	I am regretful	1	2	3	4	☐
5.	I feel at ease	1	2	3	4	☐
6.	I feel upset	1	2	3	4	☐
7.	I am presently worrying over possible misfortunes	1	2	3	4	☐
8.	I feel rested	1	2	3	4	☐
9.	I feel anxious	1	2	3	4	☐
10.	I feel comfortable	1	2	3	4	☐

11.	I feel self-confident	1	2	3	4	☐
12.	I feel nervous	1	2	3	4	☐
13.	I am jittery	1	2	3	4	☐
14.	I feel “high strung”	1	2	3	4	☐
15.	I am relaxed	1	2	3	4	☐
16.	I feel content	1	2	3	4	☐
17.	I am worried	1	2	3	4	☐
18.	I feel over-excited and “rattled”	1	2	3	4	☐
19.	I feel joyful	1	2	3	4	☐
20.	I feel pleasant	1	2	3	4	☐

APPENDIX - 5

Assessment:

Positive States of Mind Scale (PSOMS)

These next questions are about the kind of satisfying states of mind that you may have experienced in the past week. Please think about how much trouble, if any, you've had in having this state of mind.

1. Focused Attention: Feeling able to attend to a task you want or need to, without many distractions from within yourself.

Unable to Have It	0
A Lot of Trouble Having It	1
Some Trouble Having It	2
Have It Easily	3

2. Productivity: Feeling of being able to stay at work until a task is finished, do something new to solve problems, or express yourself creatively.

Unable to Have It	0
A Lot of Trouble Having It	1
Some Trouble Having It	2
Have It Easily	3

3. Responsible Caretaking: Feeling that you are doing what you should do to take care of yourself or someone else.

Unable to Have It	0
A Lot of Trouble Having It	1
Some Trouble Having It	2
Have It Easily	3

4. Restful Repose: Feeling relaxed, without distractions or excessive tension.

Unable to Have It	0
A Lot of Trouble Having It	1
Some Trouble Having It	2
Have It Easily	3

5. Sensuous Nonsexual Pleasure: Being able to enjoy bodily senses, enjoyable intellectual activity, doing things you ordinarily like, such as listening to music, enjoying the outdoors, lounging in a hot bath.

Unable to Have It	0
A Lot of Trouble Having It	1
Some Trouble Having It	2
Have It Easily	3

6. Sharing: Being able to commune with others in an empathetic, close way as in talking, walking, going out, or just being together.

Unable to Have It	0
A Lot of Trouble Having It	1
Some Trouble Having It	2
Have It Easily	3

APPENDIX – 6

STROOP COLOR WORD TASK

STROOP

COLOR AND WORD TEST

ADULT VERSION

Name: ____

Age: ________ **Sex:** __________ **Date:** ___________

FOR PROFESSIONAL USE ONLY

	Raw Score	Age/Ed. Predicted*	Residual	T-Scores**
Word Score (W)				
Color Score (C)				
Color-Word Score (CW)				
CW - Predicted = Interference (Table V) ____ - ____ = _______				

* This comes from Tables I - III.
** This should come from Table IV or VI.

DO NOT OPEN THE BOOKLET UNTIL YOU ARE INSTRUCTED TO DO SO

#30150A REV. 01/07

RED	BLUE	GREEN	RED	BLUE
GREEN	GREEN	RED	BLUE	GREEN
BLUE	RED	BLUE	GREEN	RED
GREEN	BLUE	RED	RED	BLUE
RED	RED	GREEN	BLUE	GREEN
BLUE	GREEN	BLUE	GREEN	RED
RED	BLUE	GREEN	BLUE	GREEN
BLUE	GREEN	RED	GREEN	RED
GREEN	RED	BLUE	RED	BLUE
BLUE	GREEN	GREEN	BLUE	GREEN
GREEN	RED	BLUE	RED	RED
RED	BLUE	RED	GREEN	BLUE
GREEN	RED	BLUE	RED	GREEN
BLUE	BLUE	RED	GREEN	RED
RED	GREEN	GREEN	BLUE	BLUE
BLUE	BLUE	RED	GREEN	RED
RED	GREEN	BLUE	RED	GREEN
GREEN	RED	GREEN	BLUE	BLUE
RED	BLUE	RED	GREEN	RED
GREEN	RED	GREEN	BLUE	GREEN

XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX

RED	BLUE	GREEN	RED	BLUE
GREEN	GREEN	RED	BLUE	GREEN
BLUE	RED	BLUE	GREEN	RED
GREEN	BLUE	RED	RED	BLUE
RED	RED	GREEN	BLUE	GREEN
BLUE	GREEN	BLUE	GREEN	RED
RED	BLUE	GREEN	BLUE	GREEN
BLUE	GREEN	RED	GREEN	RED
GREEN	RED	BLUE	RED	BLUE
BLUE	GREEN	GREEN	BLUE	GREEN
GREEN	RED	BLUE	RED	RED
RED	BLUE	RED	GREEN	BLUE
GREEN	RED	BLUE	RED	GREEN
BLUE	BLUE	RED	GREEN	RED
RED	GREEN	GREEN	BLUE	BLUE
BLUE	BLUE	RED	GREEN	RED
RED	GREEN	BLUE	RED	GREEN
GREEN	RED	GREEN	BLUE	BLUE
RED	BLUE	RED	GREEN	RED
GREEN	RED	GREEN	BLUE	GREEN

APPENDIX – 7

PANAS

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt like this in the past few hours. Use the following scale to record your answers.

Very slightly or not at all	a little	moderately	quite a bit	extremely
1	2	3	4	5

Interested	_____	Irritable	_____
Distressed	_____	Alert	_____
Excited	_____	Ashamed	_____
Upset	_____	Inspired	_____
Strong	_____	Nervous	_____
Guilty	_____	Determined	_____
Scared	_____	Attentive	_____
Hostile	_____	Jittery	_____
Enthusiastic	_____	Active	_____
Proud	_____	Afraid	_____

To score this scale first have a look yourself and see if you can decide which of the 20 questions are positive and which are negative. Check your own judgement with the list below. Then add your scores for the 10 positive words and separately for the 10 negative words. Now you have your positive and negative scores. The scores generated will vary along the scale of 10 – 50, with lower scores indicating low (positive or negative) affect and higher scores indicating high (positive or negative) affect.

Watson, Clark and Tellegen (1988) suggest that the normal population will have a mean positive affective score of 29.7 (SD = 7.9) and a mean negative affective score of14.8 (SD = 5.4).

The 10 items for **POSITIVE (PA)** affect are:
attentive, interested, alert, excited, enthusiastic, inspired, proud, determined, strong and active.

The 10 items for **NEGATIVE (NA)** affect are*:*
distressed, upset, hostile, irritable, scared, afraid, ashamed, guilty and nervous, jittery.

APPENDIX - 8

VISUAL ANALOG SCALE

Subjective assessment of ability to follow guided instructions for four sessions

Name:

Age:

Cancalata
(Random Thinking)

↑ Worst possible ↑ Best ever

Ekagrata
(Non meditative focusing)

↑ Worst possible ↑ Best ever

Dharana
(Meditative focusing)

↑ Worst possible ↑ Best ever

Dhyana
(Meditative defocusing)

↑ Worst possible ↑ Best ever

PUBLICATIONS

PUBLICATIONS EMERGING FROM THIS DOCTORAL WORK

1. **Deepeshwar S**, Suhas A Vinchurkar, Naveen KV, and Nagendra HR (2014). Hemodynamic responses on prefrontal cortex related to meditation and attentional task. *Frontiers in System Neuroscience* [In Press].
2. **Deepeshwar S,** Telles S. Auditory Information Processing during Meditation based on Evoked Potentials Studies. *Journal of Neurology and Psychology*, 2013: 1(2); 7. DOI: 10.13188/2332-3469.1000008
3. **Deepeshwar Singh,** Ashok Vinchurkar Suhas, KV Naveen, HR Nagendra. Measures of mindfulness and anxiety in Om meditators and non-meditators: A cross sectional study. *International Journal of Medicine and Public Health*, 2014: 4(1); 26-30. DOI: 10.4103/2230-8598.127170
4. Telles S, **Deepeshwar S**, Naveen KV, Subramanya P. (2014). Long Latency auditory evoked potentials during meditation. *Clinical EEG and Neuroscience*, 2014 [In Press].
5. **Deepeshwar S,** Suhas A Vinchurkar, Naveen KV. (2014). Positive states of mind and executive control in meditators. *SOP Transactions on Psychology (STP),* [In Press].
6. Carlos V. Rizzo-Sierra, **Deepeshwar S**, Kumar S, Bhargav H, Manjunath S, Nagendra HR, (2013). Resting state functional near infrared spectroscopy. *IEEE Explore, EMBS PACHE*: 1; 85-87. DOI:10.1109/PAHCE.2013.6568328
7. Telles S, **Deepeshwar S**, Naveen KV, Subramanya P, Singh N. (2015) P300 and heart rate variability recorded simultaneously in meditation. *Applied Psychophysiology and Biofeedback* [In Press].

Papers under Review

8. **Singh Deepeshwar**, Telles S, Naveen KV (2014). **Correlations of neuronal activity and accuracy of auditory perception in two meditative states.**. [Manuscript is under preparation].

9. **Singh Deepeshwar**, Ramachandra G. Bhat, Suhas A. Vinchurkar, Nagendra H. R. (2015). **Comparison of Eastern and Western concept of Consciousness**. [Manuscript is under preparation]

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Auditory Information Processing During Meditation Based on Evoked Potential Studies

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Abstract

Background: Auditory evoked potentials (AEPs) were recorded to examine the neurophysiological correlates of four mental states described in ancient yoga texts. These are (i) focused attention (*dharana*), (ii) contemplation (*dhyana*) (iii) random thinking (*cancalata*) and (iv) non meditative focused thinking (*ekagrata*). The auditory evoked potentials allowed changes from the periphery (cochlear nucleus) to the center (auditory association cortex) were measured.

Method: There were sixty male participants with ages ranging from 18 to 45 years (group mean age ± SD, 27.0 ± 8.3 years) who were assessed in four sessions. These four sessions were i) random thinking (*cancalata*), ii) non meditative focusing (*ekagrata*), (iii) meditative focusing (*dharana*), and (iv) contemplation (*dhyana*). The order of the sessions was randomly assigned.

The data were analysed with repeated measure ANOVA followed by a *post hoc* analysis.

Results: The BAEPs results showed that the wave V peak latency significantly increased in random thinking ($p<0.05$), non-meditative focused thinking ($p<0.01$) and meditative focused thinking ($p<0.05$) sessions which suggest that during meditation there was no change in processing time of information at the inferior colliculus. MLAEPs results showed that there were significantly increased latencies of the Na and Pa waves during meditation ($p<0.05$) which suggest reduced auditory information transmission at the medial geniculate and primary auditory cortices. The LLAEPs result showed that there was a significant decrease in the amplitude of P1, P2 and N2 waves during random thinking ($p<0.01$; $p<0.001$; $p<0.01$, respectively) and non-meditative focused thinking ($p<0.01$; $p<0.01$; $p<0.05$, respectively) sessions and a decrease in the latency of P2 wave during and after meditation ($p<0.001$) session which suggest facilitated auditory transmission at the auditory association cortex. The changes in P300 event related potentials suggested that meditation improved the interaction between the frontal lobe; hippocampus and temporal-parietal parts of the brain during the P300 auditory oddball task. Hence, through brainstem, midlatency, long latency and event related potentials changes in the auditory sensory pathway were assessed in different mental states.

Conclusion: Meditation showed no changes in auditory information transmission at the collicular level, but decreases it at the geniculate, primary and association auditory cortices.

Background

Meditation has been described as a mental training through which practitioners try to develop and increase flexibility and awareness of their mental processes, culminating in mental stability [1]. Practice of meditation over a period of time produces definite changes in perception, attention, and cognition [2]. Meditation is recognized as a specific consciousness state in which deep relaxation and increased internalized attention exist at the same time [3].

The concepts of meditation described in ancient yoga texts are associated with heightened attention or even of being aware of the experience as it happens. In Patanjali's Yoga *Sutras* (*circa* 900 B.C.) two meditative states are described [4]. The first is focusing with effort (or *dharana)* to confine the mind within a limited mental area (Patanjali's Yoga *Sutras*, Chapter 3, Verse 1). The next stage is effortless expansion or *dhyana* (Patanjali's Yoga *Sutras*, Chapter 3, Verse 2), which is the uninterrupted flow of the mind towards the object chosen for meditation. The practice of *dharana* is supposed to precede the practice of *dhyana*. When the mind is not in meditation, another ancient yoga text says that it may be in two other states, *cancalata* which is a state of random thinking (*Bhagavad Gita*, *circa* 500 B.C. Chapter 6, Verse 34) and *ekagrata* (*Bhagavad Gita*, Chapter 6, Verse 12), or focused attention without meditation, during which the attention is directed to a number of associated thoughts.

These four mental states have been studied to evaluate auditory information processing from the cochlear nerve at the periphery to the association cortices located centrally. Auditory evoked potentials were chosen to begin with, instead of other modalities of evoked potentials to avoid compounding with any other sensory or motor potentials. The auditory modality of stimuli was particularly chosen as it was found to be least disturbing to the meditator during their practice [5]. It is the premise that conscious processes actively involve several cortical mechanisms and also that corticofugal control processes may exert significant alterations in the processing of information at brainstem, thalamic and cortical levels [6-9]. Evoked potentials which form the basis of this report include brainstem (0-10 ms), mid latency (10-100 ms), long latency auditory evoked potentials (100-250 ms) and the P300 event-related evoked potentials recorded with the auditory oddball paradigm (280-450 ms). For each auditory evoked potential component the peak latency and peak amplitude has been assessed. The peak latency (msec) is defined as the time from stimulus onset to the point of maximum positive or negative amplitude within a specified latency window. The peak amplitude (μV) is defined as the voltage difference between a pre-stimulus baseline and the largest positive and negative going peak within a latency window. A decrease in peak latency is considered as suggestive of facilitated transmission due to increased speed of conduction in the underlying neural generators [10]. Conversely, an increase in peak latency can be assumed to suggest inhibited transmission due to slower conduction in the underlying neural generators. With respect to changes in peak amplitude, an increase in the amplitude of an evoked potential component has been interpreted as being indicative of effective activation of the underlying neural generator, with recruitment of additional neurons [11].

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A series of experiments on auditory evoked potentials were carried out between June 2007 and December 2012 to understand the neurophysiological effects of two meditative states (*dharana* and *dhyana*) and two non-meditative states (*cancalata* and *ekagrata*).

Method

Sixty healthy male volunteers whose ages ranged between 20 and 45 years (group mean age ± SD, 27.0 ± 8.3 years) were recruited for recording of BAEPs, MLAEPs, LLAEPs and P300 ERPs. All of them were residing at a yoga center in South India and were actively engaged in practicing yoga. Their health status was based on a routine case history and clinical examination. All the participants had a minimum of 6 months experience of meditation (group average experience ± SD, 22.5 ± 17.5 months) on the Sanskrit syllable, OM. This meditation technique can be separately practiced as *dharana* (focusing on thoughts of OM) and *dhyana* (effortless focusing on OM). Participants were trained to practice the two techniques (*dharana* and *dhyana*) separately and at will. To attempt to ensure that all of them were doing it correctly, they were given a 3-month orientation course, during which time they were supervised by an experienced meditation teacher.

All participants were assessed in four sessions on four separate days, at the same time of the day. The four sessions were (i) meditation with focusing (*dharana),* (ii) meditation without focusing *(dhyana),* (iii) nonmeditative focused thinking *(ekagrata),* and (iv) random thinking (*cancalata)*. The evaluation of the participants' ability to attain these four mental states was based on their self-report on a scale of 0 to 10, as well as on consultations with the meditation teacher.

Assessments

The assessments included (i) brainstem auditory evoked potentials, (ii) mid latency auditory evoked potentials (iii) long latency auditory evoked potentials and (iv) P300 auditory event related potentials with the auditory oddball paradigm. Each of these assessments and the results obtained will be discussed below in detail.

Statistical analysis

Statistical analysis was done using SPSS (Version 16.0). Data were tested for normality by Kolmogorov-Smirnov test. Since the same individuals were assessed in repeated sessions on separate days (i.e., random thinking, non-meditative focused thinking, meditative focusing and meditation), repeated measures analysis of variance was used (ANOVA). Repeated measures analyses of variance (ANOVA) were performed with two 'within subjects' factors, i.e., Factor 1: Sessions; Random thinking, Non-meditative focused thinking, Meditative focusing and Meditation, and Factor 2: States; Before, During (Dur1 to Dur4), and After. Repeated measures ANOVAs were carried out for each component of BAEPs, MLAEPs, LLAEPs and P300 ERPs separately, for both peak latencies and peak amplitudes. This was followed by a *post-hoc* analysis with Bonferroni adjustment for multiple comparisons between the mean values of different states ("During" and "After"). All comparisons were made with the respective "Before" state.

Results

The group mean values ± S.D. for the peak latencies (ms) and peak amplitudes (μV) for each component of BAEPs, MLAEPs and LLAEPs in four sessions (random thinking, non-meditative focused thinking, meditative focusing and meditation) in Before, During and After states are given in Table 4, Table 5 and Table 6, respectively.

Discussions

The results of the BAEPs, MLAEPs, LLAEPs and P300 ERPs are discussed below.

Brain stem auditory evoked potentials (BAEPs)

Brainstem auditory evoked potentials (BAEPs) provide an objective physiological index of auditory function at a subcortical level [12]. They reflect neuronal activity in the cochlear nerve, cochlear nucleus, superior olive and inferior colliculus of the brainstem. BAEPs (0 – 10 ms) were recorded using standard methods [13]. The peak latency and peak amplitude of BAEP components were measured. The neural generators of these components are given in Table 1. A typical trace is shown in Figure 1.

The BAEP recordings showed that the peak latency of a specific component, wave V (5.8 – 6.0 ms), increased significantly during *dharana*, *ekagrata*, and *cancalata* sessions, but there was no change during the practice of *dhyana* [13]. Since wave V is considered to correspond to the inferior colliculus located in the tectum (midbrain) [10,12], this suggested that neural transmission at the level of mid-brain may be improved by meditation without focusing. The results also suggested that *dhyana* practice alone does not delay auditory sensory transmission at the brainstem level, whereas *dharana* practice is associated with a delay which was also seen in the practices of *ekagrata* and *cancalata*. The traces of BAEPs before and after meditation are given in Figure 1a and 1b respectively.

Midlatency auditory evoked potentials (MLAEPs)

Midlatency auditory evoked potentials (MLAEPs) have been used to assess subcortical and cortical changes in meditation [14]. It is believed that even if the main changes occur in the cortex, cortico-efferent connections would result in sub-cortical changes [11]. The mid latency auditory evoked potentials reflect neural activity at the mesencephalic or diencephalic level [15], the superior temporal gyrus [16], and the dorso-posterior-medial part of the Heschl's gyrus, i.e., the primary auditory cortex [17]. The peak latency and peak amplitude of MLAEPs were measured with three components

Table 1: The latencies and the neural generators for the five components of BAEP.

BAEP components	Latency (ms)	Neural Generators
Wave I	1.9	Auditory portion of the eighth cranial nerve
Wave II	3.6	Near or at the cochlear nucleus. A portion - from the eighth nerve fibers around the cochlear nucleus
Wave III	4.2	The lower pons through the superior olive and trapezoid body
Wave IV	5.2	The upper pons or lower midbrain, in the lateral lemniscus and the inferior colliculus; A contralateral brainstem generator for wave V is suggested
Wave V	5.8	

Table 2: The latencies and the neural generators for the three components of MLAEPs.

MLAEP components	Latency (ms)	Neural Generators
Na wave	14-19	Medial geniculate body
Pa wave	25-32	Superior temporal gyrus
Nb wave	35-65	Dorso-posterior-medial part of the Heschl's gyrus i.e., the primary auditory cortex

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Table 3: The latencies and the neural generators for the four components of LLAEPs.

LLAEPs components	Latency (ms)	Neural Generators
P1 wave	40-60 ms	Secondary auditory cortex in the lateral Heschl's gyrus
N1 wave	75-150 ms	Bilateral Parts of the Auditory Superior Cortex
P2 wave	150-250 ms	Planum Temporale (PT) and the Auditory Association Complex (AAC)
N2 wave	250-280 ms	Left superior temporal gyrus and bilateral medial temporal lobe structure

which correspond to the different neural generators given in Table 2. A typical trace is shown in Figure 2. MLAEPs (10 – 100 ms) were recorded using standard methods [18].

The MLAEPs show the prolonged peak latencies of two components (the Na wave and the Pa wave) during meditation. The Pa wave amplitude decreased during all four states. Prolonged latencies of the Na and Pa wave suggest delayed auditory information transmission at mesencephalic – diencephalic levels and at the level of the primary auditory cortex (i.e., the neural generators corresponding to the Na and Pa waves) [18,19]. The traces of MLAEPs before and after meditation are given in Figure 2a and 2b respectively.

Long latency auditory evoked potentials (LLAEPs)

Long latency auditory evoked potentials (LLAEP) assess auditory information processing at the central level. LLAEPs measures are thought to reflect the activation of primary auditory cortex and association cortices [20,21]. In long latency auditory evoked potentials, currently the neural generators is believed to be due to activity at the secondary auditory cortex in the lateral Heschl's gyrus [17], bilateral parts of the auditory cortex (superior temporal gyrus) [22], and auditory association complex [20] which responds to input

Table 4: BAEPs showing peak latency and peak amplitude for four Sessions in six States for wave V.

Brainstem auditory evoked potentials (BAEPs) in four sessions									
Components	Session	Latency				Amplitude			
		Pre	During	Post	P=(During vs Pre); (Post vs Pre)	Pre	During	Post	P=(During vs Pre); (Post vs Pre)
Wave V	Random Thinking (n= 60)	5.8 ± 0.2	5.8 ± 0.5	5.8 ± 0.2	During vs Pre= 0.042	0.7 ± 0.2	0.7 ± 0.4	0.8 ± 0.3	NS
	Non meditative focused thinking (n= 60)	5.8 ± 0.2	5.8 ± 0.4	5.8 ± 0.6	During vs Pre= 0.009; Post vs Pre= 0.001	0.8 ± 0.2	0.7 ± 0.1	0.7 ± 0.2	NS
	Meditative Focused thinking (n= 60)	5.7 ± 0.2	5.9 ± 0.2	5.8 ± 0.2	Post vs Pre= 0.018	0.7 ± 0.2	0.8 ± 0.2	0.8 ± 0.4	NS
	Meditation (n= 60)	5.8 ± 0.2	5.8 ± 0.2	5.8 ± 0.8	NS	0.8 ± 0.2	0.7 ± 0.2	0.8 ± 0.2	NS

NS: Non Significant

Table 5: MLAEPs showing peak latency and peak amplitude for four Sessions in six States for Na wave, Pa wave and Nb wave.

Midlatency auditory evoked potentials (MLAEPs) in four sessions									
Components	Session	Latency				Amplitude			
		Pre	During	Post	P=(During vs Pre); (Post vs Pre)	Pre	During	Post	P=(During vs Pre); (Post vs Pre)
Na Wave	Random Thinking (n= 60)	16.0 ± 1.6	16.5 ± 2.0	16.1 ± 1.8	NS	0.6 ± 0.5	0.5 ± 0.4	0.5±0.4	NS
	Non meditative focused thinking (n= 60)	16.2 ± 1.8	16.3 ± 1.9	16.3 ± 2.1	NS	0.6 ± 0.5	0.5 ± 0.4	0.4±0.4	NS
	Meditative Focused thinking (n= 60)	16.0 ± 1.6	16.4 ± 1.7	16.0 ± 1.6	NS	0.5 ± 0.5	0.5 ± 0.4	0.6±0.6	NS
	Meditation (n= 60)	16.0 ± 1.6	16.5 ± 1.7	16.1 ± 1.9	During vs Pre= 0.032	0.5 ± 0.4	0.5 ± 0.4	0.6±0.6	NS
Pa Wave	Random Thinking (n= 60)	34.8 ± 2.8	34.6 ± 2.8	35.2 ± 2.7	NS	1.3±0.5	0.9 ± 0.4	1.3±0.6	During vs Pre= 0.001
	Non meditative focused thinking (n= 60)	35.0 ± 2.5	35.4 ± 1.7	35.5 ± 2.4	NS	1.2±0.6	0.9±0.4	1.4±0.6	During vs Pre= 0.001
	Meditative Focused thinking (n= 60)	34.9 ± 2.6	35.7 ± 2.4	35.2 ± 3.2	NS	1.3±0.5	1.1±0.5	1.3±0.5	During vs Pre= 0.004
	Meditation (n= 60)	16.0 ± 1.6	16.5 ± 1.7	16.1 ± 1.9	During vs Pre= 0.011	1.3±0.6	1.1±0.6	1.3±0.6	During vs Pre= 0.041
Nb Wave	Random Thinking (n= 60)	52.7 ± 9.0	53.0 ± 8.3	54.8 ± 9.0		0.4±0.3	0.3±0.3	0.5±0.4	NS
	Non meditative focused thinking (n= 60)	53.8 ± 9.1	55.9 ± 8.3	56.9 ± 9.0	Post vs Pre = 0.018	0.4±0.4	0.4±0.3	0.5±0.4	NS
	Meditative Focused thinking (n= 60)	53.4 ± 9.0	55.1 ± 8.3	54.7 ± 8.8	NS	0.5±0.4	0.4±0.4	0.5±0.4	NS
	Meditation (n= 60)	53.3 ± 8.7	55.4 ± 7.9	54.9 ± 8.5	NS	0.4±0.4	0.5±0.4	0.5±0.4	NS

NS: Non Significant

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Table 6: LLAEPs showing peak latency and peak amplitude for four Sessions in six States for P1 wave, N1 wave, P2 wave and N2 wave.

Long latency auditory evoked potentials (LLAEPs) in four sessions									
Components	**Session**	**Latency**				**Amplitude**			
		Pre	During	Post	P=(During vs Pre); (Post vs Pre)	Pre	During	Post	P=(During vs Pre); (Post vs Pre)
P1 Wave	Random Thinking (n= 60)	46.5 ± 7.9	47.0 ± 0.8	48.5 ± 8.3	NS	1.2 ± 1.0	0.6 ± 0.5	1.0 ± 0.7	During vs Pre 0.002
	Non meditative focused thinking (n= 60)	47.3 ± 8.3	46.6 ± 0.8	48.4 ± 8.1	NS	1.0 ± 0.8	0.8 ± 0.6	1.0 ± 0.7	During vs Pre 0.001
	Meditative Focused thinking (n= 60)	48.1 ± 9.7	47.8 ± 0.1	50.4 ± 9.0	NS	1.2 ± 1.0	1.0 ± 0.9	1.1 ± 0.8	NS
	Meditation (n= 60)	48.7 ± 9.5	46.7 ± 0.4	47.8 ± 7.9	NS	1.0 ± 0.7	0.9 ± 0.6	1.0 ± 0.6	NS
N1 Wave	Random Thinking (n= 60)	98.7 ± 14.6	97.6 ± 2.3	100.5 ± 15.8	NS	0.6 ± 0.5	0.4 ± 0.4	0.5 ± 0.4	NS
	Non meditative focused thinking (n= 60)	97.5 ± 15.2	100.3 ± 2.0	103.3 ± 15.1	NS	0.4 ± 0.3	0.4 ± 0.3	0.4 ± 0.4	NS
	Meditative Focused thinking (n= 60)	98.2 ± 15.1	99.1 ± 1.7	101.1 ± 15.1	NS	0.4 ± 0.4	0.4 ± 0.5	0.5 ± 0.5	NS
	Meditation (n= 60)	98.8 ± 14.2	99.3 ± 1.0	100.8 ± 15.7	NS	0.3 ± 0.4	0.7 ± 1.8	0.4 ± 0.4	NS
P2 Wave	Random Thinking (n= 60)	154.9 ± 13.5	154.9 ± 2.4	155.0 ± 12.4	NS	0.9 ± 0.8	0.5 ± 0.5	0.8 ± 0.6	During vs Pre= 0.001
	Non meditative focused thinking (n= 60)	155.7 ± 10.4	155.5 ± 1.1	156.6 ± 11.5	NS	0.8 ± 0.5	0.6 ± 0.6	0.9 ± 0.5	During vs Pre= 0.006
	Meditative Focused thinking (n= 60)	157.7 ± 14.2	154.5 ± 2.8	153.9 ± 11.5	NS	0.9 ± 0.6	0.7 ± 0.5	0.9 ± 0.6	NS
	Meditation (n= 60)	158.2 ± 9.2	153.3 ± 1.3	151.8 ± 9.1	Post vs pre= 0.005	0.8 ± 0.6	0.7 ± 0.6	0.8 ± 0.5	NS
N2 Wave	Random Thinking (n= 60)	221.6 ± 3.1	222.1 ± 0.3	222.6 ± 3.7	NS	0.4 ± 0.4	0.3 ± 0.3	0.4 ± 0.4	During vs Pre= 0.007
	Non meditative focused thinking (n= 60)	222.3 ± 3.7	222.4 ± 0.5	222.3 ± 3.5	NS	0.4 ± 0.3	0.3 ± 0.2	0.3 ± 0.3	During vs Pre= 0.049
	Meditative Focused thinking (n= 60)	223.21±6.0	221.92 ± 0.7	222.0 ± 3.4	NS	0.4 ± 0.5	0.3 ± 0.3	0.4 ± 0.3	NS
	Meditation (n= 60)	223.1 ± 5.6	223.1 ± 0.6	223.0 ± 5.6	NS	0.4 ± 0.3	0.4 ± 0.5	0.3 ± 0.2	NS

NS: Non Significant

from all sensory modalities [22] and left superior temporal gyrus and bilateral medial temporal lobe structure [23]. The peak latency and peak amplitude of LLAEP components (100 – 300 ms) were measured [24,25]. The neural generators of these components are given in Table 3. A typical trace is shown in Figure 3.

There were decreased peaks amplitudes of the P1 and P2 waves after random thinking and non-meditative focusing and the N2 wave after non-meditative focusing suggesting that the neural activity was reduced at the level of secondary auditory cortex, auditory association complex and anterior cingulate cortex, respectively [26]. The reason for decrease in P1, P2 and N2 amplitudes may be due to selective inhibition of certain areas within the primary, auditory association complex and secondary auditory cortex suppressing sensory responses to reduce distracting auditory stimuli, which could prevent the participants directing their attention on instructions [27] during random thinking and non-meditative focusing. The traces of MLAEPs before and after meditation are given in Figure 3a and 3b respectively.

P300 auditory oddball paradigm

The P300 component of event-related potentials (ERPs) is considered a cognitive neuro-electric phenomenon because it is generated in psychological tasks when subjects attend to and discriminate between stimuli that differ from one another in some dimension [28]. It is also called the "oddball" paradigm since subjects are required to distinguish between frequent and rare stimuli presented as a random series; responding to the rare (target) stimulus and ignoring the frequent stimuli. The generation of a P300 positive deflection is believed occur from the interaction between the frontal lobe and hippocampal and temporoparietal function [29]. The primary neural generator for the P300 components are in the anterior cingulate and hippocampal formation [30].

There was a significant reduction of the P300 peak amplitude after random thinking session (*cancalata*) whereas the peak amplitude significantly increased after focused meditation (*dharana)* and meditation without focusing *(dhyana)* [31]. These results show that following meditation with focusing and meditation without focusing, the ability to perform the P300 auditory oddball task was better, while after a session of equal duration of random thinking reduced. The neuro-electric events which underlie the P300 arise from the interaction between the frontal lobe; hippocampus and temporo-parietal function parts of the brain known to be involved in meditation [28] (Figure 4).

Summary

Auditory evoked potentials, a noninvasive method of evaluating auditory information transmission from the periphery to the center. Brainstem, mid latency, long latency, and P300 auditory event related potentials were recorded in meditation, meditative focusing, random thinking and non-meditative focused thinking. The findings

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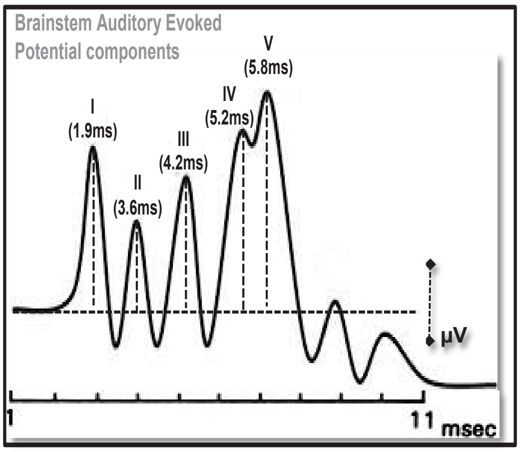
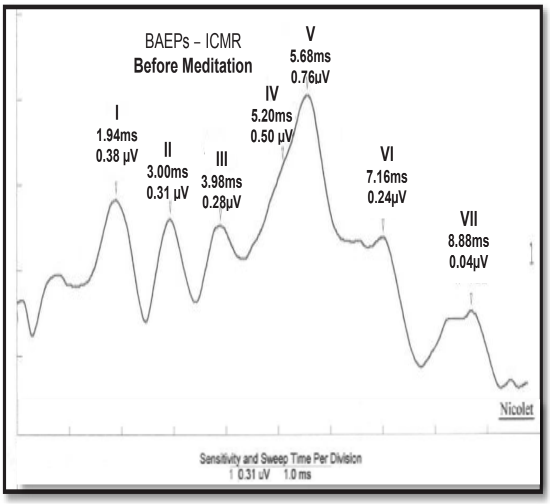


i) Traces of BAEPs before and after meditation

a. Before Meditation



b. After Meditation (with reduced wave V peak latency)

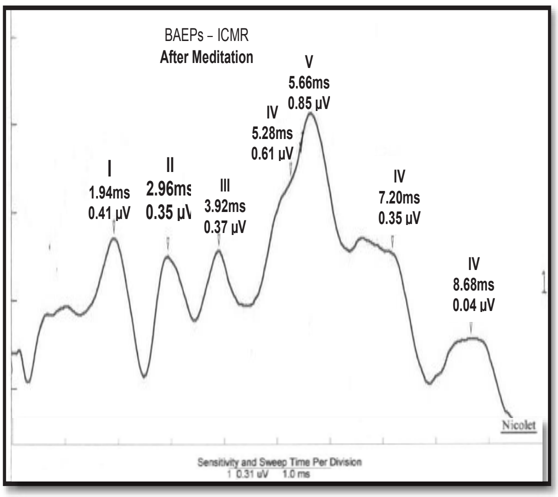
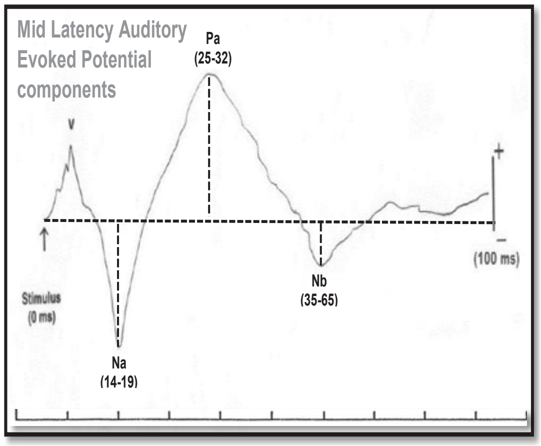


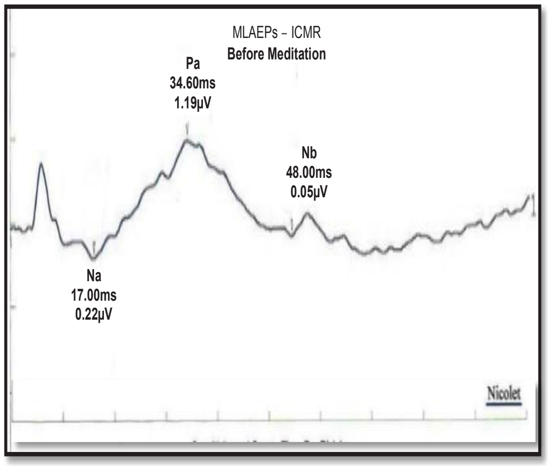
Figure 1: Typical Trace of BAEPs.

i) Typical Trace of MLAEPs



ii) MLAEPs Traces before and after meditation

a. Before Meditation



b. After Meditation (with reduced Na, Pa peak latency)

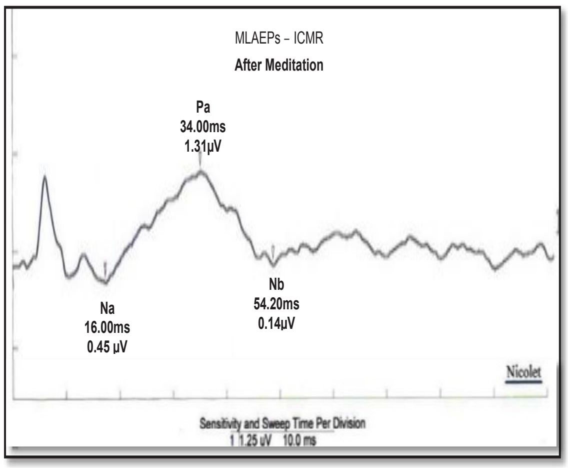


Figure 2:

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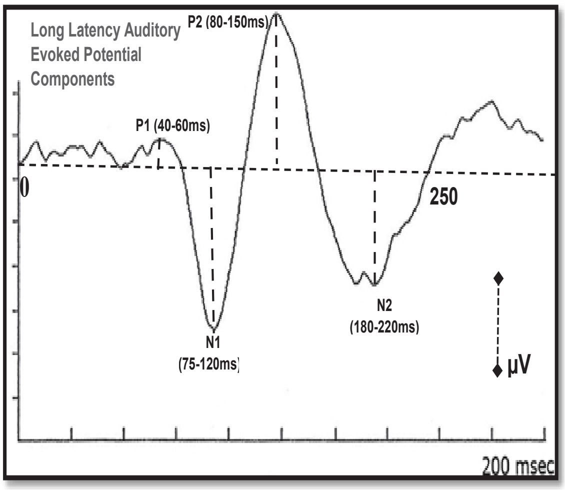
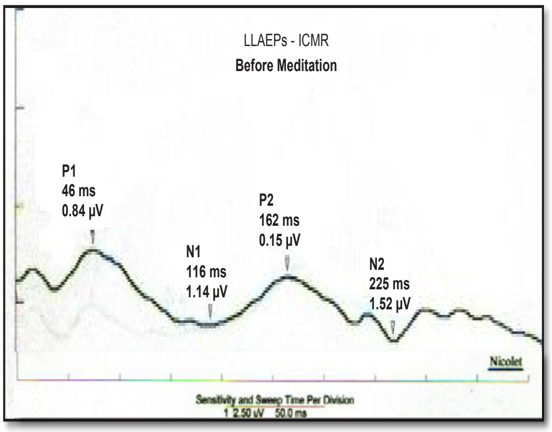
i) Typical Trace of LLAEPs



ii) Traces of LLAEPs before and after meditation

a. Before Meditation



b. After Meditation (with reduced P2 wave peak latency)

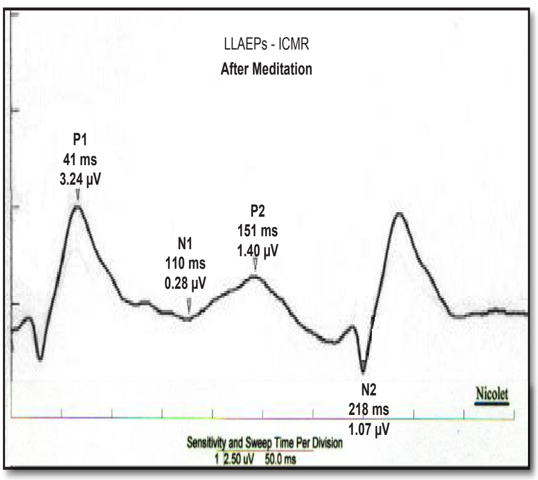
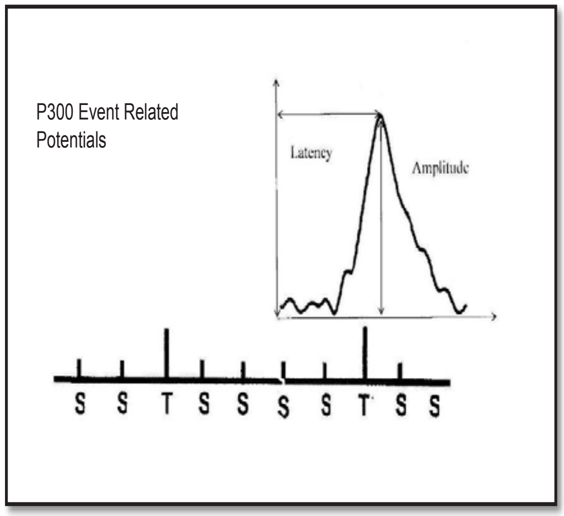


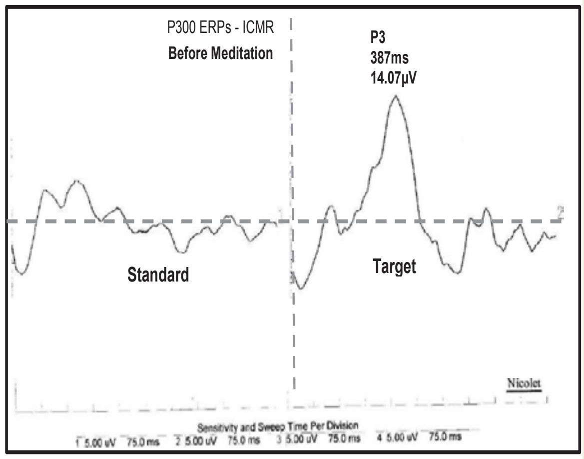
Figure 3:

i) Typical Trace of P300 ERPs



ii) Traces of P300 ERPs before and after meditation

a. Before Meditation



b. After Meditation (with increase P300 peak Amplitude)

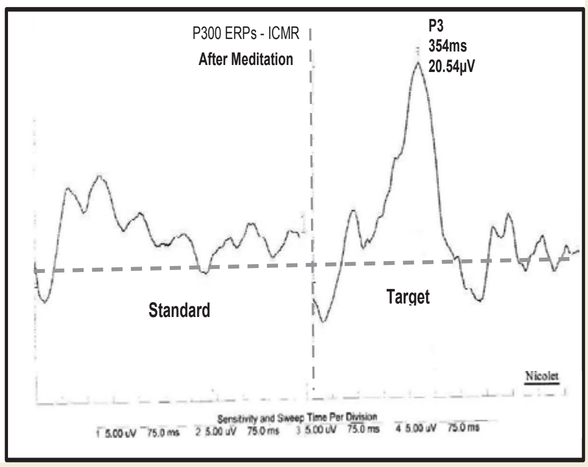


Figure 4:

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demonstrated that meditation had distinctly different effects compared to the other three states.

In summary during meditation there was:

i) A decrease in the brainsteim auditory evoked potentials at wave V peak latency suggesting reduces the speed of transmission in the midbrain (inferior colliculous).

ii) Peak latencies of midlatency of Na and Pa wave were reduced suggesting reduction in speed of transmission ot mesencephalic – diencephalic region and Heschle's gyrus.

iii) The peak amplitude of the P2 component of LLAEPs, evoke potentials was increase suggesting involvement of large area within the auditory association cortex along with recruitment of more neurons.

iv) P300 amplitude of auditory event related potentials increased while the latency reduced suggesting improved attention for the auditory oddball.

Hence, meditation is distinct state in which attention to auditory stimuli improve while the speed of auditory information up to the primary appears to be slower.

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Measures of mindfulness and anxiety in OM meditators and non-meditators: A cross-sectional study

Abstract

Background: Meditation has been shown to be an effective practice of mindfulness and psychological health. The aim of the study was to explore this relationship and to investigate the role of meditation on mindfulness skills and psychological health. **Materials and Methods:** Sixty-seven long-term 'Om' meditation practitioners and equal number of normal healthy subjects matched to the meditators on age (meditators: 23.96 ± 3.25 years; non-meditators: 21.72 ± 3.44 years), years of education (meditators: 15.13 ± 1.57 years: non-meditators: 14.12 ± 1.76 years) participated in the study. Anxiety and mindfulness were measured by the State-Trait Anxiety Inventory (STAI) and Freiburg Mindfulness Inventory (FMI), respectively. Statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS) software version 18.00 (SPSS Inc., Chicago, USA). The mindfulness and state and trait anxiety scores were analyzed using one-way analysis of variance (ANOVA) and independent *t*-test. **Results:** The meditator group showed significantly lower state ($P < 0.001$) and total anxiety ($P < 0.001$) as compared to the non-meditation group. 'Om' meditation practice was positively correlated to mindfulness ($P < 0.001$), acceptance ($P < 0.001$), and presence ($P < 0.05$); and negatively correlated to state ($P < 0.01$) and total anxiety ($P < 0.001$). **Conclusions:** The practice of meditation was associated with higher levels of mindfulness and lower levels of psychological anxiety.

Key words: Anxiety, mindfulness, Om meditation, state and trait

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INTRODUCTION

Mindfulness meditation is an ancient concept, grounded in a wide range of spiritual and religious traditions, including Yoga, Tai Chi, Buddhism, Zen, Taoism, Hinduism, etc. In Buddhist literature, mindfulness is described as the awareness that emerges through paying attention, on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment.[1] Meditation can be defined as the intentional self-regulation of attention from moment to moment through which mindfulness is cultivated.[2] In the Indian yogic tradition 'Om' is one of the fundamental symbol of meditation. It is the symbol of reality from which arises the three letters; namely, A, U, and M.[3] 'Om' meditation helps to enhance the awareness or mindfulness to all incoming sensations, emotions, and thoughts from moment to moment without focusing on any of them.[4]

During the last decade, scientific interest in meditation and mindfulness practice has an explosive and unprecedented surge. Long-term practice of meditation has been found to improve sustained attention, general well-being, mental health, enhance potency of positive feelings, and reduce anxiety.[5,6] Additionally, meditation training has been shown to improve levels of mindfulness attention, working memory, and creativity.[7] Practicing meditation may reduce psychophysiological arousal, improve concentration, selective attention, and visual scanning abilities compared to resting in a supine posture.[8,9] Mental chanting of Om (with experience of 5-20 years) showed an increase in the efficiency with which sensory information was processed as revealed by activated higher neural centers, that is, the association cortices leading to a single thought state, and a subjective feeling of deep relaxation.[10] A cyclical combination of yoga postures and supine rest in cyclic meditation (CM) improved memory scores immediately after the practice and decreased state anxiety more than rest in a classical yoga relaxation posture (*shavasana*).[9] Mindfulness meditation and gentle yoga improve mood and affective processes and are associated with improvements in immune system functioning, stress, and emotional regulation.[11] Meditation practice stabilizes the mind and decrease mental proliferation which are helpful to cultivate the ethical qualities, that is, compassion, mindfulness, loving kindness, and forgiveness. Practicing open monitoring meditation techniques try to enlarge the attentional focus to all incoming sensations, emotions, and thoughts from moment to moment without focusing on any of them is associated with increased theta activity.[12] A recent study found that 3 days of meditation training was effective at reducing pain ratings and sensitivity, as well as anxiety scores when compared to baseline and other manipulations, such as relaxation and a math distracter task. A similar training regimen improved mood and reduced heart rate when compared to a sham meditation and control group.[13] Finally, meditation is defined as a family of complex emotional and attentional regulatory strategies developed for various ends, including the cultivation of well-being and emotional balance.

There are no previous studies reporting mindfulness levels of individuals practicing meditation on the syllable 'Om'. Therefore, the present study was designed to measure the levels of mindfulness and correlate the same to state and trait anxiety scores.

MATERIALS AND METHODS

Subjects

Sixty-seven Om meditators whose age ranged from 19 to 27 (23.96 ± 3.25 years) were recruited for the study. An equal number of normal healthy male participants ($n = 67$) matched for their age, gender, and years of education were selected. G power (two-tailed) was used to calculate the sample size. With alpha set to 0.05 and power at 0.95, to get an effect size of 0.8, the calculated sample size was 42 in each group.[14,15] The non-meditator group had no previous experience of any form of meditation. All participants were recruited from Swami Vivekananda Yoga Anusandhana Samsthana (S-VYASA)—a Yoga University, Bangalore, India. These participants were recruited by announcements in the University newsletter and flyers on the notice boards. The inclusion criteria were as follows: i) No any chronic illness, particularly psychiatric, or neurological disorders; ii) male volunteers alone; iii) all meditators had been practicing meditation on the Sanskrit syllable, 'Om' for 30-200 min each day, for 5 days in a week; and iv) had a minimum of 1 year experience in meditation. None of the potential participants were excluded using these conditions. The demographic indices of meditators and non-meditators are outlined in Table 1. Signed informed consent was obtained from all participants following a detailed explanation of the study. The study was approved by the Institutional Ethics Committee of the S-VYASA University.

Assessments

This cross-sectional survey aimed to collect data concerning mindfulness and state and trait anxiety using the Freiburg Mindfulness Inventory (FMI) and State-Trait Anxiety Inventory (STAI), respectively.

Table 1: Mean group differences of two groups and standard deviations

Characteristics	Mean ± SD
Mean age	
Meditators	23.6 ± 3.25
Non-meditators	21.72 ± 3.44
Years of education	
Meditators	15.13 ± 1.57
Non-meditators	14.12 ± 1.76
Meditation experience (years)	
Meditators	7.85 ± 2.37

The description of measurements are given below.

The FMI

We used one-dimensional 14-item short version of FMI which was found to be semantically robust and psychometrically stable (Cronbach's alpha = 0.83).[16] All items were scored on a 4-point Likert scale (0: rarely; 1: occasionally; 2: fairly often; 3: almost always). Scores range from 8 to 32, with higher scores indicating higher levels of mindfulness. The FMI measures trait mindfulness and has been shown to have good psychometric properties including a high internal consistency (alpha of 0.86 in an initial validation study), and it has been shown to correlate positively with health indicators.[17] Furthermore, the scale was able to differentiate between mindfulness practitioners and non-practitioners. The two proposed subfacets of the FMI, presence (items 1,2,3,5,7,10), and acceptance (items 4,6,8,9,11,12,14) was then tested separately. This scale is semantically independent from a Buddhist or meditation context and is applicable to all population groups.

State and Trait Anxiety Scale

The anxiety levels were assessed using a questionnaire 'State-Trait Anxiety Inventory' (STAI).[18] This is a self-report assessment anxiety scale, which includes separate measures of state and trait anxiety. State anxiety (S-anxiety) is defined as a transitory emotional state characterized by consciously perceived feeling of tension and apprehension. Trait anxiety (T-Anxiety) refers to relatively stable individual differences in anxiety proneness. Depending on the characteristics of the stressful stimulus conditions, individuals experience differential levels of state anxiety as a function of their level of trait anxiety. The STAI consists of two separate subscales that contain 20 items each. The items are in the form of statements people used to describe themselves. The essential qualities evaluated are feelings of apprehension, tension, nervousness, and worry. Both subscales (S-Anxiety and T-Anxiety) use a 4-point Likert scale to allow the subject to show how often or how much each question applies to them in both situations. It has high internal consistency with Cronbach's alpha of 0.73. Also, the test is designed to take only 20 min at the maximum to reduce the amount of fluctuations in S-Anxiety that could become apparent if the test was to go for a long period of time.

These questionnaires were showing the relations among mindfulness and anxiety in participants of meditator and non-meditator groups.

Data collection

Each participant was assessed in 2 consecutive days at the same time. Participants were requested to use any necessary visual aids (i.e., glasses and contact lenses). On the day 1, participants in each group carried out the FMI first followed by the STAI on the day 2 at a time. To ensure each item was carefully considered and participants were advised they had an unlimited amount of time to complete the questionnaire. Participants received a recording blank with the front page on top and a pencil without an eraser. Participants were instructed as per the instructions stipulated on the manual of the questionnaires. Testing began once participants had confirmed they understood the given instructions. Participants were advised to provide answer as honestly and spontaneously as possible for every statement. The scoring was done by a person who was unaware when the assessment was made and whether the assessment was meditation group or control group.

Statistical analysis

The scores were analyzed using one-way analysis of variance (ANOVA). One-way ANOVA compared mindfulness and state and trait anxiety scores and independent *t*-test were used to compare mindfulness and anxiety of the data in 'Om' meditators and non-meditators. Partial correlation (r) with meditation experience and anxiety and mindfulness is given in Table 1. All statistical analyses were computed at $P \leq 0.05$, two-tailed, using PASW Statistics 18.00 (SPSS Inc., Chicago).

RESULTS

The age and years of education status were reported no significant difference in the meditation and non-meditation groups. An independent sample *t*-test and one-way ANOVA were performed to assess the difference in state and trait anxiety, and mindfulness in both the groups. The groups mean values ± SD, Cohen's d (effect size) for age, years of education, FMI mindfulness (mindfulness, acceptance, and presence), and STAI scores (state, trait, and total scores) are given in Table 2. The analysis on the FMI scores showed that participants in meditation group reported higher mindfulness scores in all three factors, mindfulness ($F = 3.85$, $P > 0.001$, $t = 5.01$), acceptance ($F = 7.152$, $P < 0.001$, $t = 4.78$), and presence ($F = 1.85$, $P = 0.038$, $t = 2.10$) compared to the participants in the non-meditation group. The non-meditation group shows higher anxiety as their state scores of STAI were higher than participants in the meditation group. Results showed that 'Om' meditation group have significantly higher mindfulness and less state anxiety compared to non-meditator group in the age-matched control group.

Partial Correlation (r) with meditation experience and anxiety and mindfulness

As shown in Table 2, the STAI scale and FMI strongly correlated with years of meditation experience. There was negative correlation found between meditation experience and STAI scores (state, trait, and total anxiety), while there was a strong positive correlation between years of meditation practice and FMI mindfulness scores (acceptance and presence). There was also a positive correlation between years of meditation with age and years of education.

DISCUSSIONS

In the present study, long-term meditators reported significantly lower state anxiety and total anxiety scores of STAI and higher level of total mindfulness scores, acceptance, and presence of FMI compared to the non-meditators. There was a strong, positive, partial correlation between experience of meditation with the total scores of mindfulness, acceptance, and presence; while there was a negative correlation with state and total anxiety. The acceptance component of the mindfulness scale is related to the nonjudgmental acceptance of the situation, while mindfulness presence is related to the experience of the moment and a cognitive reelection of all actions.[19] Meditation aims to teach more accepting relationship of one's thought rather than emphasizing the creating of more positive or adaptive thoughts. Longer meditation experience reported more frequent meditation with higher mindfulness and lower psychological distress. However, meditation techniques effectively showed, reduce self-reported state and trait anxiety.[5]

Several studies of meditation to date have reported correlations between self-reported mindfulness and psychological health. For example, Lykins and Baer (2009)[20] reported significantly higher

Table 2: Means and standard deviations, analysis of variance (ANOVA), and partial correlations (control age and years of education) for FMI and STAI scores for meditator and non-meditator groups

Characteristic		Meditators	Non-meditators	F	Percentage change (%)	Cohen's d (effect size)	Partial correlation (r) with meditation experience
State-Trait Anxiety Inventory (STAI)	S-STAI	26.24±10.21	32.75±8.29	16.29***	24.81	0.700	–0.329***
	T-STAI	31.12±10.02	33.44±7.36	2.29 (NS)	7.46	0.263	–0.114 (NS)
	Total-STAI	57.36±9.87	65.69±10.57	22.01***	14.52	0.815	–0.0363***
Freiburg Mindfulness Inventory (FMI)	Mindfulness	45.42±5.22	40.34±6.42	25.05***	11.18	0.868	0.355***
	Acceptance	24.53±4.21	20.81±4.75	22.86***	15.17	0.829	0.328***
	Presence	20.89±3.49	19.54±3.94	4.42*	6.46	0.363	0.176*

*$P < 0.05$, ***$P < 0.001$ significance level, NS = Not significant

levels of mindfulness, self-compassion, and overall sense of wellbeing; and significantly lower levels of psychological symptoms, rumination, thought suppression, fear of emotion, and difficulties with emotion regulation in meditators compared to non-meditators, and changes in these variables were linearly associated with extent of meditation practice. Linehan (1993)[21] describes the development of mindfulness skills as a central goal of several behavior therapy, a leading mindfulness-based intervention. There was a strong consistency between extent of meditation practice with trait mindfulness as well as and other outcome variables, including fear of emotions, rumination, and behavioral correlations.[22] Moreover, participants in the meditation group showed more mindfulness and were also more likely to cope with stress in adaptive ways, particularly using less avoidant-oriented strategies in stress situations.[23] Mindfulness meditation has been found to regulate anxiety. In a recent study on mindfulness meditation reported significant reduction in state anxiety scores after meditation session.[24] In the present study, we reported a strong positive correlation between experience of meditation and state anxiety and total anxiety; but there was no significant relation with trait anxiety. Our findings are consistent with previous studies that have found an inverse relation between mindfulness, stress, and state anxiety.

The trait anxiety represents a generalized tendency to be fearful, worried, and apprehensive about the future. It also reflects individual differences in the frequency and intensity with which anxiety states have been manifested in the past. The stronger trait anxiety may report more intense elevations in state anxiety in a threatening situation. There was no significant difference in trait anxiety of meditators and non-meditators in the present study because participants in both the groups were young and healthy. The immediate effect of a 30 min practice of a meditation technique called CM on state and trait anxiety was measured in normal healthy volunteers, which showed significantly better reduction in state anxiety after the CM and improve memory.[9]

Feldman *et al*., (2010)[25] compared the immediate effects of mindful breathing to alternative stress management techniques (progressive muscle relaxation and loving-kindness meditation) in novice meditators, demonstrated greater decentering when compared to those receiving the two alternative interventions; there was also reduced frequency of repetitive thoughts and negative reactions to thoughts. These findings provide further evidence that cognitive aspects of meditation (e.g., mindful breathing) may create changes in cognitive processes[26] associated with depression and anxiety (e.g., rumination) that are distinct from other validated stress management approaches. Mindfulness meditation is also documented to contribute for better coping in individuals in high stress work environments, such as medical students[5] or business executives, and community members enrolled in a wellness program.

Although studies on neurophysiological changes reported the positive impact of meditation training on brain regions responsible for constructs that are often dysregulated in individuals with depression and anxiety disorders. Recently, majority of functional neuroimaging studies investigated brain regions like the anterior cingulate cortex (ACC) and the insula were shown to be involved in the development and maintenance of anxiety disorders.[27] Meditation-related anxiety relief was associated with activation of the ACC, ventromedial prefrontal cortex, and anterior insula. Meditation-related activation in these regions exhibited a strong relationship to anxiety relief. During meditation, those who exhibited greater default-related activity (i.e., posterior cingulate cortex (PCC)) reported greater anxiety, possibly reflecting an inability to control self-referential thoughts. Meditation showed changes in activation of prefrontal cortex (PFC) and the Anterior Cingulate Cortex (ACC), as well as significant increases in alpha and theta activity.[28] In addition, theta activity was found to be more common in experienced meditators, suggesting that greater meditation expertise may result in improved ability to self-regulate a state of deep relaxation.[29] These findings are important to demonstrate a neurobiological impact of meditation on brain structures and regions (i.e., PFC, hippocampus, and limbic system) that are well-known to be affected in individuals with anxiety and depression. Several other studies show that meditation can reverse some abnormalities, like depression, anxiety, attention deficit, and posttraumatic stress disorder; producing salutary functional and structural changes in the brain. The mindfulness programs reported positive impact on symptoms of anxiety and depression,[30] as well as improvements in sleep patterns and sustained attention.[31] After several researches on meditation and mindfulness; however, clear mechanisms of change have yet to be identified. There are different behavioral, psychological, and biological pathways which have suggested how enhanced mindfulness may displace stress and anxiety-related illness and enhancing adaptive coping processes.

In summary, the present study suggested that, the intense practice of meditation on the symbol 'Om' may enhance mindfulness and reduce anxiety. Meditation techniques have been used to regulate the mind, emotions, and the responses in adverse psychological conditions. Therefore, meditation would be a mind body medicine which helps in the modulation of expectations, inner engagement, anxiety, and self-awareness.

CONCLUSION

In conclusion, the results suggest that mindful person may be less prone to anxiety-related problem. Mindfulness practice will help to increase awareness and problem solving strategies of the present moment which would facilitate effective processing as a means to enhance mental health and well-being. Further study of meditation and mindfulness may help to better disclose how the quality and depth of meditation influence mindfulness and enhancing adaptive strategies for anxiety and its related problems. Also, additional research is needed to clarify the mechanisms of change that are responsible for the beneficial effects of meditation on both psychological and physical health.

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Long Latency Auditory Evoked Potentials During Meditation

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Abstract

The auditory sensory pathway has been studied in meditators using midlatency and short latency auditory evoked potentials. The present study evaluated long latency auditory evoked potentials (LLAEPs) during meditation. Sixty male participants aged between 18 and 31 years (group mean ± SD, 20.5 ± 3.8 years), were assessed in 4 mental states based on descriptions in the traditional texts. They were (*a*) random thinking, (*b*) nonmeditative focusing, (*c*) meditative focusing, and (*d*) meditation. The order of the sessions was randomly assigned. The LLAEP components studied were P1 (40-60 ms), N1 (75-115 ms), P2 (120-180 ms), and N2 (180-280 ms). For each component, the peak amplitude and peak latency were measured from the prestimulus baseline. There was a significant decrease in the peak latency of the P2 component during and after meditation ($P < .001$; analysis of variance and post hoc analysis with Bonferroni adjustment). The P1, P2, and N2 components showed a significant decrease in peak amplitudes during random thinking ($P < .01$; $P < .001$; $P < .01$, respectively) and nonmeditative focused thinking ($P < .01$; $P < .01$; $P < .05$, respectively). The results suggest that meditation facilitates the processing of auditory information in the auditory association cortex, whereas the number of neurons recruited was less in random thinking and non meditative focused thinking at the level of the secondary auditory cortex, auditory association cortex and anterior cingulate cortex respectively.

Keywords
meditation, long latency auditory evoked potentials, yoga

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Introduction

Meditation is a self-regulated conscious process and mental training.[1] The functional changes in the brain during meditation have been studied with various techniques that have different spatial and temporal resolutions.[2]

Evoked potentials have been used in meditation studies, since the correlation between the different components of evoked potentials and the underlying neural generators are fairly well known.[3] Evoked potentials also allow changes in a sensory pathway to be understood, from the periphery through brainstem evoked potentials, to central areas with long latency auditory evoked potentials (LLAEPs).

Brainstem auditory evoked potentials (BAEPs) have been studied in Transcendental Meditation[4] and in practitioners of meditation on *OM*.[5] Midlatency auditory evoked potentials (MLAEPs) have been studied in different meditations, including the eyes-open Brahmakumaris Raj Yoga Meditation,[6] meditation on *OM*,[5-9] and Sahaja Yoga, which involves mental silence and awareness devoid of any thought.[10] The study of short latency AEPs in *OM* meditators (n = 30; meditation experience ≥6 months; Cohen's d = 0.50) suggested that the auditory information transmission was delayed at the inferior collicular level during meditation with focusing.[11] The report on transcendental meditators (n = 5; meditation experience ≥5 years; Cohen's d = 0.35) showed enhanced auditory information transmission following Transcendental Meditation. In trancendental meditation, participants consciously reorient[12(p208)] their attention to the given mantra, whereas in *OM* meditation the attention is allowed to wander.[5] The MLAEPs with Sahaja Yoga meditation[10] (n = 32; meditation experience ≥6 months; Cohen's d = 0.41) and *OM* meditation[9] (n = 60; meditation experience ≥6 months; Cohen's d = 0.47) showed there was a delay in auditory information transmission during meditation at the level of the medial geniculate and primary auditory cortex

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during meditation whereas Brahmakumaris Raja Yoga Meditation (n = 16; meditation experience ≥5 years; Cohen's *d* = 0.61) showed reduction in conduction time.[6] Sahaja Yoga Meditation involves cleansing practices and meditation to reach a state of thoughtless awareness.[13] Brahmakumaris Raja Yoga Meditation is practiced with the attention focused on a series of meaningful thoughts.[14(p96)] For both brainstem and midlatency evoked potentials, the results have differed with each meditation technique. The results of a single study on LLAEPs in Transcendental Meditation are detailed below.[15] Transcendental meditators showed no changes in LLAEPs. LLAEPs assess the higher auditory processing capabilities in central and cortical components of the auditory pathway given the scarcity of data on LLAEPs in meditation the present study was designed to evaluate LLAEPs in practitioners during meditation practiced as described in the ancient texts.

A possible reason for the differences in results with different meditation techniques, even though they all aim at facilitating spiritual evolution, is that they differ in the methods used.[16(p448),17] Most of these techniques have evolved in the past 200 years. This is relatively recent compared to the ancient texts (eg, Patanajli's *Yoga Sutras*; circa 900 BC). The present study has attempted to overcome the possible cause for differences by assessing the effects of meditation when practiced as described in traditional yoga texts.[5]

The first, most recent and comprehensive compilation of descriptions in the ancient texts is the Patanjali's *Yoga Sutras* (circa 900 BC). There are 2 meditative states described here. The first is meditative focusing (called *dharana* in Sanskrit) during which the mind is confined to a fixed and defined area of functioning. This is often considered a preparatory phase (Patanjali's *Yoga Sutra*, chapter III, verse 1). The second state is considered the actual meditation (called *dhyana* in Sanskrit), characterized by effortless, mental expansion (Patanjali's *Yoga Sutra*, chapter III, verse 2). During this stage there is an uninterrupted flow of the mind toward the object of meditation.

When not in meditation, it is said that the mind may be in 2 other states. These are random thinking (called *cancalata* in Sanskrit; *Bhagavad Gita*, chapter VI, verse 34; circa 400-600 BC) and nonmeditative focused thinking (called *ekagrata* in Sanskrit; *Bhagavad Gita*, chapter VI, verse 12).

Brainstem and midlatency auditory evoked potentials have been recorded during these four states with an encouraging degree of intersubject consistency.[5,9] LLAEPs have not been studied in these 4 states. In fact there is just one study on LLAEPs during Transcendental Meditation.[15] In that study, LLAEPs were recorded in 8 experienced meditators (meditation experience ≥6 years; Cohen's *d* = 0.18), before during and after meditation and also during light sleep. No consistent changes were noted between baseline and meditation auditory evoked potentials or between meditation and sleep.

Hence the present study was designed to assess the LLAEPs during the 4 mental states described above, to determine whether the differences in mental states would cause changes in the LLAEP components based on changes in the underlying neural generators.

Materials and Methods

Participants

Sixty males with ages between 18 and 31 years (group mean ± SD, 20.5 ± 3.8 years) were recruited as participants by announcements in the university newsletter and flyers on the notice boards. Statistical calculation of the sample size was not done prior to the experiment. However, post hoc analyses showed that for the present study, with the sample size as 48 used for final analysis, in each session (selected from the 60, as mentioned below), and with the Cohen's *d* = 0.70, the power was 0.95.[18] Cohen's *d* was obtained from the P2 component peak latency in the meditation session when "during" values were compared with "pre" values. Participants were all students of a yoga university in south India. Twelve participants were excluded from the study because of motion artifact in the signals or because of high electrode impedance during the recordings. Hence, the data from 48 participants with ages ranging from 17 to 30 years (group mean age ± SD, 19.3 ± 2.6 years) were included for the final analysis. To be included in the trial, participants had to meet the following criteria: (*a*) have normal health based on a routine clinical examination; (*b*) male volunteers alone were studied as auditory evoked potentials are known to vary with the phases of the menstrual cycle[19]; (*c*) have a minimum experience of meditation on the Sanskrit syllable *OM*, for 30 minutes each day, for 5 days in a week; and (*d*) the participants had to have meditation practice for a minimum of 3 months (with a group average experience ± SD of 20.9 ± 14.2 months). The exclusion criteria were (*a*) persons on any medication or herbal remedy; (*b*) presence of any illness, particularly psychiatric or neurological disorders; and (*c*) any auditory deficit. None of the participants were excluded based on these criteria. The baseline characteristics of participants are given in Table 1.

The project was approved by the ethics committee of the university. The study protocol was explained to the participants and their signed informed consent was obtained. Participants were not given any incentive to take part in the study.

Table 1. Characteristics of 48 Participants.

Characteristics	
Age in years (group mean ± SD)	19.3 ± 2.6
Years of education, n (%)	
≥17	17 (35.4)
Up to 15	23 (47.9)
Up to 12	8 (16.7)
Type of meditation	Meditation on the Sanskrit syllable *OM*
Experience of meditation practice in months, n (%)	
6-12	23 (48.9)
13-24	9 (19.2)
25-36	7 (14.9)
37-48	6 (12.8)
48-60	2 (4.3)
Socioeconomic status,[36] n (%)	
High-income group	9 (18.7)
Mid-income group	33 (68.7)
Low-income group	6 (12.5)

Design of the Study

Despite the fact that participants had prior experience of *OM* meditation, all participants were given a 3-month orientation program guided by an experienced meditation teacher. The purpose of this orientation was for all participants to practice the 2 different states of meditation, namely, meditative focusing and effortless meditation, based on specific instructions following a uniform method.

Each participant was assessed in 4 sessions, to which they were assigned randomly. The sessions were randomized using a standard random number table. Two of them were meditation sessions. These were (*a*) meditative focusing (*dharana* in Sanskrit) and (*b*) meditation without focusing or effortless meditation (*dhyana* in Sanskrit). The other 2 sessions were nonmeditation sessions. They were (*a*) nonmeditative focused thinking (*ekagrata* in Sanskrit) and (*b*) random thinking (*cancalata* in Sanskrit). All 4 sessions consisted of 3 states: before (5 minutes), during (20 minutes), and after (5 minutes). The design is presented schematically in Figure 1.

Assessment Procedure

Recording Conditions. Long latency auditory evoked potentials were assessed in the 4 sessions, that is, random thinking (cancalata), nonmeditative focused thinking (ekagrata), meditative focusing (dharana), and meditation (dhyana). Participants were seated in a sound attenuated, dimly lit cabin with sound level 26 dB normal hearing level and monitored on a closed circuit television to detect if they moved or fell asleep during a session. Instructions were given through a 2-way intercom, so that participants could remain undisturbed during a session. The LLAEPs were recorded with eyes closed and participants seated at ease. The temperature in the recording room was maintained at 24.0°C ± 1.0°C. The average humidity was 56% on the days the experiments were conducted. LLAEPs were recorded in the 250-ms, poststimulus time period without any prestimulus delay, using a 4-channel system (Nicolet Biomedical Inc, Madison, WI).

Electrode Positions. Ag/AgCl disk electrodes were fixed with electrode gel (10-20 conductive EEG paste) at the vertex (Cz) with reference electrodes on linked earlobes (A1-A2) and with the ground electrode on the forehead (FPz). Electrode placements were based on the international 10-20 electrode placement system.[20] The electrode impedance was kept less than 5 kohm.

Amplifier Settings. Standard settings for LLAEP recording were used.[21] The EEG activity was amplified with a sensitivity of 100 μV. The low cut filter was 0.1 Hz and the high cut filter was 30.0 Hz. LLAEPs were averaged in 500 trial sweeps in the 0 to 500 ms range. Rejection was set at 90% of the full-scale range of the analog-to-digital converter.

Stimulus Characteristics. Binaural click stimuli of 100-μs duration and alternating polarity at the rate of 5.0 Hz were delivered through acoustically shielded earphones (Amplivox, Kidlington, UK).[21] The threshold of hearing was noted for each participant to verify that their hearing was normal. The threshold of hearing was checked as follows (a) decreasing the intensity in 5-dB steps until the participant could no longer hear the clicks and (b) increasing the intensity in 5-dB steps until the clicks were audible. The click threshold was taken as the midpoint between the intensities at which the clicks could and could not be heard. This procedure was repeated twice. The thresholds ranged between 15 and 25 dB normal hearling level (nHL). The average threshold of hearing was 14.03 ± 2.98 dB nHL. The intensity was kept at 70 dB nHL. Participants had 100% compliance to the meditation orientation program and for the recordings.

Interventions

Random Thinking (Cancalata). Participants were asked to allow their thoughts to wander freely as they listened to a compiled audio CD consisting of brief periods of conversation, announcements, advertisements, and talks on diverse topics recorded from a local radio station transmission. These conversations were not connected and hence it was thought that listening to them could induce a state of random thinking.

Nonmeditative Focused Thinking (Ekagarta). Participants listened to a prerecorded lecture on the process of meditating and the object of meditation, that is, the Sanskrit syllable OM. This was intended to induce a state of nonmeditative focusing.

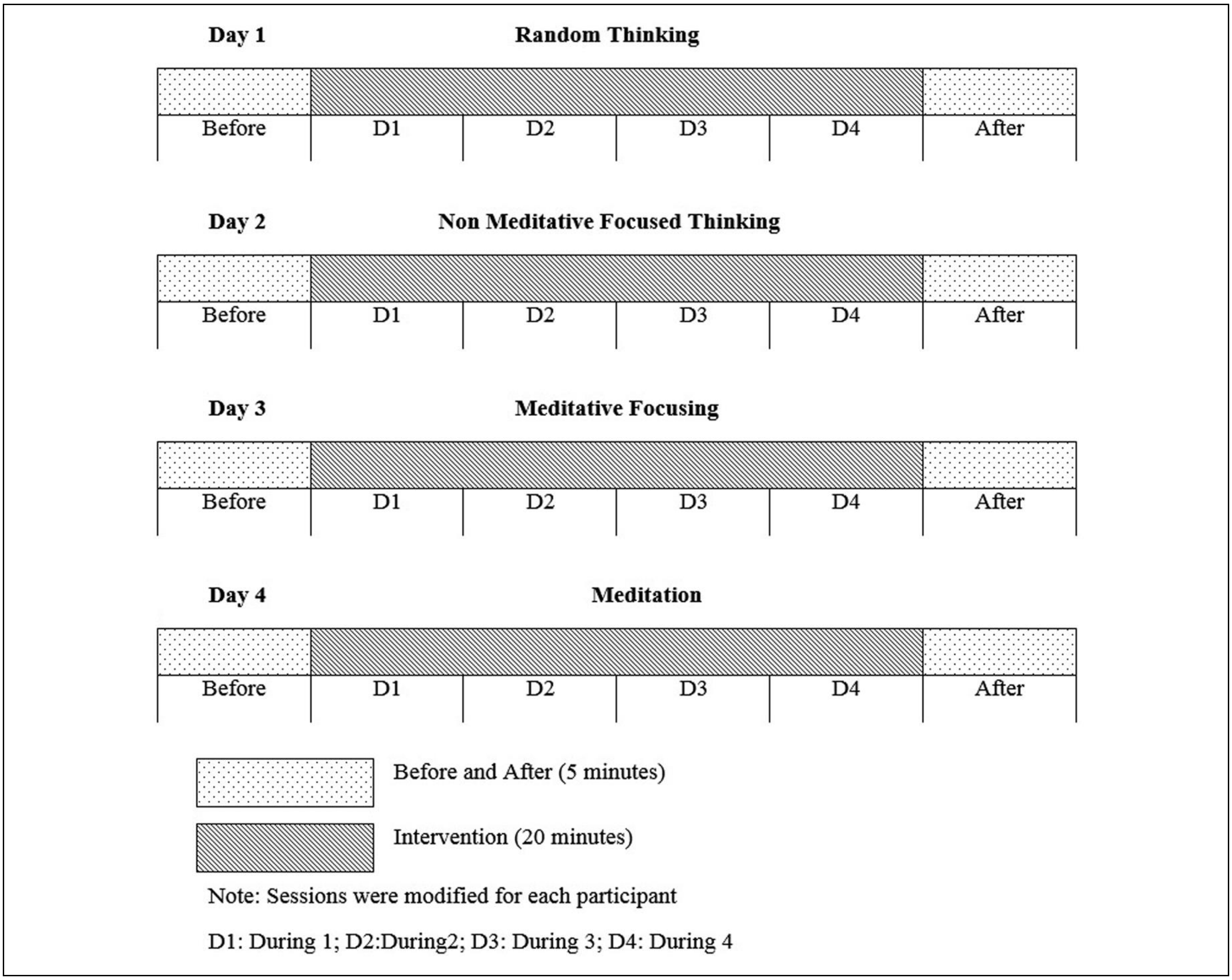

Figure 1. Schematic representation of the study design of the 4 sessions. The long latency auditory evoked potentials (LLAEPs) were recorded before, during and after the intervention. Periods of recording are shown as stippled and periods of intervention are shown as hatched.

Meditative Focusing (Dharana). Participants were asked to open their eyes and gaze at the syllable OM as it is written in Sanskrit. During this time guided instructions required them to direct their thoughts to the physical attributes of the syllable, that is, the shape and color, and then to close their eyes and continue to visualize the syllable mentally. The main emphasis during meditative focusing was that thoughts are consciously brought back (if they wander) to the single thought of OM.

Meditative Defocusing or Effortless Meditation (Dhyana). During this session participants were instructed to keep their eyes closed and dwell on thoughts of OM, without any effort, particularly on the subtle (rather than physical) attributes and connotations of the syllable. This would gradually allow the participants to experience brief periods of silence, which they reported after the session.

Data Extraction

Long latency auditory evoked potential components, namely, P1, N1, P2 and N2 waves were measured from a zero DC baseline. Peak latency was measured from the time of click delivery. The peak latencies and peak amplitudes of the following components were measured, the P1 wave between 40 and 60 ms, is the maximum positive peak preceding the N1 wave which is a negative component between 80 and 115 ms. The P2 wave is a positive component between 140 and 180 ms. It is also the first maximum positive component preceding the N2 wave component, which is between 200 and 280 ms.[22] Components of LLAEPs and their neural generators are described in Table 2.

Table 2. Components of Long Latency Auditory Evoked Potentials (LLAEPs) and Their Neural Generators.

LLAEP Components	Latency (ms)	Neural Generator
P1	40-60	Secondary auditory cortex in the lateral Heschl's gyrus
N1	80-115	Bilateral parts of the auditory superior cortex
P2	140-180	Mesencephalic reticular activating system (RAS)
N2	200-280	Anterior cingulate cortex

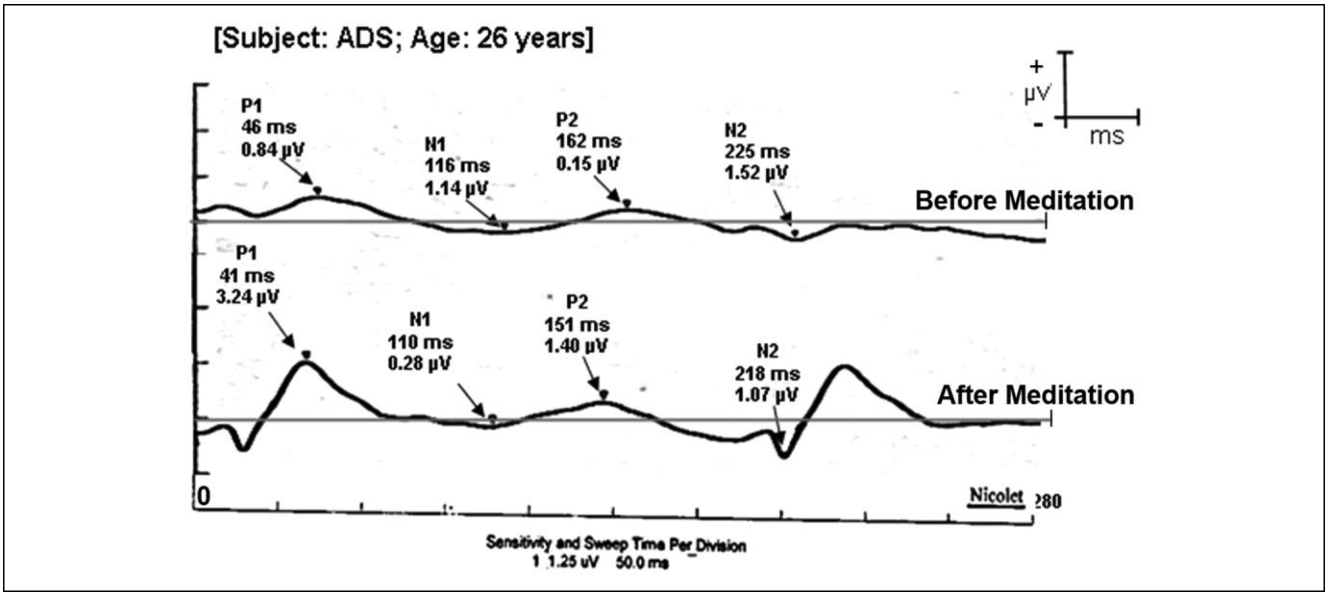

Figure 2. A single sample of a long latency auditory evoked potentials waveform before meditation and after meditation.

Data Analysis

Statistical analysis was done using SPSS (version 16.0). Data were tested for normality by the Kolmogorov–Smirnov test. Since the participants of the experimental group were assessed in repeat sessions on separate days (ie, random thinking, nonmeditative focused thinking, meditative focusing and meditation), the repeated-measures analysis of variance (ANOVA) was used. Repeated-measures ANOVAs were performed with 2 "within subjects" factors, that is, factor 1—sessions such as random thinking, nonmeditative focused thinking, meditative focusing, and meditation, and factor 2—states, that is, Before, During (1-4), and After. Repeated-measures ANOVAs were carried out for each wave of LLAEPs separately, for both peak latencies and peak amplitudes. This was followed by a post hoc analyses with Bonferroni adjustment for multiple comparisons between the mean values of different states ("During" and "After") and all comparisons were made with the respective "Before" state.

Results

The group mean values ± SD for the peak latencies (milliseconds) and peak amplitudes (μV) of P1, N1, P2, and N2 components of LLAEPs in 4 sessions (random thinking, nonmeditative focused thinking, meditative focusing, and meditation) in Before, During, and After states are given in Table 3 (peak latencies) and Table 4 (peak amplitude). A sample LLAEPs waveform is shown in Figure 2.

Repeated-Measures Analysis of Variance

The ANOVA values for the Within-Subjects factor (States), Between-Subjects factor (Sessions) and interaction between the 2 for the different components of LLAEPs are provided in Table 5. A significant interaction between Sessions and States for any component suggests that the 2 are interdependent. Sessions × States interaction was significant for P1 and P2 amplitude; and N1, N2 and P2 latency components of LLAEPs. This significant interaction is graphically presented in Figures 3 and 4.

Post Hoc Analyses With Bonferroni Adjustment

Post hoc analyses with Bonferroni adjustment were performed and all comparisons were made with respective "Before" states. There was a significant decrease in the amplitude of P1, P2, and N2 waves during random

Table 3. Peak Latencies of Long Latency Auditory Evoked Potential (LLAEP) Components for 4 Sessions.

		Latency, Mean ± SD						
		States						
Components	Sessions	Before	D1	D2	D3	D4	After	Cohen's *d*
P1 component	Random thinking	46.48 ± 7.92	47.69 ± 9.54	47.52 ± 7.78	46.71 ± 7.53	45.92 ± 7.51	48.48 ± 8.26	0.247
	Nonmeditative focused thinking	47.33 ± 8.34	47.75 ± 7.76	46.50 ± 7.68	46.04 ± 6.38	46.17 ± 7.33	48.44 ± 8.13	0.135
	Meditative focused thinking	48.15 ± 9.70	47.96 ± 8.23	47.71 ± 7.62	47.69 ± 8.25	47.69 ± 8.87	50.44 ± 9.03	0.244
	Meditation	48.69 ± 9.46	46.48 ± 7.20	47.13 ± 7.22	46.31 ± 6.91	46.96 ± 7.36	47.79 ± 7.90	0.103
N1 component	Random thinking	98.67 ± 14.64	100.65 ± 15.13	97.58 ± 16.34	95.06 ± 15.73	97.25 ± 18.48	100.52 ± 15.81	0.121
	Nonmeditative focused thinking	97.48 ± 15.22	101.75 ± 15.31	101.98 ± 14.81	99.63 ± 15.61	97.73 ± 15.44	103.33 ± 15.09	0.386
	Meditative focused thinking	98.23 ± 15.15	99.98 ± 16.80	98.31 ± 16.19	97.15 ± 15.46	100.94 ± 15.33	101.10 ± 15.11	0.190
	Meditation	98.85 ± 14.18	99.71 ± 16.51	100.46 ± 16.82	98.44 ± 16.26	98.52 ± 16.18	100.85 ± 15.71	0.134
P2 component	Random thinking	154.88 ± 13.54	158.17 ± 15.05	155.02 ± 14.90	152.85 ± 12.75	153.40 ± 13.85	154.98 ± 12.37	0.008
	Nonmeditative focused thinking	155.67 ± 10.38	154.90 ± 12.34	154.29 ± 9.85	156.27 ± 14.75	156.58 ± 12.69	156.60 ± 11.50	0.085
	Meditative focused thinking	157.73 ± 14.16	154.79 ± 11.18	154.88 ± 12.31	150.81 ± 12.80	157.73 ± 12.03	153.90 ± 11.54	0.296
	Meditation	158.23 ± 9.24	151.71 ± 11.83**	153.58 ± 10.36	154.90 ± 10.30	153.15 ± 13.20	151.81 ± 9.06**	0.702
N2 component	Random thinking	221.63 ± 3.13	222.48 ± 7.42	222.19 ± 2.76	221.94 ± 2.90	221.92 ± 2.84	222.58 ± 3.74	0.275
	Nonmeditative focused thinking	222.29 ± 3.72	221.79 ± 3.72	222.88 ± 3.22	222.50 ± 4.78	222.60 ± 3.55	222.31 ± 3.54	0.080
	Meditative focused thinking	223.21 ± 6.04	221.33 ± 4.11	222.85 ± 3.37	221.35 ± 4.51	222.13 ± 2.91	222.04 ± 3.40	0.239
	Meditation	223.10 ± 5.65	223.42 ± 6.32	223.73 ± 7.09	222.29 ± 4.52	222.88 ± 3.08	223.00 ± 5.58	0.018

[a]Values are group means ± SD. Cohen's *d* is calculated for the maximum difference in the post–pre or during–pre comparisons.
**$P < .01$; repeated-measures analysis of variance with Bonferroni adjustment comparing During and Post values with Pre values.

Table 4. Peak Amplitude of Long Latency Auditory Evoked Potential (LLAEP) Components for 4 Sessions.

		Amplitude Mean ± SD						
		States						
Component	Sessions	Before	D1	D2	D3	D4	After	Cohen's *d*
P1 component	Random thinking	1.19 ± 1.01	0.85 ± 0.62	0.65 ± 0.51**	0.82 ± 0.54	0.74 ± 0.61*	1.04 ± 0.67	0.675
	Nonmeditative focused thinking	1.05 ± 0.80	0.79 ± 0.59	0.79 ± 0.58*	0.69 ± 0.54**	0.69 ± 0.50***	0.99 ± 0.74	0.540
	Meditative focused thinking	1.19 ± 0.97	1.02 ± 0.69	0.97 ± 0.86	0.97 ± 0.60	1.01 ± 0.67	1.06 ± 0.78	0.202
	Meditation	0.96 ± 0.66	0.84 ± 0.61	0.90 ± 0.60	0.87 ± 0.72	0.90 ± 0.80	0.97 ± 0.64	0.015
N1 component	Random thinking	0.56 ± 0.51	0.44 ± 0.38	0.44 ± 0.40	0.40 ± 0.29	0.41 ± 0.34	0.50 ± 0.38	0.346
	Nonmeditative focused thinking	0.40 ± 0.31	0.36 ± 0.28	0.38 ± 0.33	0.45 ± 0.38	0.34 ± 0.25	0.42 ± 0.38	0.058
	Meditative focused thinking	0.43 ± 0.43	0.46 ± 0.41	0.44 ± 0.47	0.44 ± 0.46	0.44 ± 0.35	0.54 ± 0.46	0.247
	Meditation	0.31 ± 0.43	0.37 ± 0.36	0.69 ± 1.84	0.43 ± 0.45	0.46 ± 0.39	0.40 ± 0.36	0.227
P2 component	Random thinking	0.95 ± 0.83	0.57 ± 0.42**	0.51 ± 0.46***	0.59 ± 0.51**	0.61 ± 0.40*	0.84 ± 0.57	0.656
	Nonmeditative focused thinking	0.82 ± 0.47	0.66 ± 0.45	0.58 ± 0.47**	0.56 ± 0.47*	0.56 ± 0.37**	0.78 ± 0.47	0.615
	Meditative focused thinking	0.87 ± 0.65	0.71 ± 0.47	0.66 ± 0.62	0.78 ± 0.54	0.72 ± 0.50	0.86 ± 0.60	0.331
	Meditation	0.80 ± 0.57	0.69 ± 0.52	0.68 ± 0.47	0.64 ± 0.41	0.70 ± 0.58	0.80 ± 0.47	0.322
N2 component	Random thinking	0.39 ± 0.36	0.39 ± 0.33	0.35 ± 0.34	0.31 ± 0.26	0.30 ± 0.26**	0.42 ± 0.40	0.679
	Nonmeditative focused thinking	0.41 ± 0.30	0.36 ± 0.25	0.36 ± 0.27	0.34 ± 0.31	0.26 ± 0.23*	0.34 ± 0.28	0.561
	Meditative focused thinking	0.38 ± 0.36	0.42 ± 0.33	0.40 ± 0.37	0.39 ± 0.38	0.34 ± 0.26	0.43 ± 0.29	0.153
	Meditation	0.39 ± 0.33	0.38 ± 0.34	0.35 ± 0.29	0.39± ± 0.35	0.39 ± 0.48	0.28 ± 0.25	0.376

a.Values are group means ± SD. Cohen's *d* is calculated for the maximum difference in the post–pre or during–pre comparisons.
**P* < .05, ***P* < .01, ****P* < .001; repeated-measures analysis of variance with Bonferroni adjustment comparing During and Post values with Pre values.

Table 5. Summary of the Repeated-Measures Analysis of Variance Showing Statistically Significant Results.

Component	Factor	*F* Value	df	Hyunh-Feldt ε	Level of Significance	η_p^2
P1 wave amplitude	Session	4.08	(2.52, 118.6)	0.893	$P < .05$	0.080
N2 wave latency	Session	1.69	(2.19, 102.8)	0.766	$P < .05$	0.035
P1 wave latency	State	3.76	(3.77, 177.04)	0.827	$P < .01$	0.074
P1 wave amplitude	State	10.72	(2.76, 129.57)	0.589	$P < .001$	0.186
N1 wave latency	State	2.86	(4.14, 194.54)	0.918	$P < .05$	0.057
P2 wave amplitude	State	9.74	(4, 187.98)	0.884	$P < .001$	0.172
P1 wave amplitude	Session × State	2.08	(9.59, 450.57)	0.816	$P < .05$	0.043
N2 wave latency	Session × State	0.83	(7.59, 356.64)	0.613	$P < .05$	0.017
P2 wave latency	Session × State	1.93	(10.17, 478.16)	0.880	$P < .05$	0.039
P2 wave amplitude	Session × State	4.02	(9.9, 464.54)	0.849	$P < .001$	0.079

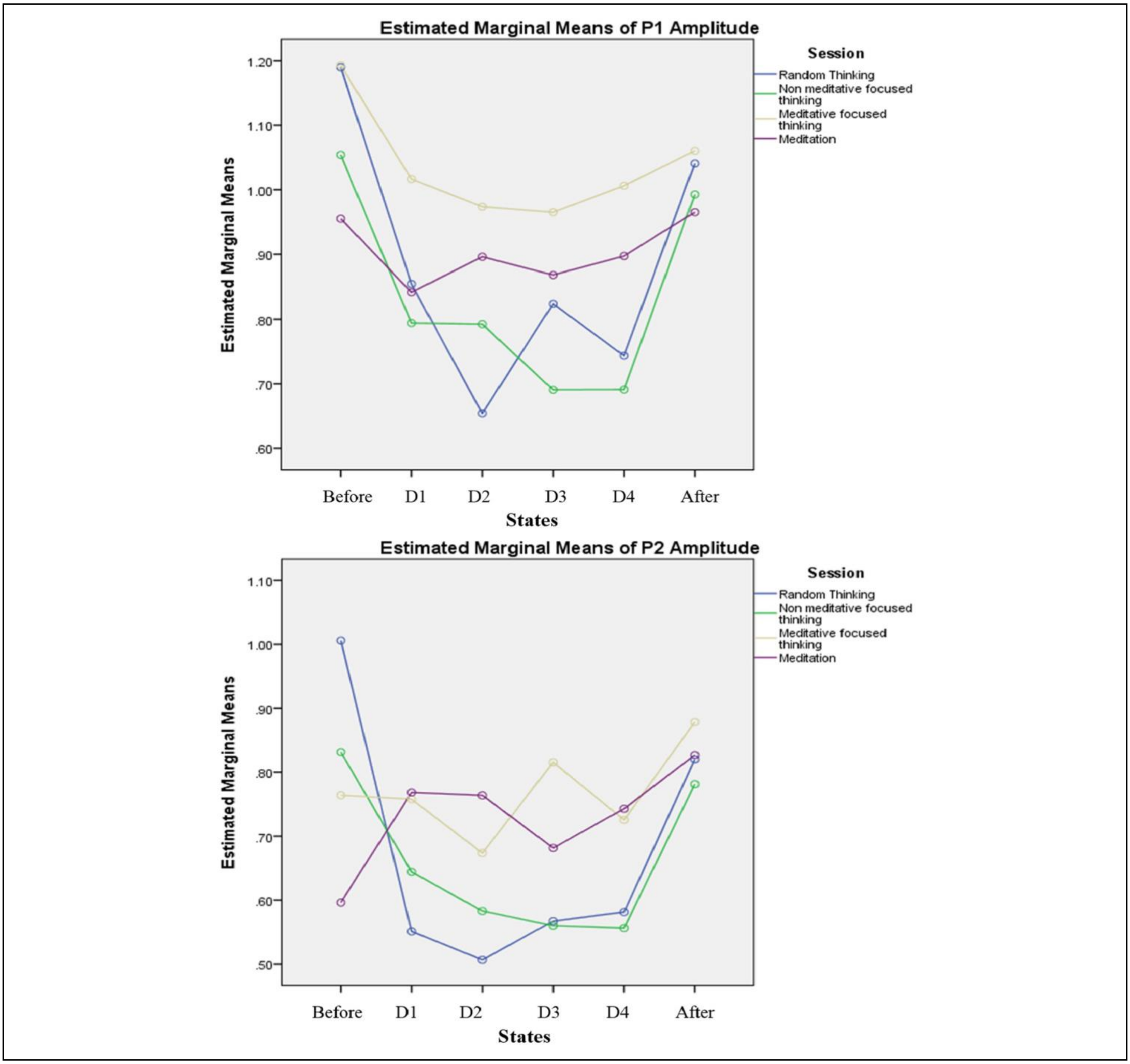

Figure 3. Graphical representation of the interaction between Sessions × States for the amplitude. Dependent variable (peak amplitude in μV) on the *Y* axis, one of the independent variables (States) on the *X* axis, and the other independent variable (Sessions) as separate lines on the graph.

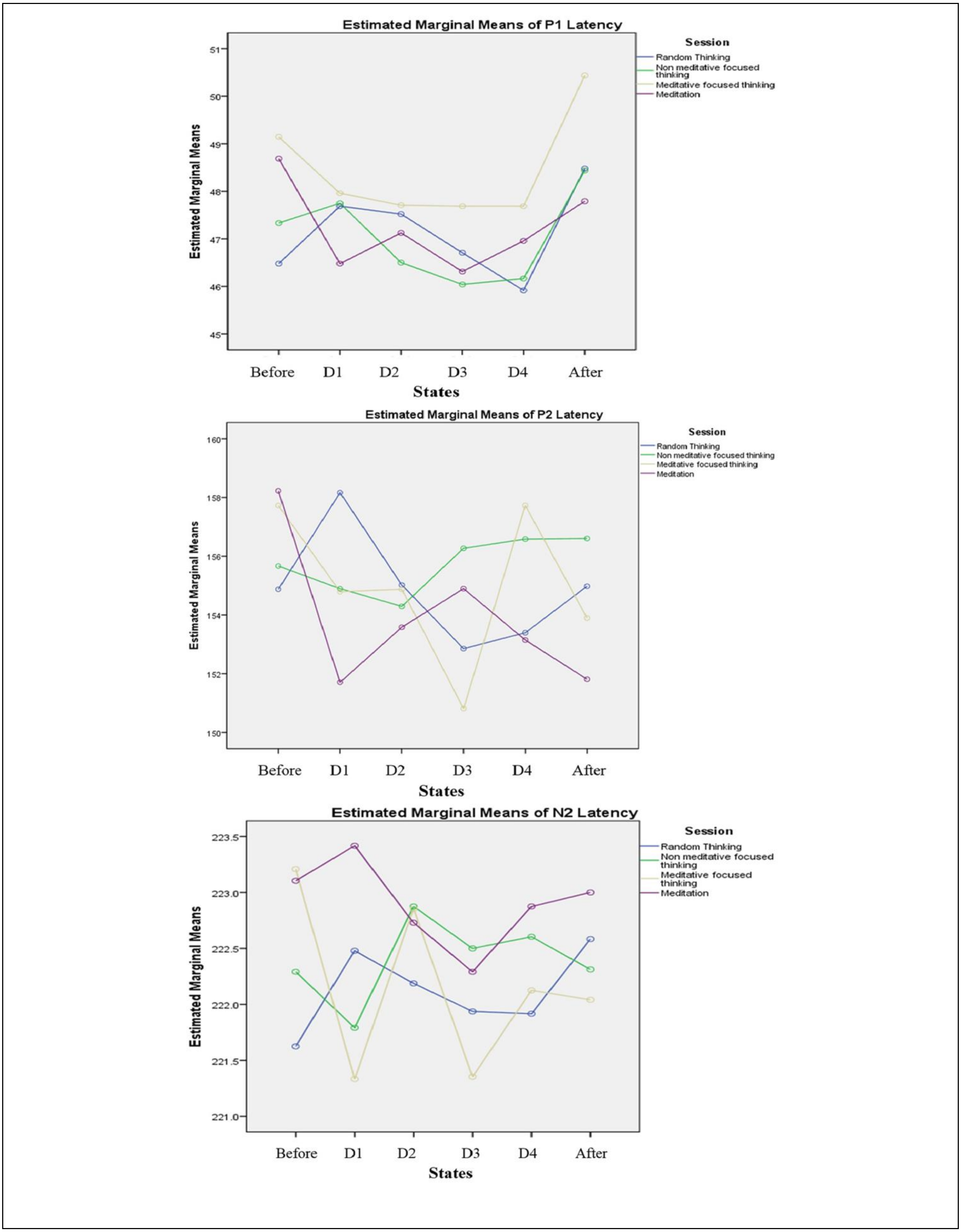

Figure 4. Graphical representation of the interaction between Sessions × States for the amplitude. Dependent variable (peak latency in milliseconds) on the *Y* axis, one of the independent variables (States) on the *X* axis, and the other independent variable (Sessions) as separate lines on the graph.

thinking ($P < .01$; $P < .001$; $P < .01$, respectively) and nonmeditative focused thinking ($P < .01$; $P < .01$; $P < .05$, respectively) and a decrease in the peak latency of the P2 wave during and after meditation ($P < .001$). All comparisons were made with the "Pre" state. Cohen's *d* values were calculated and are provided in Table 3 (peak latencies) and Table 4 (peak amplitude) for the 4 sessions at Cz.

Discussion

Long latency auditory evoked potentials are generated by thalamocortical and corticocortical auditory pathways, the primary auditory cortex and the association cortical areas.[21] The present study assessed LLAEPs during 4 mental states. During meditation the peak latency of the P2 component significantly reduced. A decrease in peak latency is suggestive of a facilitation of auditory sensory transmission because of increased speed of conduction in the underlying neural generators.[23(p278)]

At present the functional significance of the P2 component is not as clear as that of components generated more peripherally. The P2 wave partly reflects auditory output of the mesencephalic activation system.[24,25] Myoelectrography (MEG) studies have attempted to locate the neural generators of the P2 component. Both MEG data and EEG data from depth electrodes implanted in the auditory cortex were collected in the same patients.[26-29] It was found that generators for the P2 component were localized in the planum temporale as well as Brodmann area 22 (the auditory association complex). Other reports have speculated that the P2 component may receive contributions from cortical areas in the depth of the Sylvian fissure.[30] Hence, it remains possible that the P2 component arises from multiple sources with a center of activity close to Heschl's gyrus.[30] The present results suggest that the practice of meditation improves information transmission in areas concerned with complex processing of auditory stimuli as the auditory association cortices are possibly involved.

During the 2 mental states that were considered for comparison, that is, random thinking and non meditative focusing, the peak amplitudes of the P1, P2, and N2 components reduced. A decrease in amplitude suggests that the number of neuronal involvement recruited is less than in the Pre state. The neural generators of the P2 component have been mentioned above. The neuronal sources of the P1 component are difficult to localize due to low signal-to-noise ratio. Also the brain response which generates the P1 component is preceded and followed in time within 10 to 15 ms by several EP components, which arises from sources other than those generating P1.[31] Studies on animal models suggested that neuronal activity in the hippocampus might contribute to sensory gating[32]; however, this was not proved in human recordings.[33] MEG studies have shown that there may be a temporal lobe generator for P1 especially, located bilaterally in the superior temporal gyrus.[34] In addition, the frontal lobe is involved in auditory sensory gating and this activity may contribute to the P1 component. However, the maximum contribution to the P1 activity is from the temporal lobe.[35] The N2 component of auditory evoked potentials helps to evaluate the cognitive processes involved in stimulus classification.[36] The amplitude of the N2 component is directly related to changes in the left superior temporal gyrus and bilateral medial temporal lobe areas.[37] However, this description does not exclude the involvement of other cortical areas in the genesis of the N2 component. In random thinking and nonmeditative focusing sessions, a decrease in amplitude of the P1 and N2 components suggests that the overall neuronal activation and number of neurons recruited in the neural generators underlying these components was less. Other studies reported that the P2 and N2 components decrease in amplitude with a reduction in attention.[38] Since random thinking did not involve focusing of attention, the reduction in amplitude in P2 and N2 components is not surprising. In contrast, the reduction in amplitude in non meditative focusing is surprising as (*a*) participants were asked to focus during the session and (*b*) the nature of focusing was obviously different from meditative focusing as meditative focusing did not reduce P2–N2 amplitudes. The P2 amplitude is also sensitive to shifts in consciousness during the stages of sleep.[39] Based on (*a*) the self-report of the meditators, (*b*) observation of the raw EEG recorded, and (*c*) observation of the participants on the closed circuit TV. Hence, the reduced amplitude of the three components during random thinking and nonmeditative focusing may reflect a decrease in the number of neurons recruited.

The present results are different from the early study conducted on practitioners of Transcendental Meditation. This could be due to differences in the method of meditation and sample size. The sample size was 8 with Cohen's $d = 0.18$ whereas in the present study the sample size was 48 with Cohen's $d = 0.68$.

Hence, evaluating the effect of meditation based on descriptions in the traditional texts has yielded a significant result for long latency auditory evoked potentials. The main difference being, as was already mentioned, that the traditional practices started approximately over 1000 years BC, whereas other techniques have evolved in the past 200 years.

The most important finding was the reduced latency of the P2 component during meditation.

While the findings are reasonably straightforward, the study has the following limitations: (*a*) The evaluation of the quality of practice was based on a self reported visual analog scale (VAS) and hence was subjective. (*b*) Random thinking and nonmeditative focusing were the control conditions. There was no control without any intervention. (*c*) While the participants had been trained to switch between the 4 states, the possibility that they did get into the meditative state inadvertently cannot be ruled out. (*d*) The transcultural generalizability of the results remains to be determined, by conducting similar studies on a non-Indian population. This suggests an area for future research.

Conclusion

The present results suggest that (*a*) meditation facilitates the processing of auditory information in the auditory association cortex and (*b*) random thinking and nonmeditative focusing resulted in fewer neurons being recruited in auditory association areas.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Hemodynamic responses on prefrontal cortex related to meditation and attentional task

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Recent neuroimaging studies state that meditation increases regional cerebral blood flow (rCBF) in the prefrontal cortex (PFC). The present study employed functional near infrared spectroscopy (fNIRS) to evaluate the relative hemodynamic changes in PFC during a cognitive task. Twenty-two healthy male volunteers with ages between 18 and 30 years (group mean age ± SD; 22.9 ± 4.6 years) performed a color-word stroop task before and after 20 min of meditation and random thinking. Repeated measures ANOVA was performed followed by a *post hoc* analysis with Bonferroni adjustment for multiple comparisons between the mean values of "During" and "Post" with "Pre" state. During meditation there was an increased in oxy-hemoglobin (ΔHbO) and total hemoglobin (ΔTHC) concentration with reduced deoxy-hemoglobin (ΔHbR) concentration over the right prefrontal cortex (rPFC), whereas in random thinking there was increased ΔHbR with reduced total hemoglobin concentration on the rPFC. The mean reaction time (RT) was shorter during stroop color word task with concomitant reduction in ΔTHC after meditation, suggestive of improved performance and efficiency in task related to attention. Our findings demonstrated that meditation increased cerebral oxygenation and enhanced performance, which was associated with activation of the PFC.

Keywords: meditation, attention task, Stroop task, fNIRS, cerebral blood flow

INTRODUCTION

Meditation is a complex mental process that aims to calm the fluctuations of the mind and improve cognitive functions. Several meditation techniques from diverse traditions (e.g., Transcendental meditation, Buddhists, Zen, Yoga, Vipassana, Brahmakumari, Mindfulness-based stress reduction (MBSR) etc.,) demonstrated that regular practice of meditation develops awareness to the contents of subjective experience, including thoughts, sensations, intentions, and emotions (Saggar et al., 2012). It is considered as a voluntary means of mental training to achieve greater control of higher mental functions. Traditional yoga texts like Patanjali's Yoga *Sutras* (the Sage Patanjali', *Circa* 900 B.C.) and *Bhagavad Gita* (*Circa* 400–600 B.C.) very well describe the connection between meditation and mental modifications. Traditionally, two states of meditation have been described, viz., (i) focused meditation (*dharana* in Sanskrit, Patanjali's Yoga *Sutras*, Chapter III, Verse 1), and this state is supposed to lead to the next stage of effortless mental expansion i.e., (iii) meditation (*dhyana* in Sanskrit; Patanjali's Yoga *Sutras*, Chapter III, Verse 2). When not in meditation, it is said that the mind may be in two other states (Telles et al., 2012). These are (i) random thinking (*cancalata* in Sanskrit; *Bhagavad Gita*, chapter VI, *verse* 34); and (ii) non-meditative focused thinking (*ekagrata* in Sanskrit; *Bhagavad Gita*, chapter VI, *verse* 12) (Telles et al., 2014).

In recent years, there have been a number of neuroimaging studies showing that meditation improves cognitive performance as signified by behavioral and neurophysiological measures (Tang et al., 2007; Lutz et al., 2009). Previous studies have shown that the practice of meditation enhances behavioral performance viz., perceptual discrimination and sustained attention during visual discrimination task (MacLean et al., 2010). Meditation practice develops the ability to engage the attention onto an object for extended periods of time (Carter et al., 2005; Jha et al., 2007; Lutz et al., 2008). It improves the control over the distribution of limited brain resources in the temporal domain, as measured by the attentional blink task (van Leeuwen et al., 2009; Slagter et al., 2011). Long term meditation practice has been found to enhance cognitive performance (Cahn and Polich, 2006), attentional focus, alerting (Jha et al., 2007), processing speed (Lutz et al., 2009; Slagter et al., 2009), and overall information processing (van Vugt and Jha, 2011). In a study, Buddhist meditation practitioners showed mindfulness meditation was positively correlated with sustained attention, when compared to non-meditation practitioners (Moore and Malinowski, 2009). Improvements in sustained attention and attentional error monitoring demonstrated a positive correlation with increased activation in executive attention networks in meditators (Short et al., 2010). Other studies have shown that meditation is associated with improved conflict scores on the attention network test (Tang et al., 2007), reduced interference (Chan and Woollacott, 2007) and enhanced attentional performance during the stroop task compared to meditation-naïve control group (Moore and Malinowski, 2009). These studies provide significant evidence of meditation promoting the higher-order cognitive processing (Zeidan et al., 2010), particularly, the features of conflict monitoring and cognitive control processes.

The stroop task is one of the most frequently used models of the conflict processing (Szűcs et al., 2012) in cognitive neuroscience. Stroop color word task performance evaluates flexibility in the purview of cognitive processes and behavior which requires both attention and impulse control. The simultaneous presentation of the prime color and a written word stimulus will either facilitate (when the color and word stimuli are congruent, e.g., "b-l-u-e" written in the color blue) or interfere (the incongruent stroop trial, e.g., "blue" written in red) with color naming (MacLeod, 1991; Peterson et al., 1999). Previous studies on stroop test have consistently shown that responses in naming the ink color of incongruent color word are much slower than in naming the ink color of neutral (Zysset et al., 2007), and responses are often, but not always, faster when color and word are congruent than in the neutral condition. It supports the hypothesis that, both the task relevant and task irrelevant dimensions of stroop task activate the same response in the congruent condition, in contrast, these dimensions stimulate opposing response tendencies in the incongruent condition (Morton and Chambers, 1973; Posner and Snyder, 1975; Szűcs et al., 2012).

Recent studies reported that regular practice of meditation may alter brain structure and function related to attention (Lazar et al., 2005; Holzel et al., 2011; Kozasa et al., 2012). A study on 20 experienced participants of extensive Insight meditation, that involves focused attention to internal experiences, reported increased cortical thickness in prefrontal cortex (PFC) and right anterior insula associated with attention, interoception and sensory processing in meditation participants compared with matched controls (Lazar et al., 2005).

In order to examine neuronal activity and hemodynamic changes in the brain regions during meditation, the application of different neuroimaging techniques (viz., fMRI and MEG) would be beneficial. The neuronal activity during meditation has been reported in several electroencephalography (EEG) and magnetoencephalography (MEG) studies. Experienced meditators showed an increased EEG power in lower frequency bands (theta, delta and alpha) (Kubota et al., 2001; Takahashi et al., 2005) compared to controls. An EEG study on Transcendental Meditation, showed intermittent prominent bursts of frontally dominant theta activity at an average maximal amplitude of 135 μV in 21 practitioners (Hebert and Lehmann, 1977). Zen meditators showed fast theta and slow alpha power during meditation (Takahashi et al., 2005) demonstrating enhanced automatic memory and reduction in conceptual thinking following meditation (Faber et al., 2014). In a single MEG study on twelve long term Buddhist meditators were assessed in two distinct types of self-awareness, i.e., "narrative" and "minimal" in mindfulness-induced selflessness awareness (Dor-Ziderman et al., 2013). It was found that there was a reduction in gamma band (60–80 Hz) power in frontal, and medial prefrontal areas, and reduced beta band (13–25 Hz) power in ventral medial prefrontal, medial posterior and lateral parietal regions (Dor-Ziderman et al., 2013) and right inferior parietal lobules. These studies are consistent with fMRI and NIRS findings. Functional magnetic resonance imaging (fMRI) poses several challenges such as high sensitivity to participant's motion, a loud, restrictive environment, low temporal resolution, and relatively high cost (Cui et al., 2011). Some of these challenges are overcome with new optical imaging technique: NIRS measure's changes in oxy-hemoglobin and deoxy-hemoglobin (ΔHbO and ΔHbR) concentration changes from the cortical surface and less invasive and expensive than fMRI (Bunce et al., 2006). Functional near infrared spectroscopy (fNIRS) is a compact and portable optical technique to monitor hemodynamics of the brain in real time (Son and Yazici, 2006; Lin et al., 2009).

Brain hemodynamic responses during meditation, i.e., ΔHbO, ΔHbR and total hemoglobin changes (ΔTHC) are in its infancy. In fact, there is only one study that assessed deoxyhemoglobin changes with a single wavelength probe placed over the left PFC during Qigong meditation (Cheng et al., 2010). Practitioners showed decrease in deoxy-hemoglobin and increase in oxy-hemoglobin concentration that suggest, meditation lead to left prefrontal activation during meditation.

With this background, the present study was designed to assess the bilateral prefrontal hemodynamic responses in meditation and random thinking. Additionally, we investigated the hemodynamic changes and performance during a stroop color word task before and after meditation and random thinking. Since, stroop color word task is known to measure attention, interference, processing speed, and executive attention, we expected that this task to be the most sensitive to the effects of meditation.

MATERIALS AND METHODS

PARTICIPANTS

A total of 25 right handed healthy male participants with ages ranging from 19 and 30 years (Mean, SD; 23.4 ± 3.7 years) were recruited from S-VYASA (a Yoga University), South India. All participants had a minimum of 12-month experience in meditation (group average experience ± S.D., 15.6 ± 14.2 months) on the Sanskrit syllable "*OM*". Three participants were excluded from the study because of large motion artifacts in the signals due to head movements or because of failure in probe placement due to obstruction by hair (Taga et al., 2003; Minagawa-Kawai et al., 2011). Thus, only data from 22 participants (mean age 22.9 ± 4.6 years) were included in the final analysis. Participants fulfilling the following criteria were included in the study: (i) the participants with at least 12 months of meditation experience; (ii) male participants alone were studied as cognitive abilities and cerebral blood flow (Brackley et al., 1999) have been shown to fluctuate which the phases of menstrual cycle (Yadav et al., 2002); and (iii) no history of smoking; and (iv) normal health on a routine clinical examination. Participants with following criteria were excluded from the study: (i) persons on any medication or herbal remedy; (ii) participants having

Q10 **Table 1 | Characteristics of 22 participants**.

Characteristics	
Age (in years) (group mean ± S.D.)	22.9 ± 4.6 years
Years of education	
17 years and more	6 (27.3%)
Upto 15 years	10 (45.5%)
Upto 12 years	6 (27.3%)
Type of meditation	Meditation on the Sanskrit syllable "*OM*"
Experience of meditation practice (in months)	
6–12 months	4 (18.2%)
13–24 months	3 (13.6%)
25–36 months	7 (31.8%)
37–48 months	6 (27.3%)
48–60 months	2 (9.1%)

clinical evidence of medical, neuropsychological, or drug abuse that would potentially alter cerebral blood flow (Liddle et al., Q8 1992; Newberg et al., 2010; Goldstein and Volkow, 2011); and (iii) any visual deficit; and (iv) any cognitive impairment. None of the potential participants were involved in any other ongoing research activity. The characteristics of participants are given in **Table 1**.

The study was approved by the Institutional Ethics Committee of S-VYASA, a Yoga University (No.-RES/IEC-S-VYASA/11/2011). The study protocol, nature of the experiments and the operating mode of the instrument was explained to the subjects before obtaining signed informed consent.

DESIGN

The protocol utilized in the present study consisted of two sessions i.e., random thinking (*cancalata*) and meditation (*dhyana*), and eight States (Pre, Stroop_Pre, During (D1-D4 each of 5 min), Stroop_Post, and Post). Each participant was assessed for both the meditation and control session on two separate consecutive days. The sessions were randomized online with randomization software[1]. During the acquisition and analysis of data, researcher was blinded to the session of the individual. The total duration of the each session was 60 min: Pre (5 min), Stroop_Pre (15 min), During (20 min), Stroop_Post (15 min), and Post (5 min). The schematic presentation of the design has been given in **Figure 1**.

Apart from their prior experience of meditation on "*OM*", all participants were given a 3 month orientation, 5 days a week under the guidance of an experienced meditation teacher. The purpose of this orientation was for to ensure uniformity among all practitioners based on specific instructions.

INTERVENTIONS

Each participant sat cross-legged with eyes closed and followed pre-recorded instructions throughout meditation and random thinking sessions. An emphasis was placed on slowly, practice with awareness of physical and mental sensations, and relaxation. The duration of each session was 20 min between 06:00 to 06:30 h conducted 5 days a week. The theoretical aspects of the meditation were detailed by the meditation teacher on the first day. Following this, the practice of each session began with pre-recorded instructions. The practice of meditation was evaluated based on their self-reporting and by consultations with the meditation teacher. The two phases—random thinking (Rand) and meditative defocusing were as follows:

1. ***Random thinking:***
   Participants were asked to listen a compiled audio CD consisting of brief periods of random conversation, announcements, various advertisements and non-connected talks recorded from a local radio station transmission and allow their thoughts to wander freely. All these non-connected conversations could induce the state of random thinking.
2. ***Meditative de-focusing or effortless meditation:***
   In effortless meditation session, each participant was instructed to dwell effortlessly on thoughts of "*OM*", particularly on the subtle (rather than physical) attributes and connotations of the syllable with closed eyes. This involved combined mental chanting with effortless defocusing on syllable "*OM*". This gradually allowed the participants to experience brief periods of silence, which they reported after the session.

ASSESSMENTS PROCEDURE

Laboratory environment

All Participants were assessed in a sound and light dampening Faraday cage. Participants' were monitored using a closed circuit television outside the cabin to detect if they moved or fell asleep during a session. During the session, instructions were passed through a two-way intercom, so that participants could remain uninterrupted. The recording room temperature was maintained at 24.0 ± 1.0°C with 56 percent average humidity during the conduct of experiments. The background noise level was 26 dB of the acoustically shielded chamber. For each participant, the data acquisition session lasted 60 min.

Functional near infrared Spectroscopy (fNIRS)

A 16-channel continuous wave fNIRS imager system (FNIR1000-ACK-W, BIOPAC Systems, Inc., U.S.A) was employed to map changes in ΔHbO, ΔHbR and ΔTHC over bilateral PFC. The system consisted of a flexible probe to match contour of the human forehead (see **Figure 2**). The probe embedded with four LED diodes as light sources (at λ_1 = 730 nm, λ_2 = 830 nm, λ_3 = 850 nm) and ten photodiodes as detectors that were symmetrically arranged in an area of 3.5 × 14 cm^2, conducing to 16 nearest source—detector (i.e., channels) at 2.5 cm separation displayed in **Figure 3**. A source-detector distance provides a penetration depth of 1.25 cm (León-Carrion et al., 2008; Kim et al., 2010; Leon-Dominguez et al., 2014). The description of the probe setting is detailed in earlier studies (Krawczyk, 2002; Izzetoglu et al., 2005; Leon-Dominguez et al., 2014). During the experiment, the probe was firmly held with a velcro band on the forehead, and stretched from hairline to eyebrow in a sagittal direction and from ear to ear in axial direction

[1] http://www.randomizer.org

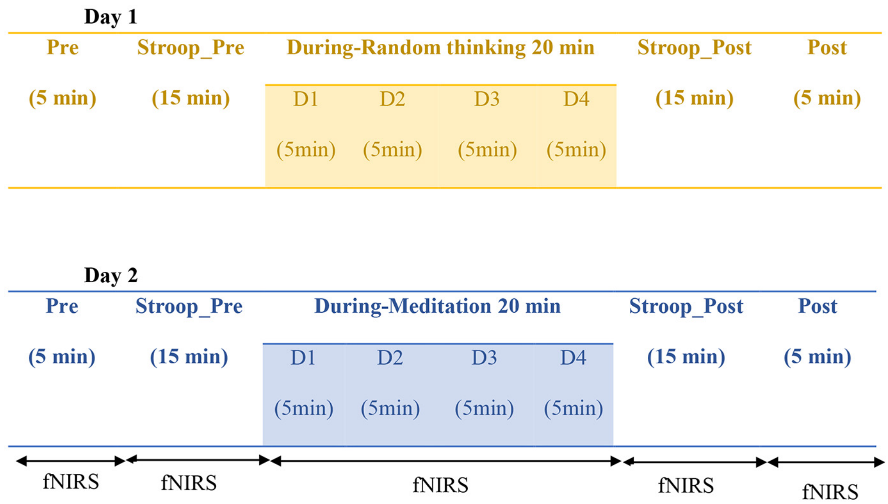

FIGURE 1 | Schematic representation of the study design. Note: Sessions were modified for each participant D1: During 1; D2: During 2; D3: During 3; D4: During 4.

(Tian et al., 2009). The probes were positioned bilaterally on forehead, over the left and right frontal poles, a part of dorsolateral PFC, and a portion of the ventrolateral PFC. Regional cerebral blood flow (rCBF), ΔHbO, ΔHbR, and ΔTHC for each hemisphere were updated every 0.5 s. The four LEDs flashed in sequence; the reflected light from the brain as detected with the nearest photodiodes of each LED and converted into digital signals using an analog-digital converter (ADC) card in the control box. The digital data were sent to the laptop though a serial port. The sampling rate was 3 Hz across all 16 channels. The principles of measurement were based on the modified Beer-Lambert law for highly scattering media (Plichta et al., 2006) that agrees assessing changes in ΔHbO and ΔHbR at a certain measured point (Hoshi and Tamura, 1993). Increases in ΔHbO and corresponding decrease in ΔHbR can be interpreted as a sign of functional brain activation.

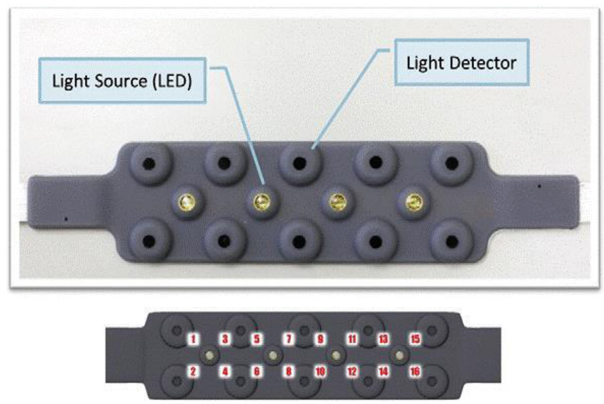

FIGURE 2 | The complete setup employed is herein presented. The fNIRS sensor is displayed with 4 light sources and 10 detectors (top) and 16 optode (channel) measurement locations registered on the sensor.

Stroop color word task

Subjects were seated comfortably on a reclining chair in a Faraday cage, facing a 21 inch LCD monitor placed at a distance of 70 cm from their eyes. Participants were required to focus on the center of the screen which was guided by a fixation object "+" followed by stimuli. Participants did a modified multiple-trial stroop task and were confronted with neutral, congruent, and incongruent stimuli on a black background using E-Prime 2.0.8.90 (Psychological Software Tools, Inc., Pittsburgh, PA, USA). The stroop color word task consisted of red, green and blue colored boxes and the corresponding written words "RED", "BLUE" and "GREEN". The color was presented as color square (4.5 × 4.5 cm) boxes on a black background. The duration of the presented square boxes and words was 500 ms each. Congruent trials comprised of square color boxes followed by words describing the color of the box written in the same color (e.g., the BLUE square box and the printed word "BLUE" in blue ink); incongruent trials comprised of words describing the color of the box written in a color other than that of the box (e.g., the RED square box and word RED written in blue ink); neutral trials comprised words written in white (e.g., the BLUE square box and word BLUE printed in white ink). Participants were instructed to reply as speedily and accurately as possible to the name of the color word (while ignoring the color itself) consistent to the color of the Box with a button press of the response key using the thumb of their right hand. To increase the potency of the conflict stimulus, 20% of trials were congruent (approximately 45 trials), 20% were incongruent (approximately 45 trials) and 50% were neutral (90 trials). The duration of the stimulus was 500 ms, with a variable interstimulus interval (ISI) of 1000–2500 ms the experimental steps are illustrated in **Figure 4**.

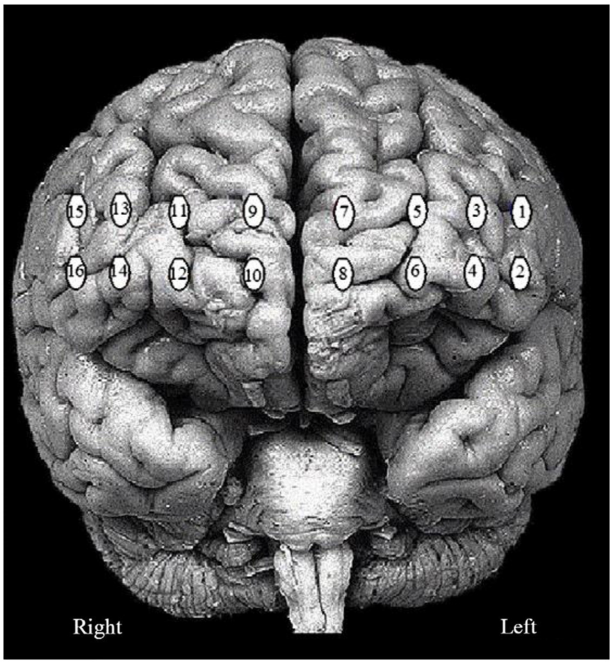

FIGURE 3 | The 16 fNIRS optode (channel) measurement locations registered on the brain surface image are presented.

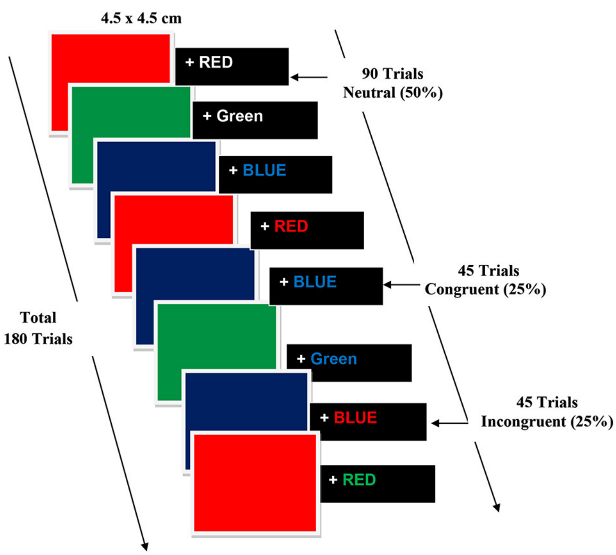

FIGURE 4 | Experimental steps of Color word Stroop Task.

Data acquisition

The participants were assessed in two separate sessions i.e., random thinking and meditation while recording hemodynamic activity on the PFC using 16-channel continuous wave fNIRS system. On the preceding day and on the day of the recording, participants were asked to avoid tea and coffee which are known to influence cognitive performance (Nehlig, 2010) and cerebral blood flow (Addicott et al., 2009). Where this was unavoidable the session was engaged on another day. The participants wore a flexible sensor pad over prefrontal region and covered with a black cloth. The probable artifacts such as heart rate pulsation, respiration and high frequency noise in raw data, which may possibly be induced by autonomic arousal caused during stroop task, was eliminated with pre designed finite impulse response (FIR) filters based on type, order, window function and cut-off frequency. For the present study, raw data were acquired from the probe, which is pre-filtered by two filters and processed in the data processing unit using COBI filter module. The first filter is a 10th order low-pass filter with cutoff frequency of 0.1 Hz with Blackman window. The second filter is a 20th order low-pass, with the normalized cut-off frequency of 0.1 Hz which uses a Hamming window. The filtered data were averaged according to the tasks and conditions for further statistical analysis.

Data analysis

The hemodynamic responses of bilateral PFC were recorded and data were averaged according to the task condition (pre, stroop_pre, during, stroop_post and post). Statistical analysis has been carried out on these differential values. Filtered data were tested with Kolmogorov-Smirnov test for normality. Repeated measures analysis of variance (RM-ANOVA) was used because the same individuals were assessed in repeated sessions on two separate days (i.e., random thinking and meditation). RM-ANOVA was performed with three "within subjects" factors, i.e., Factor 1: Sessions (random thinking and meditation); Factor 2: PFC (right and left). Factor 3: States ("Pre", "Stroop_Pre", "During" (D1 to D4), "Stroop_Post" and "Post"). The repeated measures ANOVAs were carried out for concentration changes of oxygenated and deoxygenated hemoglobin and total hemoglobin change (ΔHbO, ΔHbR and ΔTHbC) across the right and left PFC. This was followed by a *post hoc* analysis with Bonferroni adjustment for multiple comparisons between the mean values of different states ("During" and "Post") and all comparisons were made with the respective "Pre" state.

Moreover, for analysis of stroop task we compared the mean reaction time (ms) of neutral, congruent and incongruent conditions and hemodynamic responses of stroop color word task before and after the sessions (random thinking and meditation). The results were averaged for each side of PFC (right and left), parameter and subject separately to compare between different conditions and sessions. A repeated measures ANOVA was carried for multiple comparisons following Bonferroni adjustment. Statistical analyses were carried out using the Statistical software SPSS version 20.0 (SPSS Inc., Chicago, USA). The alpha level was set at $p < 0.05$. The effect size (d) defined by Cohen (1988), as the mean change score divided by the standard deviation of change, calculated for further statistical analysis.

RESULTS

BEHAVIORAL RESULTS

Reaction times (RTs) were computed solely from the correctly answered trials. With respect to RT, a repeated—measures 3 way ANOVA with Sessions (random thinking and meditation) × States ("Stroop_Pre", "Stroop_Post") × Conditions (neutral vs. congruent vs. incongruent). Repeated measures ANOVA demonstrated a significant main effect for Sessions ($F_{(1,21)} = 4.862$, $p = 0.039$, $\eta^2 p = 0.188$); Conditions ($F_{(2,42)} = 24.12$, $p < 0.001$, $\eta^2 p = 0.535$); States ($F_{(1,21)} = 6.696$, $p < 0.023$, $\eta^2 p = 0.242$), and the significant interaction between Sessions × States ($F_{(1,21)} = 45.36$, $p < 0.001$, $\eta^2 p = 0.684$).

Post hoc analysis revealed that there was a significant improvement in cognitive performance after meditation in all three conditions (neutral, congruent and incongruent) compared to random thinking session given in **Table 1**. The RTs differed in all the conditions (neutral vs. congruent vs. incongruent) in both the sessions. These findings verify that our attentional manipulation was indeed effective.

The RTs were compared using two-tailed paired sample *t*-test, revealed significant differences among all three conditions (neutral, congruent and incongruent) in two different sessions (meditation and random thinking). In random thinking session, there were significant differences in neutral vs. congruent: $t_{(21)} = -3.86$, $p = 0.001$; congruent vs. incongruent: $t_{(21)} = -2.31$, $p = 0.031$; neutral vs. incongruent: $t_{(21)} = -5.92$, $p < 0.001$ whereas in meditation session, there was a significant difference in neutral—congruent: $t_{(21)} = -4.47$, $p < 0.001$; congruent—incongruent: $t_{(21)} = -1.85$, $p > 0.05$ (NS); neutral—incongruent: $t_{(21)} = -6.148$, $p < 0.001$. The mean RTs were significantly shorter in the neutral ($p = 0.002$), congruent ($p < 001$) and incongruent ($p < 0.003$) conditions after meditation session whereas after the random thinking session, mean RTs were delayed in the neutral ($p = 0.034$) and incongruent ($p = 0.008$) conditions. The average RTs for neutral, congruent, and incongruent trials of the stroop color word task are given in **Table 2**. Subjects made negligible errors during the color word matching stroop task. For error rates, we did not make any statistical test, since their distributions are clearly not Gaussian. However, it can be supposed that interference effect also reveals itself in error rates. In summary, behavioral results of the stroop color word task are in accordance with the literature, as demonstrated by a clear interference effect in the participants for meditation and random thinking sessions.

HEMODYNAMIC RESPONSES IN STROOP COLOR WORD TASK

In the present study, the 16 channel fNIRS device provided a set of time series recorded over the PFC. The locations of the probed regions are shown in **Figure 2**. The order of the channels is from left to right, i.e., "1" is on the left and "16" is on the right as depicted in **Figure 3**. Analysis of hemoglobin signals i.e., ΔHbO or ΔHbR is still a controversial issue, specifically which hemoglobin signal is more reliably associated with brain activity still remain unclear (Schroeter et al., 2002). In this study, we have utilized three wavelengths (i.e.,750, 803 and 850 nm). This combination is suitable only for detecting ΔHbO signal. Therefore we used ΔHbO, ΔHbR and ΔTHC signals for statistical analysis. The groups mean values ± S.D. for the ΔHbO, ΔHbR and ΔTHC in stroop task and the two sessions (random thinking and meditation) in "Pre", "During" and "Post" states are given in **Table 3**.

For ΔHbO, the repeated—measures ANOVA for Sessions (Random thinking and Meditation) × PFC (Left and Right) × States ("Stroop_Pre", "Stroop_Post") revealed no significant main effect for Sessions, States and PFC. There was a significant interaction between PFC × States ($F_{(1,175)} = 9.87$, $p < 0.01$, $\eta^2 p = 0.053$); Sessions × PFC × States ($F_{(1,175)} = 3.17$, $p < 0.01$, $\eta^2 p = 0.040$).

For ΔHbR, the repeated—measures ANOVA demonstrated significant main effect for Sessions ($F_{(1,175)} = 9.99$, $p < 0.01$, $\eta^2 p = 0.054$); PFC ($F_{(1,175)} = 4.57$, $p < 0.05$, $\eta^2 p = 0.025$). Also, there was a significant interaction between Sessions × PFC ($F = 5.11$, $p < 0.05$, $\eta^2 p = 0.028$); Sessions × States ($F_{(1,175)} = 22.13$, $p < 0.001$, $\eta^2 p = 0.112$); Sessions × PFC × States ($F_{(1,175)} = 9.81$, $p < 0.01$, $\eta^2 p = 0.053$).

For total hemoglobin (ΔTHC), the repeated—measures ANOVA revealed that there was a significant main effect for PFC ($F_{(1,175)} = 9.71$, $p < 0.01$, $\eta^2 p = 0.053$), and the significant interaction between Sessions × PFC ($F_{(1,175)} = 5.33$, $p < 0.01$, $\eta^2 p = 0.03$); Sessions × States ($F_{(1,175)} = 19.87$, $p < 0.001$, $\eta^2 p = 0.102$); PFC × States ($F_{(1,175)} = 5.96$, $p < 0.05$, $\eta^2 p = 0.033$); Sessions × PFC × States ($F_{(1,175)} = 14.20$, $p < 0.001$, 0.075).

The *post hoc* analysis with Bonferroni corrections demonstrated forehead hemodynamic responses during stroop task related to random thinking and meditation sessions are given in **Table 3**. The results demonstrated a significant decrease in the concentration of ΔHbO in left PFC ($p = 0.016$) and in the right PFC ($p = 0.032$) after random thinking session during stroop color word task, whereas, there was a significant improvement in ΔHbO in left PFC ($p = 0.006$) and right PFC ($p = 0.046$) following the meditation session.

Table 2 | Group mean values ± S.D. of the reaction time scores (ms) of Stroop color word Task.

Sessions	States	Pre	Post	*t*-value	*P* value	% Change
Rand	Neutral	643.18 ± 130.654	660.00 ± 113.641	−2.274	**0.034***	2.62
	Congruent	783.64 ± 117.333	790.91 ± 119.440	−0.876	0.391	0.93
	Incongruent	871.41 ± 136.070	892.73 ± 136.004	−2.920	**0.008****	2.45
Med	Neutral	638.64 ± 118.615	617.73 ± 121.653	3.533	**0.002****	−3.27
	Congruent	794.55 ± 118.029	764.55 ± 112.238	6.205	**<0.001*****	−3.78
	Incongruent	865.00 ± 137.797	819.09 ± 133.627	3.302	**0.003****	−5.31

**p < 0.05; p < **0.01; ***p < 0.001; repeated measures of ANOVA with Bonferroni adjustment comparing Post values with Pre values. Values are group means ± S.D. Rand—Random Thinking; Med—Meditation.*

Table 3 | Group mean values ± S.D. of the oxyhemoglobin (ΔHbO), deoxyhemoglobin (ΔHbR) and total hemoglobin change (ΔTHC) of Stroop color word task before, during and after random thinking (rand) and meditation (Med).

Sessions	Voxels	Pre	Stroop_Pre	During				Stroop_Post	Post
				D1	D2	D3	D4		
						Oxyhemoglobin (ΔHbO)			
Rand	**Left PFC**	−0.71 ± 3.71	−0.64 ± 7.39	0.51 ± 7.58	0.15 ± 6.69	0.25 ± 7.16	0.21 ± 7.61	0.83 ± 7.41	0.80 ± 7.22
	Right PFC	−2.65 ± 5.56	0.81 ± 4.59	−2.21 ± 12.47	−1.30 ± 12.45	−1.69 ± 12.67	−1.65 ± 12.49	−1.56 ± 11.90	−1.00 ± 10.02
Med	**Left PFC**	−0.43 ± 6.53	−0.93 ± 2.55	−1.13 ± 3.17	−0.79 ± 3.22	−0.64 ± 3.54	−0.77 ± 3.98	−0.09 ± 5.15	0.44 ± 5.25
	Right PFC	−2.45 ± 7.18	−1.30 ± 2.64	**−0.71 ± 4.07***	**−0.44 ± 3.84***	**−0.19 ± 3.86****	−0.89 ± 3.70	−0.79 ± 3.89	**0.35 ± 4.41*****
						Deoxyhemoglobin (ΔHbR)			
Rand	**Left PFC**	−0.20 ± 15.36	−1.70 ± 4.23	−2.03 ± 5.27	−0.98 ± 5.94	−0.73 ± 6.45	−0.73 ± 6.57	−0.32 ± 8.80	−0.91 ± 8.10
	Right PFC	−5.18 ± 10.80	−2.86 ± 3.65	−3.22 ± 6.89	**−1.78 ± 5.75*****	**−0.48 ± 8.08*****	**0.01 ± 8.05*****	**1.22 ± 8.18*****	**0.19 ± 10.25*****
Med	**Left PFC**	−1.57 ± 6.61	−1.27 ± 8.85	−2.82 ± 18.20	−2.25 ± 18.82	−2.38 ± 19.15	−2.29 ± 18.82	−2.28 ± 19.80	−2.23 ± 17.63
	Right PFC	−3.90 ± 8.22	−3.00 ± 7.93	−7.19 ± 23.46	−8.16 ± 23.09	−8.14 ± 23.43	**−8.15 ± 22.72***	−7.28 ± 23.56	−7.04 ± 19.93
						Total hemoglobin change (ΔTHC)			
Rand	**Left PFC**	−1.70 ± 5.39	−1.83 ± 9.87	−1.58 ± 20.98	−1.39 ± 21.02	−1.73 ± 21.40	−1.66 ± 21.16	−1.71 ± 21.56	−1.02 ± 19.70
	Right PFC	−4.29 ± 6.67	−3.28 ± 9.05	−8.85 ± 28.49	**−9.07 ± 27.55***	**−10.41 ± 26.99*****	**−10.28 ± 26.52*****	**−10.26 ± 26.89****	**−8.41 ± 21.55****
Med	**Left PFC**	−0.78 ± 17.63	−2.98 ± 7.98	−3.50 ± 9.7	−2.18 ± 10.23	−1.82 ± 10.74	−1.98 ± 11.34	−1.21 ± 14.27	−1.15 ± 13.88
	Right PFC	−5.11 ± 11.97	−4.36 ± 5.29	−4.37 ± 7.48	**−2.83 ± 7.18****	**−1.94 ± 8.48*****	**−2.16 ± 9.14****	**−1.45 ± 10.11****	**−0.57 ± 11.07*****

***p < 0.01; repeated measures of ANOVA with Bonferroni adjustment comparing During and Post values with Pre values. Values are group means ± S.D.*

From the above observations, it can be concluded that meditation enhances bilaterally activation of the anterior PFC and consequently, a stronger increase of oxygenation and cerebral blood flow during stroop task at the right PFC due to interference reduction.

HEMODYNAMICS RESPONSES IN MEDITATION AND RANDOM THINKING

For ΔHbO, the repeated—measures ANOVA for Sessions (Random thinking and Meditation) × PFC (Left and Right) × States (Pre Stroop_Pre, D1-D4, Stroop_Post, Post) demonstrated a significant main effects for States ($F_{(7,1225)} = 5.23$, $p < 0.001$, $\eta^2 p = 0.029$). There was a significant interaction between the PFC × States ($F_{(7,1225)} = 2.42$, $p < 0.001$, $\eta^2 p = 0.014$); Sessions × Hemispheres × States ($F_{(7,1225)} = 7.32$, $p < 0.05$, $\eta^2 p = 0.040$).

For ΔHbO, the repeated—measures ANOVA showed there was a significant main effect for Sessions ($F_{(1,175)} = 12.20$, $p < 0.001$, $\eta^2 p = 0.065$); PFC ($F_{(1,175)} = 7.89$, $p < 0.01$, $\eta^2 p = 0.043$) and States ($F_{(7,1225)} = 3.55$, $p < 0.001$, $\eta^2 p = 0.019$). There was a significant interaction between the Sessions × PFC ($F_{(1,175)} = 4.13$, $p < 0.001$, $\eta^2 p = 0.023$); Sessions × States ($F_{(7,1225)} = 9.99$, $p < 0.001$, $\eta^2 p = 0.054$); Sessions × PFC × States ($F_{(7,1225)} = 10.37$, $p < 0.001$, $\eta^2 p = 0.056$).

For total hemoglobin change (ΔTHC), there was a significant main effect for Sessions ($F_{(1,175)} = 5.07$, $p < 0.05$, $\eta^2 p = 0.028$); PFC ($F_{(1,175)} = 12.20$, $p < 0.001$, $\eta^2 p = 0.065$); and States ($F_{(1,175)} = 2.79$, $p < 0.01$, $\eta^2 p = 0.016$) and a significant interaction between the Sessions × PFC ($F_{(1,175)} = 6.45$, $p < 0.05$, $\eta^2 p = 0.036$); Sessions × States ($F_{(7,1225)} = 9.06$, $p < 0.001$, $\eta^2 p = 0.049$); PFC × States ($F_{(7,1225)} = 2.34$, $p < 0.05$, $\eta^2 p = 0.036$]; Session × PFC × State ($F_{(7,1225)} = 14.51$, $p < 0.001$).

Post hoc analyses with Bonferroni corrections were performed on ΔHbO, ΔHbR and ΔTHC and all comparisons were made with respective "Pre" state. These have been summarized in **Table 3**. There was a significant increase in ΔHbR at the right PFC ($p = 0.005$) after random thinking session whereas there was a significant increase in the left PFC ($p = 0.02$) and in right PFC ($p < 0.001$) after meditation session. Similarly, in ΔTHC, there was a significant decrease in blood flow change in the right PFC ($p < 0.001$) after the random thinking session whereas there was a significant increase in blood flow change in the left ($p = 0.03$) and in right PFC ($p < 0.001$) after meditation session.

In summary, as described in **Table 3** and in Line diagrams (**Figures 5–7**), there was a positive trend to show a significant increase in the concentration of oxyhemoglobin change (ΔHbO) during meditation session at right PFC (as shown in **Figure 5**). There was a significant decrease in deoxyhemoglobin change (ΔHbR) (as shown in **Figure 6**) during meditation session whereas there was a significant increase in the concentration of deoxyhemoglobin change during random thinking session at the right PFC. Additionally, there was also a significant increase in the total hemoglobin change (ΔTHC) during and after meditation sessions (**Figure 7**) and decrease in the total hemoglobin change (ΔTHC) during and after random thinking session.

DISCUSSION

The primary goal of the present study was to ascertain whether meditation increases rCBF at bilateral PFC, measured with fNIRS, compared to random thinking. Our secondary goal was to observe the RT scores and relative changes in cerebral blood flow, and to determine if there are persistent effects following meditation session compared to random thinking session. Results as confirmed with recent studies on meditation with spectroscopy (Cheng et al., 2010), SPECT imaging (Newberg et al., 2001, 2010a,b; Cohen et al., 2009) and fMRI (Short et al., 2010; Guleria et al., 2013; Zeidan et al., 2014) have revealed that meditation program resulted in significant increases in baseline CBF ratios in the prefrontal, superior, inferior and orbital frontal cortex, dorsolateral prefrontal cortex (DLPFC), right dorsal medial frontal lobe, cingulate gyrus and right sensorimotor cortex. In present study, we found that brain activation, measured by changes in ΔHbO and ΔTHC concentration in the right prefrontal area was followed by a strong decrease in ΔHbR concentration during meditation. Additionally, the rCBF significantly increased in the right frontal lobe during stroop task after meditation, which suggest the improvement in the participant's performance (reaction time) during the task. The total blood oxygenation (ΔTHC) level in the PFC could rise with increasing task load from neutral to congruent, and then incongruent; this would demonstrate a positive correlation with performance measures. The changes in regional blood flow is mediated by changes in neural activity in a single region or in several selective regions of the brain (Lauritzen, 2001).

Earlier studies have demonstrated that the PFC is activated particularly on the right PFC and anterior cingulate cortex (ACC) in willful act and tasks that require intense focused and sustained attention (Frith et al., 1991; Pardo et al., 1991; Vogt et al., 1992; Petersen and Posner, 2012). A study on eight Tibetan Buddhist meditators demonstrated improved activity in the PFC bilaterally (though greater on the right hemisphere) and the cingulate gyrus during meditation (Newberg and Iversen, 2003). This suggests that meditation begins with activation of the PFC and anterior cingulate gyrus associated with the will or intent to clear the mind of thoughts or to focus on an object (Edwards et al., 2012).

Meditation increases CBF and decreases cerebrovascular resistance (CVR) suggesting a contributing vascular mechanism (Jevning et al., 1996) which reflect cerebral activation. The CVR reduction being associated with cognitive improvement which suggests a vascular contribution to cognitive enhancement (Nation et al., 2013). During meditation, the activation of right PFC is theoretically associated with the activity in the reticular nucleus of the thalamus. This activation may be accomplished by the PFC's production and distribution of glutamate, a known excitatory neurotransmission (Cheramy et al., 1987; Finkbeiner, 1987), which communicate with other brain structures such as lateral geniculate and lateral posterior nuclei of the thalamus (Portas et al., 1998). An early study on meditation with single photon emission computed tomography (SPECT) demonstrated a general increase in thalamic activity that was proportional to the activity levels in the PFC (Newberg et al., 2001; Edwards et al., 2012). The activation on the

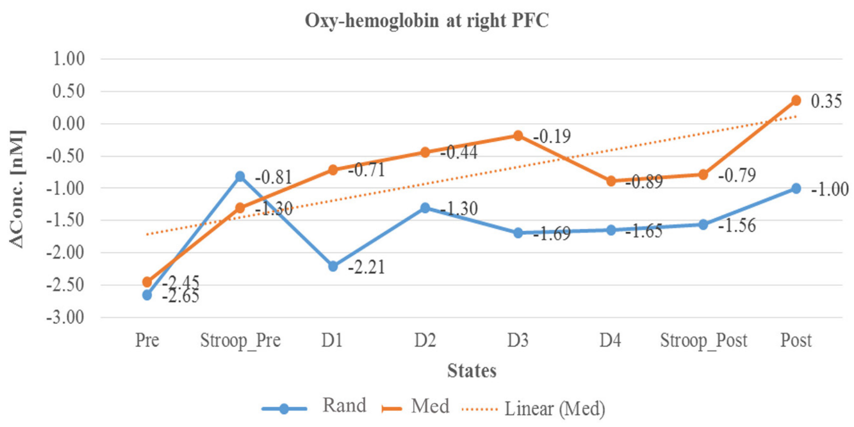

FIGURE 5 | Line graph represents averaged Oxy-hemoglobin change at right prefrontal cortex (rPFC) in two sessions i.e., random thinking and meditation and Stroop task. Note: Line graph represents comparisons between baseline, stroop_pre, during sessions (random thinking and meditation), stroop_post, and post. Stroop Pre showed higher Oxy-hemoglobin change compared to baseline. During and after meditation, the cerebral oxygenation was higher in rPFC compared to random thinking.

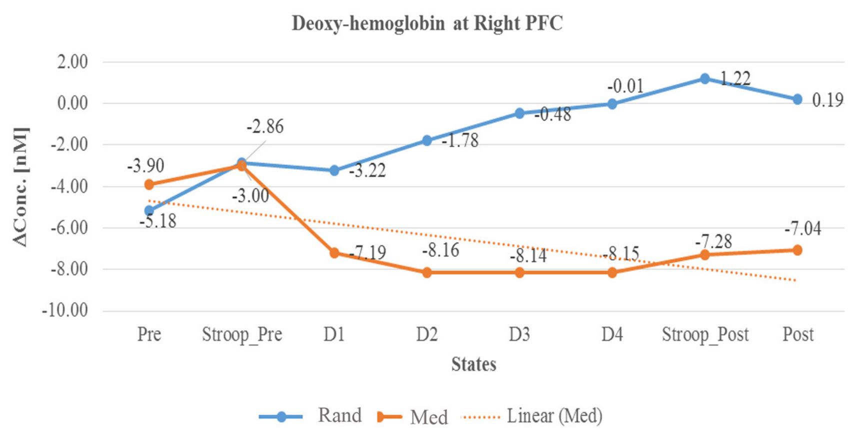

FIGURE 6 | Line graph represents averaged Deoxy-hemoglobin change at right PFC in two sessions i.e., random thinking and meditation and Stroop task. Note: Line graph represents de-oxyhemoglobin changes was higher in right PFC during random thinking (D2, D3, and D4), stroop task and after random thinking. In other hand, during meditation, there was a decrease in de-oxyhemoglobin in D3 level in rPFC.

right PFC causes increased activity in the reticular nucleus during meditation, the results may be decreased sensory input entering into the posterior superior parietal lobule which is involved in the analysis and integration of higher order visual, auditory, and somesthetic information (Adair et al., 1995).

A major strength of the present study was to examine the states of meditation and random thinking related hemodynamic responses in cerebral oxygenation during performance of the stroop color word task. It is a well established phenomenon that executive processes are facilitated by the frontal lobe and due to stroop interference brain activity may depend on increased ability to recruit frontal neural resources (Schroeter et al., 2004b). This allowed us to examine whether there is an increase in oxygenation with meditation corresponding to an ability to recruit appropriate resources for task performance or a decrease in activation corresponding to better optimization and possible reduction in task difficulty with meditation. In a study, fNIRS showed stroop interference is consistently associated with the ACC and the lateral prefrontal cortex (LPFC), especially the DLPFC, where the ACC is considered to be susceptible to conflict, and the DLPFC is purported to implement cognitive control (Carter et al., 2000; Leung et al., 2000). DLPFC may involve attentional maintenance while ACC monitors performance (MacDonald et al., 2000). Another similar study suggested meditation may enhance specific subcomponents of attention such as conflict monitoring or performance (Jha et al., 2007). Although fNIRS cannot monitor the cortical activation in the ACC because its measurement is limited to lateral cortical surfaces, it has successfully monitored the activation of the LPFC associated with stroop interference (Schroeter et al., 2002, 2003, 2004a,b; Ehlis et al., 2005).

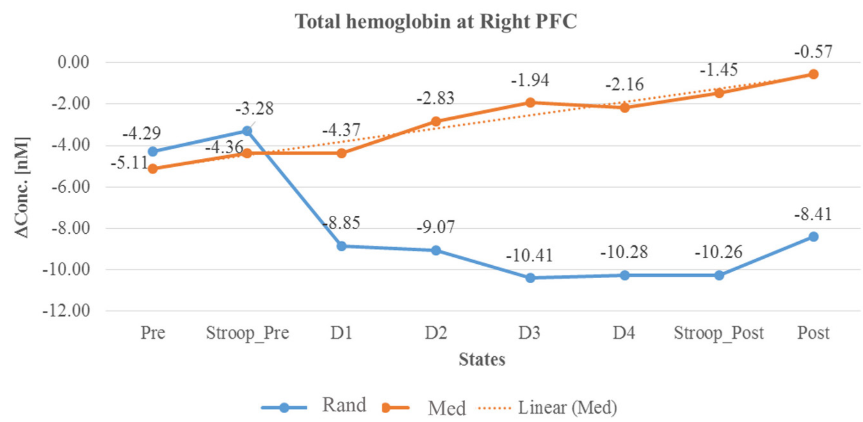

FIGURE 7 | Line graph represents averaged total hemoglobin change at rPFC in two sessions i.e., random thinking and meditation and Stroop task. Note: Line graph represents total hemoglobin change was higher in rPFC during meditation (D2, D3, and D4), in stroop task, and in post session. In other hand, there was a decrease in rPFC during random thinking (D2, D3, and D4), in stroop task and in post session.

There have been several neuroimaging studies evaluating the cerebral blood flow and performance of different meditation practices using behavioral, EEG and (Carter et al., 2005) fMRI imaging. Previous studies on meditation and EEG reported, greater midline theta power and slow alpha power in the frontal area during meditation (Takahashi et al., 2005; Chan et al., 2008). Zazen meditation showed increased alpha-1 and alpha-2 frequency activity of EEG in right prefrontal areas including insula, parts of the somatosensory, motor cortices and temporal areas (Faber et al., 2014). A subsequent study, on Satyananda Yoga meditation practice, showed greater source activity in low frequencies (particularly theta and alpha 1) during mental calculation, body-steadiness and mantra meditation (Thomas et al., 2014). Additionally, body-steadiness and mantra meditation showed greatest activity in right side of superior frontal and precentral gyri, parietal and occipital lobes. Similarly, neuroimaging studies on meditation practice, when compared to the control session showed significantly increased oxy-hemoglobin and CBF in the medial PFC which was associated with the intense focus-based component of the practice (Wang et al., 2011). Meditation involves attentional regulation and leads to increased activity in brain regions associated with attention such as DLPFC and ACC. The long-term practitioners had significantly more consistent and sustained activation in the DLPFC and the ACC during meditation vs. control in comparison to short-term practitioners (Baron Short et al., 2010). These studies suggest that willful acts and tasks that require sustained attention are initiated via activity in the PFC, particularly in the right hemisphere (Posner and Petersen, 1990; Frith et al., 1991; Pardo et al., 1991; Ingvar, 1994). Meditation requires focus of attention on objects which thereby activates PFC, particularly in the right hemisphere (Cohen et al., 2009), as well as the cingulate gyrus (Herzog et al., 1990; Lazar et al., 2000; Newberg et al., 2001). This demonstrated that during meditation there was an increased activity in the PFC bilaterally (greater on the right) and the cingulate gyrus (Newberg and Iversen, 2003). Therefore, the process of meditation seems to happen by activation of the prefrontal and cingulate cortex which are associated with the will or intent to clear one's mind of thoughts or to focus on an object.

In other imaging studies on meditation, there have been inconsistent results regarding the frontal cortex. A recent study showed decreased frontal activity during externally guided word generation compared to internal or volitional word generation (Crosson et al., 2001). Thus, prefrontal and cingulate activation may be associated with the volitional aspects of meditation. Meditation with fluorodeoxyglucose (FDG) PET in eight subjects undergoing Yoga meditative relaxation (Herzog et al., 1990) reported increased rCBF in the frontal: occipital ratio of cerebral metabolism. Specifically, there was a mild increase in the frontal lobe, but marked decreases in metabolism in the occipital and superior parietal lobes. In addition to these studies, the PFC is reported to have a crucial role in social cognitive skills and along with the cingulate gyrus governs social behavior tasks related to Theory of Mind, empathy, moral reasoning, and evaluation of emotional states (Declerck et al., 2006). The PFC is essential for flexible behavior because it inhibits the habitual responses that have become inappropriate (Mesulam, 1998). But, an increase in the activity of PFC (determined by fNIRS) is not necessarily beneficial always. For example, animal experimentation has shown that the electrical activation of the medial PFC prevent the proper sequence of pressing the lever and collecting the reward (a pellet of food) in an operant condition task (Jurado-Parras et al., Learn. Mem., 2012) and also prevent the expression of an already acquired classically conditioned eyelid response (Leal-Campanario et al., 2007, 2013). However, in our study we infer that activation of prefrontal cortices after meditation had beneficial effects on cognition as manifested by improved performance in stroop color word task.

The present study reported increased oxy-hemoglobin concentration because of enhanced neural activity and cerebral blood flow in the prefrontal area during meditation compared to random thinking. In such studies, it is very important to understand the influences of systemic artifacts such as those from the heart, breathing, superficial perfusion, etc., which may be induced by the cognitive tasks related stress and autonomic responses. For example, a recent study performed on peripheral physiological measurements with temporal correlations of fNIRS and fMRI signals concluded that the physiological basis of the systemic artifact is a task-evoked sympathetic arterial vasoconstriction monitored by a decrease in venous volume and these artifacts are fairly common (Kirilina et al., 2012). They also suggested that the separation of fNIRS signals originating from activated brain and from scalp is a necessary precondition for unbiased fNIRS brain activation maps and pre-processing of the raw data using high definition filters is necessary.

In summary, the results of the present study provided first evidence that the oxygenation levels are increased in the PFC during meditation compared with random thinking in the same practitioners. Further event-related NIRS studies may apply well-tested fMRI paradigms in studies with children and patients, utilizing the advantages of the method.

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Resting state functional near infrared spectroscopy

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Resting state functional near infrared spectroscopy

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The present study investigated the spatial-temporal variation of oxygenated hemoglobin (HbO), deoxygenated hemoglobin (Hb), blood volume (BV) and blood oxygenation (BO) concentration changes in the prefrontal cortex, measured with functional near-infrared spectroscopy (fNIRS) during resting state. We examined 36 healthy right handed subjects seating with their minds and body quiet and still, as well as their eyes closed for 5 minutes. The spatial mean concentration change of the four estimated parameters across subjects was found near zero; Moreover, the mean concentration changes across subjects for HbO and Hb were found to be more reduced than those of BV and BO. In addition, there were no statistically voxelwise significant differences for the mean concentration changes related to HbO, Hb, BV, neither BO; This finding strongly suggests for a spatial stability in the mean concentration changes during resting state.

Keywords – **Brain oxygenation, Continuous wave, Functional near-infrared spectroscopy, NIRS, Optical imaging**

Introduction: fNIRS has been in development as a useful tool for neuroimaging studies [1-3]. Among these, the instruments for continuous wave (CW) measurements based on the modified Lambert–Beer law (MLB) [4,5] are the most readily available commercially. Instruments of this type allow observation of dynamic changes in regional cerebral blood flow (rCBFs) in real time by monitoring the concentration changes in cerebral HbO and Hb. However, it is difficult to quantitatively measure HbO and Hb concentrations in the cerebral tissue separately from those in the extracerebral tissue. These problems have limited the use of fNIRS. Indeed, proper resting state calibration studies are missing within the fNIRS literature. As a matter of fact, this has not been well understood by many fNIRS users. Here, a common fNIRS-CW system is employed to determine the variation in the spatial-temporal resting state activity in cerebral tissue across healthy subjects. **Methods:** Thirty six right-handed healthy subjects (27 males and 9 females, with a mean age (± SD) of 27.92 (± 4.78) years and 24.11 (± 2.71) years respectively) volunteered for the study. They seated with their minds quiet as much as possible and their eyes closed; the prefrontal cortex was monitored for 5 minutes employing a fNIRS-CW system first described by Chance et al (1998) [6]. The sensor has a temporal resolution of 500 milliseconds per scan with 2.5 cm source-detector separation allowing for approximately 1.25 cm of penetration depth. The employed fNIRS system is composed of three modules: a flexible headpiece (sensor pad), which holds 4 light sources and 10 detectors to enable a fast placement of all 16 optodes/voxels. Home built-in algorithms in MATLAB were employed for the data analysis. Further, balanced one-way ANOVA was performed voxelwise, for each of the independent four estimated parameters directly related to prefrontal activity: 1. HbO, 2. Hb, 3. BV: HbO + Hb, 4. BO: HbO – Hb. **Results:** Voxelwise, the spatial mean concentration change of the four estimated parameters across subjects is near zero; although, the variation across them is remarkable, specifically, the voxelwise standard deviation is higher for voxels 8, 9 and 10. These voxels spatially correspond to the center of the frontal lobe. Moreover, the mean of changes across subjects for HbO and Hb concentration are more reduced, with smaller standard deviation than those of BV and BO. Furthermore, there are no statistically voxelwise significant differences for the mean concentration changes related to HbO, Hb, BV, or BO. The highest Std values voxelwise for HbO, Hb, BV and BO are 2 (min: -2.96, max: 7.37), 1.6 (min: -6.26, max: 4.59), 2.8 (min: -3.08, max: 13.08), and 2.0 (min: -3.34, max: 8.09) micromol, relating voxels 9, 8, 9 and 9 respectively. These results show that none of the 16 voxels have means significantly different from each other, across 36 subjects, for none of the four estimated parameters. **Conclusion:** We investigated the spatial-temporal variation of HbO and Hb concentration changes over the prefrontal cortex during resting state. The present study strongly suggests a spatial stability in the concentration recorded during 5 minutes; the human frontal lobe resting activity follows a spatially homogeneous trend. However, it is evident that the high variation found across subjects, specially at the center of the frontal lobe deserves special attention and detailed research study.

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