Meditation and Brain: An Overview

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Abstract

Effects of meditation on brain are not yet well characterized, although this topic has received considerable attention. The recent studies have challenged the traditionally held view that learning changes only the way the brain functions and instead showed that structural changes at the macroscopic level are possible. From a neuroscience perspective, meditation can be conceived as the interaction of diverse and distinct attentional mechanisms. Recent reports have begun to focus

on well-characterized neural measures of attentional engagement during (state) and from (trait)meditation, which delineate specific effects of these ancient practices on brain activity and its subsequent influence on cognitive and emotional processing.

1. Introduction

Meditation is an ancient Indian spiritual practice that aims to quieten the mind and has shown significant promise as a tool to promote health and combat diseases. Though such practices are millennia old, little is known about their neurobiological concomitants. For centuries, scientists and philosophers have been fascinated by the brain but until recently, they viewed it as nearlyincomprehensible. In earlier period, heart was considered as the seat of emotion or consciousness.Now it is well established that brain is the essence of mind and soul and also the

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seat of intelligence, creativity, emotion and memories. All of our conscious and unconscious perceptions are filtered, altered, analyzed and organized by a gigantic symphony of neuronal players and then distributed to other body organs via nerve impulses and biochemical messengers. Because of the accelerating pace of research in neurological and behavioural science and the development of new research techniques, scientists have learned more about the brain in the last 50 years than in all previous centuries.

According to the Eastern spiritual tradition, meditation is a technique for spiritual development, where the aim is to attain inner peace, concentration and positive emotions. It comprises a heterogeneous group of practices. Two principal types of meditations are Mindfulness and Concentration. Various practices of meditation e.g. transcendental meditation, *Prekṣā* meditation, Zen meditation (Zazen), *Vipaśyanā* ("Insight") meditation, Compassion meditation (loving kindness), *Cakra* meditation, Qi gong meditation, *mantra* meditation, Christian meditation, yoga meditation, Chinese meditation, Japanese meditation and Jewish meditation etc. are examples of different techniques. *Prekṣā Dhyāna* is a popular meditation technique of Jain (*Terapanth*) *Dharma* formulated by its tenth spiritual leader, Acharya Mahaprajna in the middle of the 20th century. The main aim of practicing *prekṣā* meditation is purification of soul, psyche and consciousness.

Meditation can be conceptualized as a family of complex emotional and attentional regulatory training practices. By simple definition, it is engagement in contemplation, especially of a spiritual or devotional nature. To elaborate further, meditation is an attempt to concentrate mind on a single form or an idea or an aspect of divinity at the exclusion of all other forms, thoughts and ideas. The mind is focused inwards and this effort of concentration acts as a stimulus to gain access to knowledge of 'object of meditation'. The aspirant makes an attempt to minimize perceptions through senses like touch, sight, hearing, etc. This helps in controlling restlessness of mind and directs it towards inner contemplation by which the mind, as if, becomes still.

Cognitive and neuroscience research for the past several years has shed new light on the influences that meditative traditions have on the meditation practice. Although meditation research is in its infancy, a number of studies have investigated changes in brain activation (at rest and during specific tasks) that are associated with the practice of, or that follow, training in mindfulness meditation (Tang *et al.*, 2015).The therapeutic potential of meditation for physical

and mental well-being is now well documented. Though this article is technical, we have attempted to simplify it for better assimilation by scientific community at large.

2. Nervous System

Regular commentary on human nervous system is beyond the scope of this chapter and we will briefly describe few relevant structures only.

The human brain has unlimited power of functioning and controls all functions of the body. It is an organ of 1300-1400 gm containing more than one hundred billion neurons. These nerve cells communicate with one another by a hundred trillion interconnections, also known as synapses. It receives and interprets information from the outside world and inner self, interpret and stores them and direct and coordinate required actions. Electrochemical impulses of the nervous system make it possible to obtain information about the external or internal environment and do whatever is necessary to maintain homeostasis. The fundamental purpose of the nervous system is (1) to receive

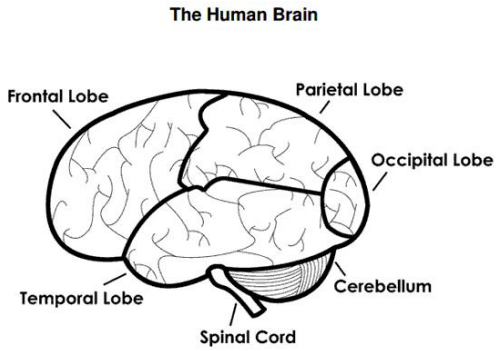

Fig 1: Brain seen from side (source: http://www.gender.org.uk/about/07neur/74_brain.htm).

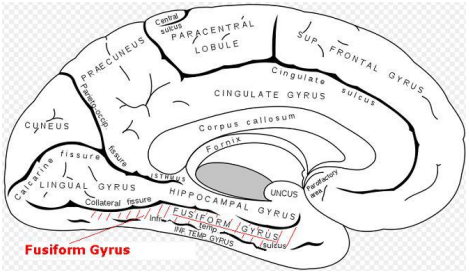

Fig. 2: Brain seen from medial side showing limbic lobe and other structures (source: http://guerrillagroup.com/tag/orvel-ray-wilson/)

information from receptors cells and organs specialized to detect changes inside the body and its external environment; (2) to process and store this information and determine the appropriate responses; and (3) to issue commands to effectors, cells and organs (mainly muscle and gland cells) (Saladin, 2004).

Prefrontal Cortex System

The Prefrontal Cortex System **(**PFC) is the most evolved part of the human brain and often termed as 'executive control centre'. It occupies the front third of the brain. It has extensive connections with the limbic system. It modulates by sending inhibitory signals to the limbic and sensory parts of the brain to reduce distraction.

It is divided into three sections i.e. dorsal lateral (on the outside surface), inferior orbital (on the front under surface) and the cingulate gyrus (which runs through the middle of the frontal lobes). While the dorsal-lateral portion of PFC is mainly involved in sustaining attention span and selection of behaviour based on short term memory, the inferior orbital portion of PFC is responsible for impulse control, mood control, behaviour and social skills.

The capacity of the individual to generate goals, to achieve them and to learn from mistakes is considered an essential aspect of a mature and effective personality. PFC controls "executive functions," such as capacity to formulate goals, time management, to change course and improvise in the face of obstacles, attention span, perseverance, self-monitoring, forward thinking, ability to feel and express emotions, influences the limbic system, empathy, judgment, behaviour, impulse control, planning, organization and critical thinking.

Parietal lobe

It supports perception of the body and its surrounding in the space. Anterior or front portion of this lobe receives and processes sensory information about temperature, taste, touch and movement coming from the body. There is a large association area that controls fine sensation (judgment of

texture, weight, size, shape). Current scientific evidences suggest that meditation results in suppression of parietal lobe functions and individuals attain a state of 'No time and No Place'.

Diencephalon

It is located beneath the cerebral hemispheres and consists of thalamus and hypothalamus. Thalamus is a large cluster of nuclei that serves as a synaptic relay station and important integrating centre for most inputs to the cortex. It plays a role in interpretation of sensory impulses, such as pain, temperature, light, touch and pressure. Hypothalamus lies below the thalamus. It is a tiny region whose volume is only 5 to 6 cm^3. It controls mind-over-body phenomenon and is essential to the survival of the individual and the species. It is the most primitive part of the limbic system and is the source of raw, powerful, undirected feelings emotions. It plays a major role in regulating hormones, the pituitary gland, body temperature, and many other vital activities. It plays a role in controlling behaviour such as hunger, thirst, ability to feel extreme pain or pleasure, sleep, and sexual response. It controls and integrates the autonomic nervous system and is responsible for translating our emotional state into physical feelings of relaxation or tension. It is the principal intermediary between the nervous system and the endocrine system.

Limbic system

It is a group of structures located on the medial aspect of each cerebral hemisphere and diencephalon (Fig. 2). It is a functional system that mediates emotional responses and memory processing. Along the lower edge at the tip of each of the temporal lobes is the amygdale which is the centre for basic feelings, particularly fear and sexual responses, and receives inputs from the visual, auditory and sensory parts of the cortex, with numerous further connections to the frontal lobes. It has crucial role in the mediation and control of major emotions like friendship, love, rage and aggression (Chalabi, 2005).

Hippocampus

A part of temporal lobe, it is an important constituent of limbic lobe. Its function is to convert short-term memory into long-term memory. The hippocampus in the right hemisphere is concerned with visual, emotional, tactile and nonverbal memories while that of the left side stores verbal and mathematical memories.

Autonomic Nervous System

It is involved with the self-governing (automatic) regulation of three aspects of the body: smooth muscle, cardiac muscle and the glands. It controls the functions and involuntary muscles of the respiratory, circulatory, digestive, and urogenital systems. Two antagonistic and anatomically separate systems comprise the autonomic nervous system i.e. sympathetic division and parasympathetic division.

The sympathetic division stimulates the heart, dilates the bronchi, contracts the arteries and inhibits the digestive system. This system serves to prepare the organism for fighting in order to ensure survival in face of an environmental threat. This division has wider connection to the eyes, salivary gland, sweat glands and blood vessels in the skin, heart, lungs, stomach, kidneys, adrenals, pancreas, intestines, external genitalia, and bladder.

The parasympathetic nervous system arises above and below the sympathetic nervous system in the brain and from the lower part of the spinal cord. It produces the opposite effect of the sympathetic division. Parasympathetic division prepares the organism for feeding, digestion and rest.

Pituitary gland: It is also known as “master gland” or master of orchestra” as it controls other endocrine glands in the body. It is connected to the hypothalamus by the pituitary stalk. It secretes hormones that control sexual development, promote bone and muscle growth, respond to stress and fight disease.

Pineal gland: It is located deep in the brain in the middle. It helps in regulating the body’s internal clock and circadian rhythms by secreting melatonin. It has some role in sexual development. It involutes with advancement of age. Though religious literature puts pineal gland as the highest seat of spiritual gain, scientific evidences are lacking.

Physiology

Brain is made up of two types of cells i.e. nerve cells (neurons) and glia cells. Neurons possess a very high rate of metabolism requiring a constant supply of nutrients and oxygen. Till recently, it was believed that numbers of neurons are fixed at birth and they cannot be regenerated in adult life. However, recent evidences have contradicted this view. This has provided a great boost to meditation and other techniques which aim at rejuvenating brain. Glia (Greek, meaning glue) is

the cell of the brain that provides neurons with nourishment, protection and structural support. They are about 10 to 50 times more than the nerve cells.

Evolutionary aspect

The evolutionary process adds higher centre to the primitive nervous system. These higher centre have inhibitory influence; in other words they suppress the functions of lower centre. Thus, the brain stem is controlled by the higher limbic system and the limbic system in turn is controlled by higher neo-cortex. The neuromodulators with their influence on various neurotransmitters effectively bring about this inhibitory modifications and inter-relations among various brain centres (hierarchy).

Neo-cortex keeps all the involuntary movements, hyper-reflexivity, rage, aggression, and similar animal tendencies under check so that it can effectively pursue its own highly developed activities of logic, memory, reason, language, calculations, judgement, and concepts etc. Conscious, willful and imaginative functions are therefore normal state of awareness of the human beings.

When meditation acts as a constant repetitive stimulus, certain qualitative and quantitative permanent changes develop in the nervous system. The neurotransmitters and neuromodulators may stimulate growth of dormant or latent neurons to develop a centre (or centres). The brain develops new connections and plasticity resulting in the capacity to think, to rationalize and react in a different way to the sensory input than what is expected. The new developed higher centre will exert inhibitory control over the present day neo-cortex, and thereby, over the mind as a whole. The consciousness and all mental activities will hence be suppressed. The person will reach a state beyond mind itself, which can be called transcendental awareness.

3. Assessment of Changes in Brain with Meditation

Effects on brain can be studied with psycho-cognitive tests, electrophysiological assessment (EEG, Magnetoencephalography, evoked potentials, skin resistance etc.), functional neuroimaging (fMRI, PET, SPECTS, Doppler blood flow study etc.), hormonal and biochemical changes, and epigenetic studies etc. To maintain brevity, we will touch upon only EEG and fMRI in this article.

All brain imaging techniques are indirect in some manner as they do not provide a direct way of “seeing” the brain. Techniques for measuring electrical and magnetic fields that excite the brain have a very high temporal (time-based) resolution but do not tell us about the brain structures

where the activity is occurring. Neuroimaging techniques, particularly fMRI, can plot *what* activity is occurring *where*.

Brain waves and meditation

Electroencephalogram (EEG) waves: Neurons communicate with each other by electrical changes. We canrecord these electrical changes in the form of EEG waves.These brain waves are described in terms of frequency bands. There are five frequency bands i.e. alpha, beta, theta, delta and gamma brain waves. Our overall brain activity is a mix of all the frequencies at the same time in different combinations guided by the situation.

Alpha waves (8-12 Hz) are associated with relaxation, non-arousal state of brain and the lack of active cognitive processes.

Beta waves (13-30 Hz) are associated with active thinking, active attention, focused on the outside world or solving concrete problems.

Theta waves (4-8 Hz) are associated with dreaming and drowsiness. They are of two types i.e. that which is associated with lower levels of alertness and other that is associated with alertness, attention and processing of cognitive tasks. Theta brain waves in meditation are said to open the "third eye" for practitioners. In practical terms, theta waves invoke a deep sense of relaxation and also encourage creativity and make problem solving and memorization easier.

Delta waves (1-4 Hz) are associated with deep sleep but may also be present in the waking state. Delta waves are said to occur during meditationin experienced practitioners as they access the unconscious mind.

Gamma waves (above 30 Hz up to 70 Hz) are associated with processing of meaningful activity and integration of stimuli into a coherent whole. It is seen in expert meditators.

Most of the studies have noted an increase in alpha waves, particularly in novices (Kasamatsmu and Hiraim, 1966; Khare and Nigam, 2000; Shreyash Prajna and Sanchetee, 2014). EEG in Yogis showed changes of calmness in the form of "alpha rhythm" during both eyes closed and eyes open recordings. A few other studies have shown theta wave prominence which is possibly related to duration of meditation practice (Lagopoulos 2009;Vijayalakshmi*et al.,* 2011).

Travis (2001) studied effect of transcendental meditation and observed (1) significantly lower breath rates; (2) higher respiratory sinus arrhythmia amplitudes; (3) higher EEG alpha amplitude; and (4) higher alpha coherence. Lagopoulos (2009) examined EEG changes during nondirective meditation. They found significantly increased theta power when averaged across all regions but greater in the frontal and temporal–central regions. There was also a significant increase in alpha power in the meditation condition compared to the rest condition, when averaged across all brain regions, and it was found that alpha was significantly greater in the posterior region as compared to the frontal region.

Qin (2009), carried out a follow-up EEG study on a subject with 50 years of experience in Qigong. Resting EEG showed frontally dominant alpha-1 as compared to occipital dominant alpha-2 described in 1962. During the Qigong practice, alpha-1 enhanced quickly and became far more prominent than 50 years ago. Compared with baseline, these activities remained to be higher at rest after the Qigong practice. Cahn et al. (2010) observed decrease in frontal delta power, especially in those participants not reporting drowsiness during meditation and relative increase in frontal theta power during meditation, as well as significantly increased parieto-occipital gamma (35–45 Hz) power, but no changes were observed for the theta (4–8 Hz), alpha (8–12 Hz), or beta (12–25 Hz) bands. Their findings suggest that long-term *Vipaśyanā* meditation contributes to increased occipital gamma power related to long-term meditational expertise and enhanced sensory awareness.

Vijayalakshmi *et al.* (2011)observed that mean value of alpha and theta waves showed an increase after meditation. The amplitude of delta showed an increase of 73.34% and a decrease of 26.67%. The increase in the alpha and theta parameters suggests relaxation after meditation.

Thus major finding indicates that theta and alpha powers are related to proficiency of practice. However, the alteration in the dynamics of these rhythms with extended meditative practice is non-linear and topographically specific. These observations imply that increases in alpha power as a state effect of meditation may be related to learning meditation in the early stages for some subjects, but long-term practitioners demonstrate little enhancement of alpha state effects (Cahn *et al.,* 2010). Theta band activity increase seems to be a marker of meditation across a number of different practice types, although it appears more specifically related to the focused attention on meditative forms (Lutz *et al.*, 2009; Baijal and Srinivasan, 2010; Cahn *et al.*, 2010). In addition,

growing evidence indicates that increased gamma band fast amplitude activity can be observed in advanced practitioners, which supports the interpretation that many meditative practices involve active up-regulation of attentional capacities (Lutz *et al.,* 2004, Cahn *et al.,* 2010). In general five patterns of changes have been observed i.e. high-amplitude alpha, slow alpha + theta, theta + delta, delta, amplitude suppressed ("silent and almost flat"). In addition, alpha blocking phenomena was also observed characterised by no change in alpha rhythm with external stimuli. Long-term meditation practitioners have also shown to have a higher tolerance for pain. This effect has been correlated to altered function and structure in somatosensory cortices and an increased ability to decouple regions in the brain associated with the cognitive appraisal of pain (anterior cingulate cortex and dorsolateral prefrontal cortex).

Brain imaging

Recent neuroscientific evidences suggest that meditation alters the function and structure of distributed neural processes underlying attention and emotion (Brefczynski-Lewis *et al.*, 2007, Pagnoni and Cekic 2007, Lutz *et al.*, 2009).

Meditators show greater gray matter concentration in regions that are activated during meditation e.g. right anterior insula which is involved in interoceptive and visceral awareness, left inferior temporal gyrus, mid-temporal area, left posterior intraparietal sulcus and right hippocampus (Lazar *et al.*, 2005). The mean value of gray matter concentration in the left inferior temporal gyrus is predictable of the amount of meditation training.

Activity as well thickness of anterior parts of the brain such as orbitofrontal cortex (OFC) and temporal areas is often enhanced in meditators (Lazar *et al.*, 2005, Pagnoni and Cekic 2007, Vestergaard-Poulsen*et al.*, 2009). There is reduced activity with thinning of cortex in the regions of the brain, located in the parietal and occipital areas including the postcentral cortex, inferior parietal cortex, middle occipital cortex and posterior cingulated (Kang *et al.*, 2013). Functional neuroimaging studies using PET and fMRI have shown enhanced activity or larger volume of the hippocampus in meditators. Recent research suggests that such enhancement of hippocampus could lead to the reactivation of memories and exaggerated self-esteem (Lazar *et al.,* 2005).

The core components of meditation practice are attention control, emotion regulation and self-awareness. Each of these components has been identified to involve specific structures in the brain (Fig 3 & Table 1). During the processing of aversive and self-referential stimuli, mindful

awareness is associated with reduced medial prefrontal cortex (MPFC) activity, a central default mode network (DMN) component. Other components of DMN are dorso-medial PFC (DMPFC), ventro-medial PFC (VMPFC), inferior parietal lobule (IPL), precuneus (PC), posterior cingulate cortex (PCC) and inferolateral temporal cortex (ITC). Relative to beginners, experienced meditators had weaker functional connectivity between DMN regions involved in self-referential processing and emotional appraisal. In addition, experienced meditators had increased connectivity between certain DMN regions (e.g. DMPFC and right inferior parietal lobule) compared to beginner meditators. Luders *et al.* (2009) investigated 22 active practitioners of meditation and found larger gray matter (GM) density in the orbitofrontal cortex which is related to emotional regulation processing.

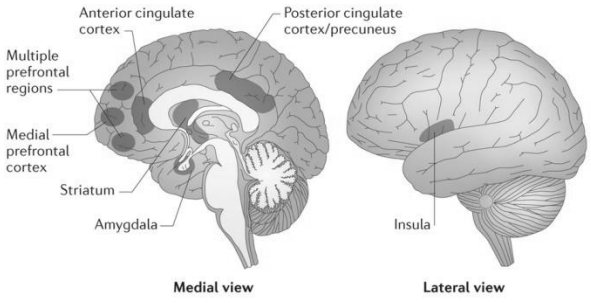

Figure 3. Brain regions involved in components of mindfulness meditation (Tang *et al*.,2015).

Table 1: Brain regions involved in the components of mindfulness meditation.

Region	Self regulation of Attention	Emotion	Self awareness
Anterior cingulate cortex	Yes	Yes	-
Posterior cingulate cortex	-	-	Yes
Prefrontal Cortex	Yes	Emotion	-
Frontopolar cortex & sensory cortex	-	-	Yes
Insula	Yes	Yes	Yes
Corpus Striatum	Yes	Yes	-
Amygdala & Limbic System	-	Yes	-

Diffusion tensor imaging (DTI) is a quantitative method used to assess the integrity of anatomical connectivity in white matter (Lazar *et al.*, 2005, Luders*et al.*, 2011, Tang *et al.*, 2012). It has demonstrated changes in relevant areas more effectively.

4. Effect of *Prekṣā* Meditation (PM) on Different Systems

On physical level: Exertion, more than the stored energy in body, reduces the working efficiency of the inner organs of our body. PM assists each body cell to revitalize itself. It makes respiration more efficient and improves circulation and quality of life.

On mental level: It is an age of competition which creates tension in humans. Due to tension many physical and psychological diseases take place. PM reveals the mysteries of mind and helps to concentrate at one place and experience the inner consciousness which becomes helpful in elevating the mental level.

Meditation and Endocrine System: Biochemical and hormonal studies provide a physiological basis to document changes which occur with meditation. In summary, meditation increases the production of growth hormone, dehydroepiandrosterone (DHEA), gamma amino butyric acid (GABA), melatonin, insulin, thyroid hormones, serotonin and dehydroepiandrosterone and decreases levels of cortisol, lactate, catecholamines (epinephrine and norepinephrine).

Melatonin is a hormone produced by the pineal gland. It has circadian rhythm and is an important determinant for good sleep. It is a potent anti-oxidant and has important role in mood changes, aging, sexual maturation, reproduction, cancer, immune system response and many diseases. Meditation is associated with increase in level of melatonin by 75% to 300%.

Betal and Gaur (1998) studied effect of PM on drug abusers' personality and observed that regular practice decreases drug abuse. They also found that, besides this improvement in psychological health, the subjects reduced the tendency of taking drugs.

Gaur and Saini (2002) concluded reduction in anxiety and hassles of prisoners who performed PM. They revealed that the prisoners significantly reduced ($p < .001$)their anxiety and hassles, in several areas i.e., health, family, society, occupation, economy etc.

Gaur and Shah (2007)studied effect of PM on delinquent behaviour and CNS and ANS functions and observed that EEG activity in the occipital areas and frontal area slowed down significantly ($p < .0005$) in experimental group. Similarly, heart rate and respiration rate also slowed down in the experimental group.

Sharma and Gaur (2008) studied effect of PM on mental health, reactions to frustration and personality variables of prisoners and found significant difference on all the 11 factors of their mental health viz; anxiety, despair, anger, headache, fatigue, sleeplessness, constipation and acidity($p<.0005$). Moreover they found experimental group to be more relaxed, restful, enthusiastic, hopeful, calm, fresh, and active having better sleep and appetite. Their total health criteria increased significantly ($p< .0005$).

Shekhawat and Mishra (2011**)** studied efficacy of PM on cardiovascular functions and blood profile of adults and found that:

- A significant decline in blood pressure (systolic, diastolic and mean pressures) was observed in experimental group both after three and six months of PM.
- Quantitative serum total cholesterol, triglyceride, low density lipoprotein and very low density lipoprotein in experimental group were significantly reduced after six months practice of PM.
- The quantitative blood glucose in experimental group decreased significantly after practice of PM.
- The six month PM intervention has also resulted in significantly increased hemoglobin level in experimental group.

Kapoor and Mishra (2011**)** found that meditation can remove academic pressure and anxiety, eliminates conflicts, enhances emotional stability and vitalizes an individual for satisfactory performance in the area of student's work and relationships.

4.1 Other electrophysiological changes with meditation: 1) Yogis could slow both heart rate and rate of respiration. 2) Yogis could slow the rate of metabolism as confirmed by decreased oxygen consumption and carbon dioxide output. 3) Skin resistance to electric stimulation was increased (indicating increased tolerance to external stimuli).

Our usual 'alarm' reaction to emotional and physical stress is in the form of "fright, flight, and fight" mediated through over-secretion of certain neuro-transmitters and neuro-modulators by way of stimulation of sympathetic nervous system. Under the influence of these chemicals and hormones, we reflexively become panicky or aggressive, our blood pressure rises. Thus stress and anxiety is the end result if we allow our natural age-old sympathetic reactions to act and to come to surface. But today these 'alarm' reactions have no place in our lives. Rather, they should be

replaced by more calm and serene reactions of equanimity and fearlessness. Such desirable reactions of non-aggression and peaceful attitude are generated by yoga and meditation.

5. Philosophical basis of *Prekṣā* Meditation

There are two broad branches of philosophy –i.e. spiritualist and non-spiritualist. According to non-spiritualist philosophy, a living organism is understood in terms of gross body sense-organs and brain. On the other hand, the spiritualist philosophy goes beyond gross body and adds subtle *taijasaśarīra*, *kārmāṇaśarīra*, conscious mind, psychical expression (*Adhyavasāya*) and finally the psyche or the soul itself as the constituents of the living organisms. Soul forms the nucleus of the organism transcendentally and it is pure in nature. Proceeding towards the physical body, they pass through the domain of *leśyā* and convert into urges and impulses, which are the forerunners of emotions, passions and feelings produced in the gross body. These compulsive forces first affect the endocrine system and encourage them to secrete and distribute the chemical messengers (hormones), suitable and corresponding to the nature and intensity of the impulses. These hormones circulate through blood and goes to the brain and nervous system- this creates the neuroendocrine system. This system controls and regulates not only every bodily function but also profoundly influences mental states, emotions, thought, speech and behavioral patterns of an individual.

6. Research Potentials

1. To study evolution of human brain from foetus to adult to address to the relevance of its functions at each stage and to find out if the evolution is longitudinal or parallel.
2. To compare brain size, area and structure in different species in animal kingdom including humans and correlate them with their functional efficiency.
3. Changes in different areas of brain with meditation.
4. Role of different types as well as components of meditation.
5. Role and relevance of pineal gland in meditation.
6. Role and relevance of spinal cord in *Kuṇḍalinī.*
7. To identify role of different areas or part of brain in conscious awareness.
8. To scrutinize Jain literature concerning physiological subjects to find confirmation of statements made in this article.
9. Why does brain have two hemispheres and what are their independent functions?

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