CHAPTER – 3

SCIENTIFIC LITERATURE REVIEW

TABLES & FIGURES

CHAPTER 3 – SCIENTIFIC LITERATURE REVIEW

3.0 INTRODUCTION

This Chapter concerns the scientific study of creativity, including modern definitions [165-168] and the development and applications of neuropsychological tests capable of assessing such abilities.[169] Creativity is a power of mind often attributed to geniuses and other gifted or talented individuals.[167] In popular language as well as historically, terms like "*genius*", "*gifted*", "*talented*" and "*creative*" are often thought of as synonymous.[168] Creativity occurs primarily in the arts and humanities – literature, music, dance, or visual arts – with little recognition that creativity is crucial for other fields as well, such as biology, mathematics, physics, chemistry, earth science, and engineering.[167] In the current context, it is of interest to note that in the east words concerned with creative genius exist, such as *Pratibhāḷı, Alochāna* and *Prajñā*, but adjectives attributed to individuals are not found. The west is given to the cult of the individual, but less so in the east.

3.1 AIMS AND OBJECTIVES

For the main part of this study I aimed to investigate whether Cyclic Meditation (CM) influences creativity and associated EEG synchrony. Also, to evaluate any correlations between the two.

3.1.1 AIMS

The first aim is to capture through phenomenological, cognitive, and neuroscientific studies of creativity, how creatives / geniuses experience the creative process. What are those cognitive states which enables an individual to create and express their selves, as creativity.

3.1.2 OBJECTIVES

1. To Measure Impact of Cyclic Meditation practice on ATTA Creativity Test
2. To follow associated changes in EEG synchrony
3. To identify any Correlations between these two sets of changes.
4. To compare these to any effects of *Shavasana* practice by controls.

3.2 METHODOLOGY

The current research aims to explore and investigate methodological possibilities, the possibility of the combining of the eastern (Vedanta) and western (imaging) techniques to connect the qualitative and quantitative methodologies to investigate the cognitive states enabling the creative process and expression of heighted self, leading to infinite happiness, infinite bliss, infinite freedom and expansion of one's being known as Self. (Refer Fig.1.1)

3.3 MATERIALS AND METHODS

A key aspect of this chapter was a systematic search of the databases listed below was made, based on the area of research and then narrowing to the heart of the main area of my thesis. The resources commonly from Journal Databases, Library catalogue of the University of Florida (on advice of Dr. Kenneth Heilman & Dr.Vinod Deshmukh) since 2001 till date; very specific professional websites on the creative innovation directory and neuro-cases, and western newspaper databases for updates. While undertaking a systematic review, I had to specify the criteria that were used to select articles and papers included. Inclusion criteria was specific to my project and experiment. However, the following highlights some common inclusion criteria and how these were applied to my Thesis and in particular the current chapter for inclusion criteria. Relevant to the topic, Peer reviewed Age of material, Design of the study and geography; examples of application for search were: Articles directly related to my area of thesis,; papers must be peer reviewed only, less than 10 years old, and quantitative as well as qualitative studies included.

3.4. CONCEPT OF CREATIVITY - FIRST MODERN EFFORT IN THE FIELD AND COGNITIVE NEUROSCIENCE

The first modern effort to systematically define and study creativity with the systematic tools of modern psychology was conducted by Lewis Terman at Stanford University, [170] driven by an intense desire to understand how the human mind works. Terman began by assuming that 'genius' was the same as 'high intelligence'. Starting in 1921, he began his landmark '*Study of Genius'* continuing until 1956, when he passed on. The universal opinion of his work was that, to make any kind of cognition of creative work possible, a certain level of intelligence is required.[9, 11] However; a further kind of mental faculty must build on it. 'Creativity' is the correct term to describe such a faculty, that empowers people to write novels, sonnets, or symphonies, or to identify new concepts by which to solve scientific problems, even as simple as mathematical equations.[167]

3.5. UNDERSTANDING THE PROCESS OF CREATIVITY AND BRAIN MECHANISMS

During the past several decades, there has been tremendous increase in understanding the process of creativity and its associates in the brain. Creativity has been defined by Mumford as the 'capacity to generate novel, socially valued ideas'.[165] Sternberg defined it 'as an ability to produce work that is novel, original and appropriate'. [166] Creativity is an increasingly popular field of study in many scientific disciplines. It impacts the cognitive sciences, education,[167] social psychology,[171] psychiatry[172] and neuroscience. [173]

3.5.1 TECHNICAL DEFINITION OF CREATIVITY

A dictionary like Webster's offer three definitions of creativity: the power or ability to create; marked by originality; or simply 'productive'.[174] Writing a list of non-words, randomly applying colors to a canvas, or generating a random list of variables may be novel or original but not creative. [174] Thus, the Webster's dictionary definition is inadequate. According to Bronowski (1972), creativity is finding unity in what appears to be diversity. [11, 175] Great art works have a myriad of colors and forms and great musical works have a large variety of melodies and rhythms, but in both paintings and symphonies the artist is able to develop a thread that unites diverse elements and displays order. Creative scientists such as Copernicus was able to see order in what appeared to be a disorderly solar system. Einstein was able to see the thread that unites matter and energy. Pfenninger and Shubik (2001) suggest that creativity is the innate ability to 'associate novel contexts with principles of order'. [176] Heilman defines creativity as the discovery of "unity in the variety, in what is called diversity in nature".[11,177] In this thesis creativity is defined as the ' ability to understand, develop and express in a systematic fashion, novel and orderly relationships, what is called unity in diversity, the thread that unites to the source of creative cognition.'

3.5.2 PROCESS OF CREATIVITY

Regarding understanding what is involved in the creative process itself, western thought suggests that four distinct stages may be involved, as briefly referred to in Chapter 1. Helmholtz (1826) and Wallas (1926) suggesting the four stages: [167, 168]

1. Preparation: In this stage, intellectual resources are accumulated, out of which to construct the new ideas required. During the solution of a particular problem, the preparation stage is used to investigate all aspects of the problem as the thinker readies the mental soil for sowing the seed of its solution. Skills and knowledge are acquired in this stage. For example Einstein developed great skills in Physics and Math before he made his great discoveries.[167]

Picasso acquired considerable experience in drawing forms and mixing colours before he decided to create an artistic revolution, restructure the expression of forms, and painted his '*cubist–masterpieces'*.[11, 177]

2. Incubation: Following preparation comes a period of unconscious processing known as incubation. A period of time usually needed for a person to consider a problem in depth, and clearly internalize all that it involves, eventually allowing a solution to come to mind. During this time, no direct effort is exerted upon the problem at hand. New mental combinations may arise such as those that distinguished the thought of Einstein, Newton, and Picasso. Two divergent processes take place: one, incubation, no conscious deliberation on the problem occurs and second, in sets of unconscious, involuntary mental events, termed by Wallas, 'fore-conscious' and 'fore-voluntary' occurs, because although they are not consciously directed, they originate in conscious attention.

3. Illumination: Helmhotz (1826)[167] and Wallas (1926)[168] introduced the term illumination to describe what happens when a key idea arises in the mind. By incubating ideas about a phenomenon, many creative people arrive at a cognition, which alters their subsequent cognitive processes, and which is often termed an epiphany, or '*Aha*' experience. Such experiences represent the '*heart of creativity'* – the key process of creative cognition.

4. Verification: Following incubation is the illumination stage. Based on French polymath Henri Poincare's concept of sudden illumination, that flash of insight, the conscious self can't will, (free-will) and the subliminal self (higher intelligence) can only welcome, once all elements gathered during the preparation stage have floated freely around during incubation and are now ready to click into an illuminating new formation. This is a natural, spontaneous state of mind and cannot be forced. It is accompanied by the final flash or mental 'click', which is the culmination of successful trains of association and thinking. Such trains of associations form connections between the seemingly unconnected areas within the brain's essential networks in the creative process.

   This term is slanted towards scientific usage. Creative scientists usually perform experiments attempting to prove or disprove their cognition, which is treated as a scientific hypothesis or conjecture. In the arts it may be different, as ideas may come to an artist as rapidly as he or she may express them. In the last stage conscious and deliberate effort of testing the validity of idea and reducing the idea into form happens, hence the last stage fulfils the scientific verification of the concept or idea that arose during the first three stages i.e. preparation, incubation and illumination.[167, 168]

Thomas Kuhn (1996) noted in his '*Structure of Scientific Revolutions'* [178] that many important discoveries are based on observing an '*Anomaly*'. They happen when a scientist perceives significance in apparently accidental occurrences, incidental pattern recognition or gestalt. Scientists who make such discoveries are those who see significance in such accidents. Although the discoveries are based on an anomaly, only '*prepared minds'* are creative enough to perceive the importance of the phenomena that they observe. [167, 168]

Other views oppose the four stages named. Weisberg (1986) suggested that creativity does not require great leaps, i.e. illumination. Processes leading to many discoveries might not require subconscious incubation, but rather a series of conscious steps.[179] Even Helmholtz and Wallas see illumination not necessarily as an independent factor, but as the culmination of the incubation process.[167,168]

A comprehensive definition of creativity was given by Csikszentmihalyi in 1999,[180] who proposed that it required three interrelated components: He offered distinct definitions of terms such as the '*domain* and the *field'* and in doing so explained the roles of culture and society as they affect creativity. Csikszentmihalyi's model is a tri-partite one. Along with (a) cultural and (b) societal, he also included (c) intra-personal factors (i.e., factors located within an individual's psychological make-up) in pre-disposing individuals towards having their products or ideas accepted in a domain called flow.[180] There are congruencies between his concept of flow and my own experiential concept of creativity. For example, both Csikszentmihalyi and I refer to creativity as a distinct mental state. Also, there is evidence of distinct patterns of neural activity occurring in frontal and parietal brain regions during both these states.[181,182]

The three interrelated components are:

1. The Domain: The domain is an area of knowledge, such as music, forming an aspect of knowledge or culture.
2. The Field: The field consists of people like critics, collectors, museum curators, journal reviewers, or funding agencies, who act as gatekeepers to the domain.

3. The Person: The person is the one who has a new idea, or sees a new pattern, of sufficient importance for its novelty to be selected by the field for inclusion into its domain.

Today, this definition seems quite exclusive, for the *Adi Saṅkarācārya* and Picassos, the Einsteins and Disneys, of this Concept. Creativity is required in many if not most human activities as lowly as speaking a few sentences, to drawing a simple picture. Originality of expression is then one of its

hallmarks, though other factors such as fluency and flexibility of expression and elaboration of an initial impulse are also clearly critical and important aspects.

At the elite level, the key is that all three components must be present for such a level of creativity to be recognized: it should create something new, typically enlarging a domain, or transforming it, or even creating a new domain; also, the arbiters should come from the field responsible for the domain; such objective evaluation is important. Csikszentmihalyi referred to his three-in-one picture as a "systems model" of flow. [181,182]

3.5.3 GENESIS OF THE WORD *'CREATE'*

The word "create" derives from the Latin *'creare'*, which means to "produce, make, or create."[183] There is an obvious link between a human creator of sonnets or statues, and a godly '*Creator of the Universe'*. Thus, some of the great creators of the past were honored with the accolade '*divine*'. For example, the Italian biographer of Renaissance artists, Giorgio Vasari, refers to "the divine Michelangelo".[184] The word creativity has historically been used interchangeably with the term "genius". Genius is a common Latin word, originally derived from the Greek "*ginesthai*", which meant " to be born, or come into being",[185] In common usage in Roman times, genius originally referred to a god or spirit given to each person at birth that would determine his or her character and fortune. [186-188] This meaning soon evolved into the more familiar usage of genius as employed in later centuries when people began to use the word to describe people who had extraordinary intellectual abilities, or capacities for creative imagination. Genius was the most popular term for referring to great creative capacities from the 17th to the early 20th centuries. The earliest works on creativity were published in the 19th century. Italian psychiatrist Cesare Lombroso wrote a book, '*Genius and Insanity'*; English naturalist Francis Galton published '*Heredity Genius'*. In the early 20th century, the English physician Havelock Ellis wrote, *'A Study of British Genius'*.

These books were all efforts to examine interwining between heritability of creativity and mental illness. Only when the modern discipline of psychology emerged in the 20th century did the term "creativity" begin to be used, together with attempts to define it in a scientific way. [186-188]

3.6 CREATIVITY AND DIVERGENT THINKING

The concept of divergent thinking was put forth by William James (1890) suggesting the ability to change strategies was important in divergent thinking.[188] Creativity requires novel understanding and expression of orderly relationships. Novelty requires that the creative person takes a different direction from the prevailing modes of thought or expression, which is called divergent thinking. [189]

Creativity is measured and verified by divergent thinking tasks, wherein many possibilities can be developed from one starting point, which stimulates creative thinking resulting in new answers, ideas or new patterns. Divergent thinking is an important, measurable aspect of creativity. According to Guilford, divergent thought production depends on information retrieval, and relates to the number of varied responses. [189]

3.6.1. DIVERGENT THINKING AND FRONTAL LOBE

The frontal lobes play an important role in divergent thinking and developing new strategies.[190] Oliver Zangwell (1966) suggested that frontal lobe dysfunction would disrupt divergent thinking.[191] There are two components to divergent thinking, disengagement and developing alternative solutions.[192-194] The frontal lobes have strong connections to the polymodal and supramodal regions of the temporal and parietal lobes, which excite or activate semantic conceptual networks important for alternative solutions and divergent thinking, the core of the creativity.[49, 50]

3.6.2. BASIC INFORMATION OF THE TEST

Following the work of Guilford (1950)[196] the most popular creativity tests in current usage were developed by Ellis Paul Torrance and his associates in 1966. [197] Ever since, western approaches to investigating creativity have been based on their experimental tests. They have been renormed four times in 1974, 1984, 1990, and 1998. There are two forms (A and B) of the TTCT-Verbal and two forms (A and B) of the TTCT-Figural. Scholastic Testing Service, Inc. (in Bensenville, IL.) holds the copyright for the TTCT and has provided a 1998 norms manual for the test. The TTCT can be administered as individual or group tests and used for kindergarten through graduate students. They require 30 minutes working time. [198]

3.6.3 PURPOSE

The TTCT was part of a long-term research program emphasizing classroom experiences that stimulate creativity.[199] Torrance (1966, 1974) defined creativity as “a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty, searching for solutions, making guesses, or formulating hypotheses about the deficiencies: testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results”. Torrance (1966, 1974) suggested the following uses for his test: [200-202]

1. To understand the human mind and its functioning and development
2. To discover effective bases for individualizing instruction

3. To provide clues for remedial and psychotherapeutic programs
4. To evaluate effects of educational programs, materials, curricula, and teaching procedures.
5. To become aware of latent potentialities.

3.6.4 AREAS AND DIMENSIONS FOR ASSESSMENTS

Several revisions of the TTCT-Figural manual have been made, though the test has remained unchanged. The first edition in 1966 measured fluency, flexibility, originality, and elaboration, which were taken from the divergent-thinking factors found in Guilford's Dimensions of Aptitude. The scoring is as follows: [203,204]

1. Fluency - by the number of interpretable, meaningful, and relevant responses to the stimulus.
2. Flexibility - by the variety of categories of relevant responses.
3. Elaboration - by the addition of pertinent details by Torrance, 1966; Cramond, Benson & Williams, 2008
4. Originality - by responses which are unexpected, unusual, unique or statistically rare.

3.6.5 ADMINISTRATION

The Torrance tests can be administered to different age groups, including high school students, university students, and adults. The tests for high school students are of four kinds, each focusing on a different dimension of creativity. For wider usage, Torrance developed a shortened form of the test, the Abbreviated Torrance Test for Adults (ATTA). [203]

The ATTA, used in our study, yields results for four norm-referenced abilities: Fluency, Originality, Elaboration and Flexibility. It also provides criterion-referenced creativity indicators for (a) Verbal responses (Richness and Colorfulness of Imagery; Emotions/Feelings; Future Orientation; Humor-Conceptual Incongruity; Provocative Questions), and (b) Figural responses (Openness-Resistance to Premature Closure; Unusual Visualization-Different Perspective; Movement and/or Sound; Richness and/or Colourfulness of Imagery; Abstractness of Titles; Context: Environment for Object, Articulateness in Story telling; Internal Visual Perspective; Expressions of Feelings and Emotions; Combination/Synthesis of Two or More Figures; and Fantasy). [203, 204] Our subjects were young adults, so ATTA was used. For assessment of creative cognition today, the ATTA is the instrument in widest use, often to assess professional skills. Although ATTA does not offer a comparison with professional situations, its scales of fluency, flexibility, elaboration and originality, can assess divergent thinking involved in verbal, visual and figural creativity. Below, a representative sample of studies is reviewed.[203, 204]

3.6.6 RELIABILITY

ATTA reliability for our study was adopted from the test-retest reliability and scorer reliability. The numerical value for the test-retest reliability is .340-.682 ($p<.01$) and for scorer reliability it is .311-.975 ($p<.01$). The linguistic parts of correlational coefficient in criterion referenced creativity indicators is .457 ($p<.01$); whereas, that in figure parts is .368 ($p<.05$). [203,204]

Scores for fluency, flexibility, originality and elaboration, yielded by the ATTA, can be co-related with EEG activity in various areas of the brain like the frontal and parietal regions.[59] EEG studies of healthy subjects point to interhemispheric and intra-hemispheric communication of neuronal networks being important. These offer evidence for communication and connectivity between brain areas being important for divergent thinking.[11, 16, 194,195] The Wechsler Adult Intelligence Scale and Torrance tests, found that creative individuals had more inter- and intra-hemispheric EEG coherence respectively, than those who were less creative.[36, 205] Overall, these EEG studies support a relationship between divergent thinking and physiological interactions, associations and connections between brain regions.[36, 63,206,207]

3.7 NEUROSCIENCE OF CREATIVITY

A comparatively low number of scientific publications concern brain correlates of creativity, about 550, (Source: Thomson Reuters © WEB of KNOWLEDGE; Topic:"Creativity" and "Brain"), small compared to the 19,300 listed papers on the brain-intelligence, cognition relationship (ibid.).
These studies investigated brain activity during a broad range of creativity-related tasks, ranging from divergent thinking, to insightful problem solving, to artistic or musical creativity, using a variety of neuroimaging methods. Together, these studies constitute a wide range of original studies and review articles on the neuroscience of creativity. [9,11 ,207](Refer Review Table No.2&3)

3.7.1 NEURAL CORRELATES OF CREATIVE COGNITION IMPORTANT BRAIN REGIONS INVOLVED IN CREATIVITY

The Science of Creativity is beginning a long search for potential cognitive and neural mechanisms. Creativity is not found in one distinct section of the brain or a single clump of nerves. The creative process involves a number of brain regions, and a concerto of brain-wide neuronal activity. Most importantly, all divergent thinking involves the Frontal Lobe. [9,11,207] Clinical studies suggest that the frontal lobes are important for divergent thinking and specialized knowledge, as do functional imaging studies. The domain specific and specialized knowledge is stored in specific portions of the parietal lobes, as discussed in this section in depth. [11,16]

The frontal lobes have strong connections with the polymodal and supramodal regions of the parietal lobes where concepts and knowledge are stored and retrieved during the goal direction attention and rest. The co-activation and communication between these regions is normally not strong, so they are not well connected. Studies reveal that associations between them can be triggered by alterations during meditation, any goal directed activity, or focusing attention, all of which alter levels of neurotransmitters such as norepinephrine.[11,16] Hence our attempt to search for such associations, using one of the most powerful yoga techniques called Cyclic Meditation.[3]

3.7.2 UNDERSTANDING BRAIN ORGANIZATION TO UNDERSTAND CREATIVITY NETWORKS

Dietrich (2003) conceptualized the brain as being hierarchically ordered; [31] different brain areas have different functions, some being more basic, simple, and fundamental, others being more complex.[208,209] From an evolutionary perspective, the brain can be viewed as having been formed from the inside out, with simple functions on the inside. The innermost structures dealing with unconscious functions fundamental to survival are hypothesized to be the oldest; while the outer structures dealing with conscious functions, such as thinking, planning, sensing, and acting, have evolved more recently.[210-212]

3.7.3 IMPORTANT AREAS INVOLVED IN CONSCIOUSNESS AND CREATIVITY

The human brain can be naturally divided into three main areas: the forebrain, the midbrain, and the hindbrain, also known as Triune Brain. (Refer Fig. 3.1). The hind and midbrain, including structures such as the cerebellum, pons, and medulla oblongata (as well as a variety of key bundles of neurons called nuclei), are key in unconscious automatic functions related to survival. [213, 214] When conceptualizing a neuro-anatomical hierarchy of consciousness, the anatomically lower (and more medial) brain areas (e.g., brainstem) are placed lower in the hierarchy, whereas the increasingly integrative and complex functioning regions reside further from the core of the brain, in the higher and more lateral regions (e.g., dorsolateral prefrontal cortex). The more complex regions are located in the cerebral cortex, with the prefrontal cortex being the pinnacle higher-order region**.** [208]

Figure 3.1

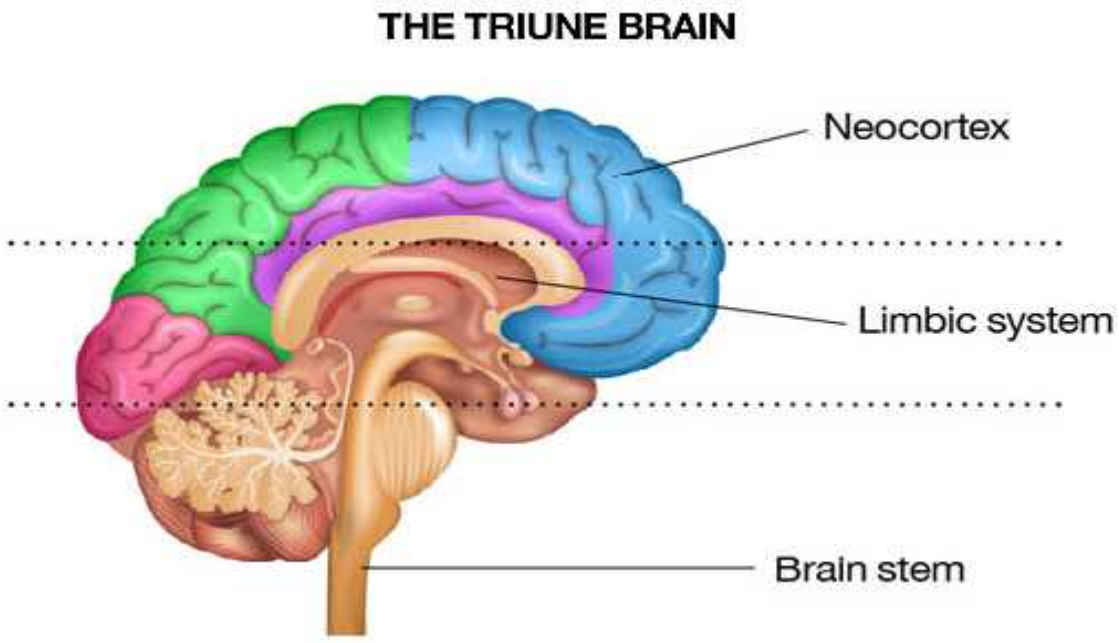

Figure 3.1 depicts the human brain, naturally divided into three main areas: the forebrain, the midbrain, and the hindbrain, also known as Triune Brain

The higher brain areas will be discussed further in this Thesis, because the higher and more frontal areas have been implicated in divergent thinking and creativity. [216-218] I will focus on the forebrain, particularly the frontal (prefrontal cortex) and parietal regions, and the important networks and their inter-connectivity and synchrony enabled by meditation. [3, 31]

Anterior to the motor association cortex lies the prefrontal cortex. Comprising nearly half the frontal lobe, the prefrontal cortex is involved in integrating perceptual information, formulating plans and strategies, and instructing the motor cortices to execute actions. [219] The sum of the processes occurring in the prefrontal cortex is often referred to as executive functioning. [220] (Refer Figure 3.2). The brain networks involved are further explained in creativity section.

Figure 3.2 – The Main Regions of the Brain and their Functions

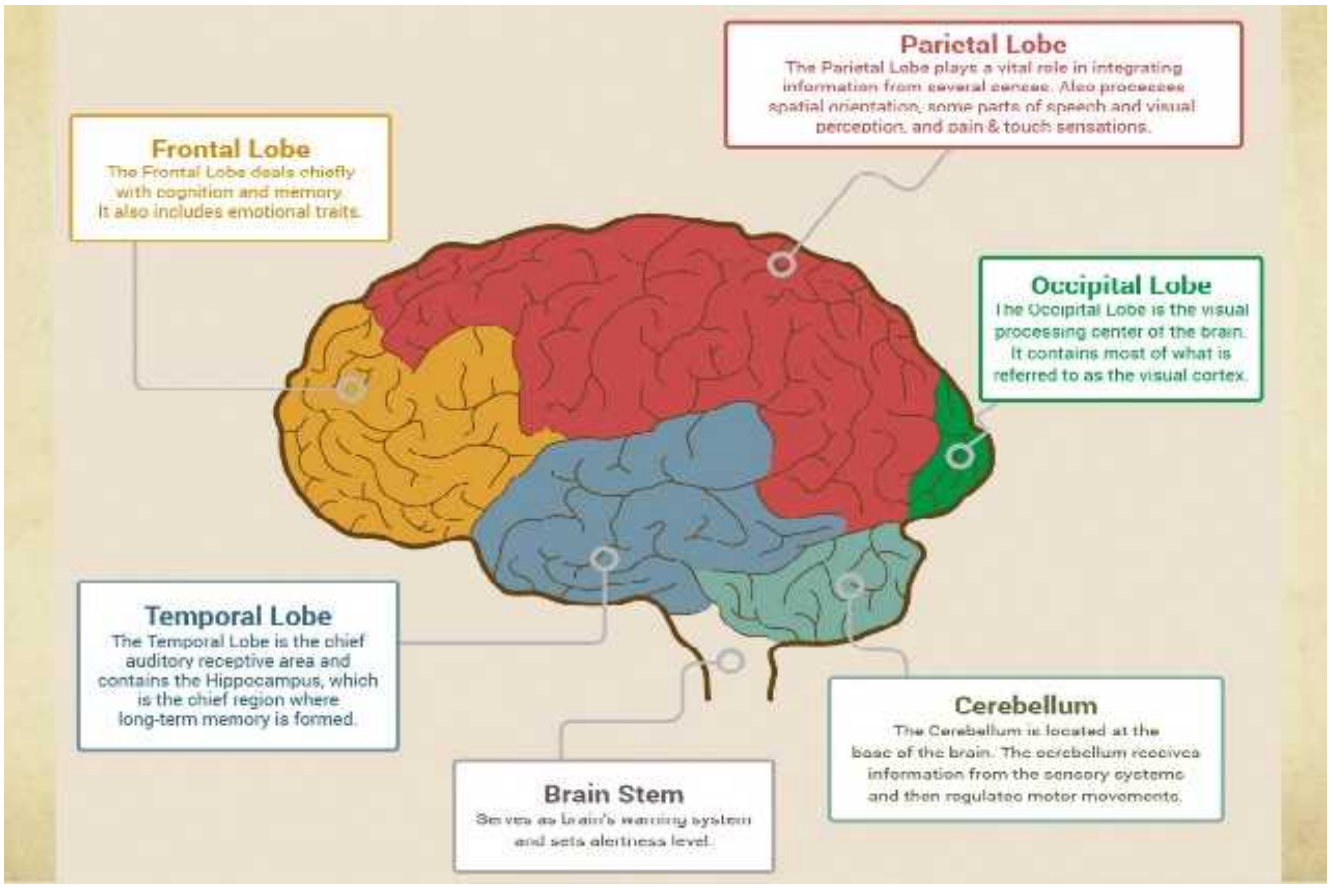

Figure 3.2 depicts the main regions of the brain i.e. frontal, parietal, occipital, temporal, the cerebellum, and brain stem, their main functions and involvement in the creative process.

3.7.4 CONSCIOUSNESS, SELF AND INFORMATION PROCESSING IN THE PREFRONTAL CORTEX ENABLING THE FLOW OF CREATIVITY

Functionally the prefrontal cortex is divided into two regions: the ventro-medial and dorsolateral prefrontal cortices. The ventro-medial prefrontal cortex is associated with social functioning and the sense of self. Due to its complex interconnections with the limbic cortex, the ventro-medial prefrontal cortex is involved in emotion-related learning; [221] more incisively it is involved in assessing personal consequences to one's own behaviour.[219] The ventro-medial prefrontal cortex is involved in the manifestation of emotions into consciousness through the delivery of emotional information from deep limbic structures into working memory, essential for creativity.[219]

In contrast, the dorsolateral prefrontal cortex primarily receives innervation from other regions of the cerebral cortex, i.e. the temporal, occipital, and parietal lobes, and its primary output is towards the motor cortices. As such it is not related to emotion-based learning like the ventro-medial prefrontal cortex, but is involved in cognitive functions such as working memory, directed attention, and temporal integration, coherence and synchrony. [222-224]

Dietrich (2004) proposed that the dorsolateral prefrontal cortex is involved in information processing whereby thoughts emanating from the temporal, occipital, and parietal lobes are rendered into conscious awareness in working memory.[219] Functions of the dorsolateral prefrontal cortex have thus been implicated in higher order cognitive abilities such as abstract thinking, self-reflective consciousness, and cognitive flexibility. A number of cognitive neuro-scientific theorists [219, 220, 224] have thus interpreted the dorsolateral prefrontal cortex as the site of 'full-fledged, self-reflective consciousness'.[219] (Refer Review Table No.3)

3.7.5 DELIBERATE AND SPONTANEOUS PROCESSING AND THE PREFRONTAL CORTEX

Working memory has been conceptualized as the site of consciousness,[219,220] however the manner in which information manifests into working memory differs according to the cognitive processing mode of the person at each time. Dietrich (2004a) delineated between two different processing modes occurring during cognitive ideation—a deliberate mode and a spontaneous mode. The deliberate mode can be compared to what has in past literature been called analytical processing, whereas the spontaneous mode can be compared to what has been called intuitive processing.[225] Instigated by circuits in the prefrontal cortex, deliberate processing tends to yield thoughts that are rational, structured, and conforming to internalized social norms; whereas spontaneous processing tends to yield an intuitive stream of unfiltered, non-conforming thoughts manifested into working memory. [219,220] In the deliberate processing mode, the attention guides information retrieval, i.e. semantic memories, stored in long-term memory, whereas in the spontaneous processing mode, attention is less active, allowing intuitive thoughts to surface into conscious awareness.

In deliberate processing, the dorsolateral prefrontal cortex is recruited in a search engine-like process, actively retrieving specific information and transiently rendering it into working memory. (Refer Fig. 3.3

Figure 3.3 – Frontal and Parietal Regions with attentional nodes and its processing

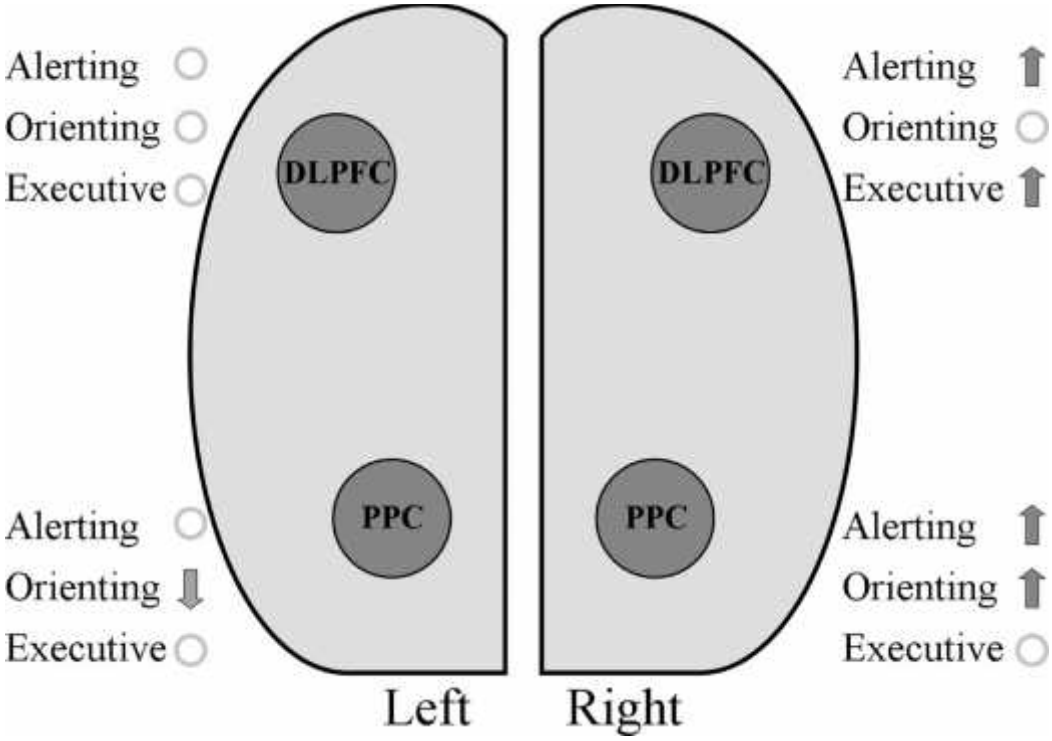

Figure 3.3 depicts the regions of interest i.e. frontal and parietal areas and their modes of Processing attention and information in the left and the right hemispheres.

3.7.6 IMPORTANT REGIONS FOR INFORMATION AND KNOWLEDGE RETRIEVAL DURING CREATIVE COGNITION

The prefrontal cortex instigates the information retrieval process in a circuit which retrieves cognitive information from the temporal, occipital, and parietal lobes.[6,34] Conversely, in spontaneous processing, the attention system does not actively select the content of working memory, but rather it down-regulates. This allows unguided thoughts to enter the working memory buffer as a stream of intuitive ideas. In other words, during spontaneous processing, when the dorsolateral prefrontal cortex is down-regulated, unpre-meditated ideas surface into working memory from the temporal, occipital, and parietal lobes. [182] As such, the quality of content rendered into working memory differs depending on whether semantic information is retrieved by deliberate processing, or whether intuitive thoughts are allowed to emerge into consciousness via spontaneous processing.[208]

This is mediated by the frontal lobes, the executive attention networks and goal directed activity.[182,208]

The prefrontal cortex has also been implicated in inhibitory control of inappropriate behaviors, i.e. self-control and self-regulation.[226] L'hermitte (1983), Pilon, and Serdaru (1986) found that patients with attentional problems, frontal lobe patients, were overly dependent on immediate environmental cues. The ventro-medial prefrontal cortex was interpreted as being involved in filtering environmental information, and in censoring inappropriate or maladaptive responses. This is especially relevant to the creative process, because during spontaneous composition it is important for creative people to be able to bypass internal censoring and to express their intuitive stream of thoughts, i.e. their 'internal voice'.[219, 220] This is demonstrated in the dimension of flexibility experienced during meditation, and gamma band EEG activity in the frontal and parietal regions in this thesis.[3]

3.8 SELF AND IMPORTANT BRAIN NETWORKS

Recognition and differentiation are major aspects of the preparatory and incubatory stages of the creative process. Subsequent organization of information pertains to the self, and the process of self-reference, i.e. people interpret incoming stimuli and information in relation to their self and self concept as background information.[37] The process of encoding this information in memory facilitates recall; hence, the effect of self-reference on memory. Investigations into self-schema, self-concept and self-awareness provide clues to understand the self-referential network in storage and retrieval of information, memory and specialized knowledge important for creativity.[227]

3.8.1 THE SYMPHONY OF SELF AND THE SYNCHRONY IN BRAIN GIVES RISE TO CREATIVE COGNITION

Concept of the four States of Consciousness (SoC) describes the states of mind and the levels of mind, both from the perspectives of modern science and distinct states in the eastern sciences. [24] The one who experiences them is termed 'the knower'; the terminologies used in east and west are distinct. For details (see Table 2.1). Modern neurologists locate the mind in the brain and say that consciousness results from electrochemical neuronal activity.[228] Neuroscience conclusively demonstrates that higher levels of mind and consciousness are enhanced by techniques of meditation, in which the mind and self play dynamic roles. Functions, such as intuition, insight, imagination, understanding, thought, reasoning, intent, decision-making, will and creativity, all of which derive from '*the light of the spirit*', and which have close connections with the frontal and parietal lobes, are measurably enhanced.[228]

Vast numbers of studies have been published on psychology of mind and states of consciousness such as the sleep and dream states in clinical contexts. However, eastern science set about understanding our wakeful mind, its processes and much more. The transition from dream state to full wakefulness, and then to the highest state such as pure consciousness,[24] has begun to be studied by modern science with support from the Vedic Sciences. Eastern sciences have better ways of defining and explaining these heightened states or levels of mind from systematic points of view: the transitions from dream to sleep, from sleep to wakefulness, from wakefulness into the heightened state of awareness, experienced as pure consciousness, from which self functions on a day-to-day basis.[24] Scientists like Antonio Damasio have integrated models of these two by connecting the Self, Brain and Mind, to understand the deeper layers of consciousness and their levels of creative cognition.[75, 81] The mind is what creates different levels of self as can be further explained through scientific findings on the neural basis of consciousness and the Self. [228,229]

3.8.2 THE NEURAL BASIS OF CONSCIOUSNESS AND THE LEVELS OF SELF

Antonio Damasio's integrated model of consciousness and self [75, 81] consists of three levels of self, experienced by fully-conscious beings: 1. Proto self, 2. Core self, and 3. Autobiographical self. The proto self is 'an integrated collection of separate neural patterns that map, moment by moment, the most stable aspects of an organism', i.e. its physical structure, related to the brain stem and cerebral cortex. The protoself serves the current disposition and state of the individual. Second, the core self is a stable personality trait encompassing an individual's subconscious, fundamental evaluations about himself/herself, their own abilities and control. Those who have high core-self will think positively and be confident about their abilities. The role of core self is to monitor changes to the protoself produced by interactions between the individual and the objects in its world, it means the mind-body coordination. The third level, the autobiographical self, is a combination of the first and second levels, and a complete picture of our history, memories and past events and anticipated future. Ordinary western identity emerges from the autobiographical self. [75, 81] These 3 hierarchical levels constitute aspects of the self, determining it as an evolutionary process. Understanding these three levels shows how brain makes mind, and in turn the Self enables deeper states of consciousness and deeper levels of Creative Cognition. In eastern sciences this concept is linked to the three bodies and the five koshas.[92] (Refer Fig.2.1) Damasio's integrative model says minds emerge when the activity of small circuits, i.e. the neural networks are organized across large networks so as to compose momentary patterns, known as the '*symphony of the self*'. This symphony is termed as a pattern of synchrony or coherence in the creative process.[75]

Such patterns represent things and events located outside the brain, whether in the body or external world; some patterns even represent the brain's own processing of other patterns. In brief, the brain maps the world around it and also maps its own doings [75, 81]. Such maps are experienced as images, patterns, forms, qualia and gestalts, giving rise to creative cognitions; forms and images in our body and around it, concrete as well as abstract, actual or previously recorded in our memory. [81] This has been beautifully laid out as the foundation of Self, Mind, Brain and Creativity in the book '*Self comes to Mind'*, [75, 81] in modern cognitive and neuroscience.

This further highlights that the Self is a dynamic process, enabling access to different levels of consciousness,[228, 229] which are correlated to the frontal executive attention and salience brain networks, both of which play key roles in the creative process. This understanding and its neural basis tell us how brains create a subtle process that we name as mind and limbic system functions involving our emotions and feelings. Damasio lays out an interesting perspective on how the brain creates mind, describing the variety of maps, [75, 81] made in the mind in three categories:

1. Maps of the organism's internal structure and state (interoceptive)
2. Maps of other aspects of the organism (proprioceptive), and
3. Maps of the world external to the organism (exteroceptive).

3.9 BRAIN NETWORKS, CONVERGENT-DIVERGENT ZONES (CDZ'S) AND THE LANDSCAPE FOR CREATIVE COGNITION

Mind process is made through connections between and across the distributed network [230] of neural circuits through special neural ensembles that relate maps from one area to those of another area of the brain connecting the different regions of the four lobes. These coherent ensembles are necessary for an integrated self to emerge to guide individual life; by influencing and guiding the sum total of an individual's life's experiences and memories. [231] Brain circuits play a role like that of a chief executive officer (CEO), monitoring all of the channels so as to effectively and efficiently operate the action-decisions that balance the variety of parallel goals of the self; with a sense of coherency and synchrony.[232] The imaging, mapping, forms and pattern making capabilities of the brain, along with the fluid intelligence and creativity displayed by human brains, are the result of evolution of the specialized neural architecture called convergence-divergence zones (CDZ's).[230] What do such CDZ's of interconnected events do? They build patterns of interconnected events that become our conscious memories, thereby allowing exposure to only a single element from the original experience to trigger the retrieval of the full-blown original memory, which means that they process pattern formation and completion, means of associations, coherence and synchrony.

Moreover, retrieval of rich memory sets from partial information in turn provides substrates for factual reasoning, insights and intuition. Major networks (Refer Fig. 3.4) involved in this process are the common networks involved in the process of creativity and meditation, such as the default mode network,[7,38] executive attentional network,[190,242] salience network,[80] and self referential network,[5,37] along with the activation of cortical midline structures. [231] Next, we discuss networks considered to play important roles in creative thought and its process .[232]

Figure 3.4 – Major Networks active during Meditation and Creativity

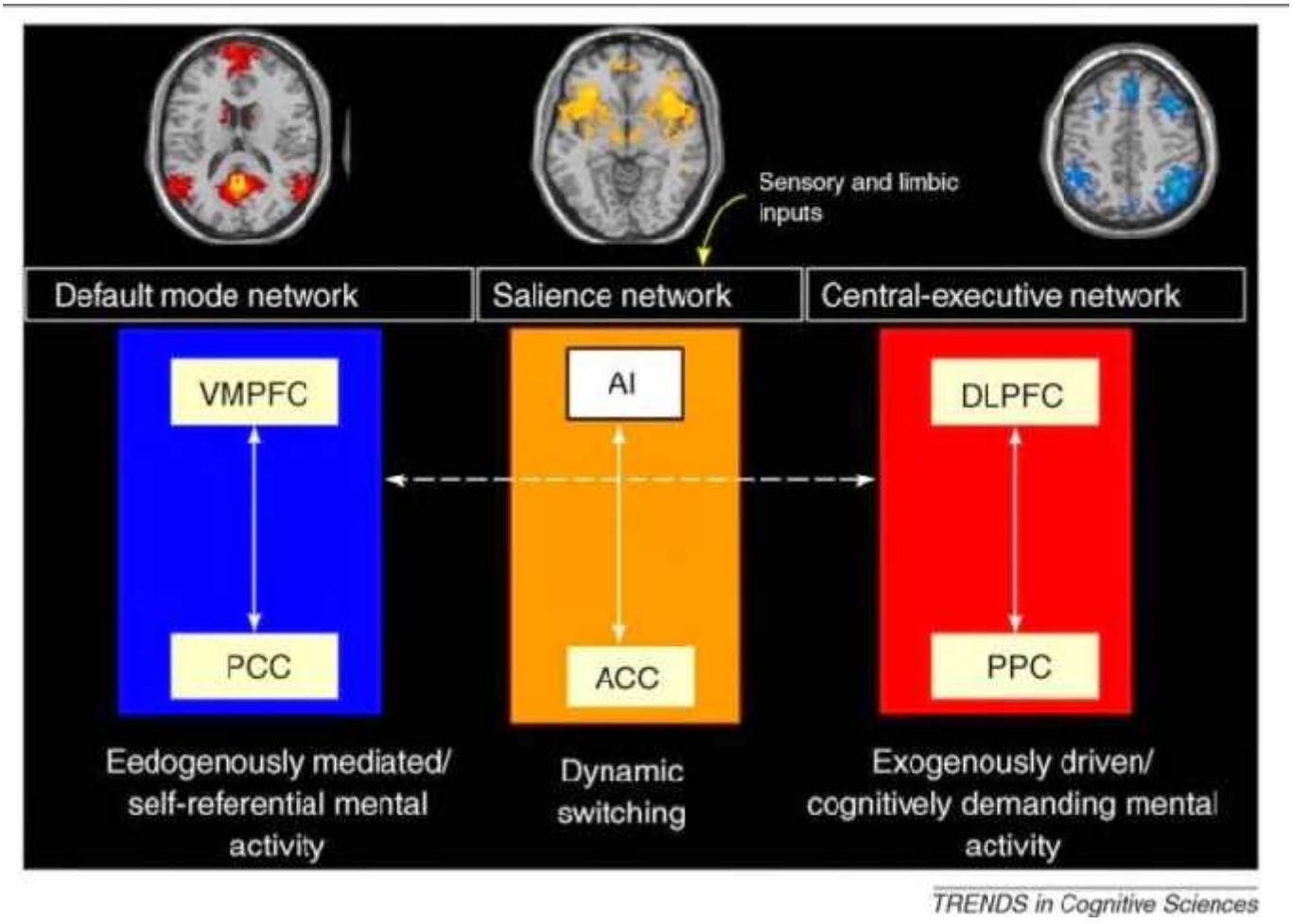

Figure 3.4 – depicts major networks, such as DMN, SN, CEN during the process of meditation and creativity, mainly in self-referential mental activity, dynamic switching of the frontal and parietal regions, during cognitive task.

3.9.1 THE IMPORTANT BRAIN NETWORKS

Creative process demands the activation of the main networks such as default mode network (DMN), the central executive network (CEN) and the salience network (SN). These networks are also known for their characteristics such as imagination network, attention and memory, and the network related to the self for integration and coordination with the help of the corpus callosum. Their electrical activity and integration and coordination are discussed in below sections.

3.9.2 THE EXECUTIVE ATTENTION NETWORK (EAN)

The executive attention network is active during a thorough level of focus and concentration (Refer Fig.3.4), in accomplishing the task with the technique of a goal directed activity.[232] By connecting lateral regions of the prefrontal cortex and areas toward the back of the parietal lobe, this network is active and engaged when focusing attention on a task and utilizing working memory. The EAN is not engaged in all creative processes; sometimes, allowing your mind to wander away from the watchful gaze needed for creativity stages. [233] The medial prefrontal (frontal polar) cortex is involved in generating autobiographical narratives and the creation of self, [234-236] important in the stages of preparation and incubation, with the sense of attention, awareness and balance in the arousal states, known as executive functioning.[3] Such functioning, enabled by focus, concentration and attention, supports organization, creation of goals, prioritizes and guides the process of achieving them in a step-by-step manner. Such activity carried forward by the frontal lobes, by managing the concurrent emotions and memory, by the technique of updating, shifting and inhibition of the attentional network, based on the strength of the Self, was called the Serial Order Effect by Christensen, Guilford, & Wilson, in 1957. [237,238] Those who are efficient in executive functioning are found to be more creative, employing the faculty of new information, i.e. the concept of fluid intelligence, defined as the ability to apply a variety of mental operations to solve novel problems,[239,240] involving the executive network with the distinct regions such as frontal and parietal lobes.[234] Our study found that the technique of CM enhanced the attentional and awareness faculties resulting in fluid intelligence, enhancing the cognitive flexibility and fluency in the experimental group, by recruiting the executive function in the frontal and parietal lobes.[3] (Refer Review Table No.3.3)

3.9.3 THE DEFAULT MODE NETWORK (DMN)

The default mode network [7,] is also called the imagination network [37, 111], and is used to construct dynamic mental simulations. (Refer Fig No.3.5) Situated deep in the prefrontal cortex and temporal lobe, with connections to parts of the parietal cortex, it builds pictures based on previous experiences and imagines alternative scenarios and events. [37, 111] This network is active during daydreaming, when brain is not focused on the outside world, and is implicated in functions such as collecting facts about the self, reflecting on personal emotions and remembering past events. Also involved in social cognition and empathy. (Refer Review Table No.3) Divergent thinking in the creative process involves two important networks, the executive, and default mode networks, by focusing internal attention and top-down control in cognitive control, spontaneous thought and idea generation, suggesting dynamic coupling between the above mentioned networks first in attention and later in maintaining awareness and goal directed activity, followed by the process of incubation and illumination or spontaneous expression.[242] The dual process theory of creation and thinking put forth by William James using a heuristic or explicit thinking mode for processing information tends to vary, based on individual thinking patterns, and can be correlated to aspects of DMN activity, self and consciousness. These should be further studied over time periods of longer durations mapping the salience network, which involves the feelings, emotions and memories of varied kinds important in the process of creative cognition, with depth and larger sample sizes across different age groups.[37,111]

3.9.4 THE SALIENCE NETWORK (SN)

The dynamics between the networks discussed above, responsible for creative cognition, also known as large scale networks, is maintained by the salience network, as per the demand of the present moment. The salience network is grounded on the insula, which involves feelings and emotions, and plays a key role in executive and default mode network activation, or deactivation. This interaction creates a loop or circuitry in the process of thinking or cognition, which helps the brain decide what to pay attention to, based on the self-perception and stimuli. Our eyes, ears, mouth, nose and skin are constantly bombarded with sensory stimulation. The salience network helps us to choose which inputs to pay attention to, and which to ignore.[242] This network is involved in switching between relevant networks of neurons, turning the most appropriate groups off or on depending on its assessment of a situation in goal-directed activity.[244] The ability to switch between networks, and maintain ongoing processes of cognition, is a vital aspect of creativity. [244]

For instance, focusing on a creative puzzle with all attention recruits the skills of the executive attention network. On the other hand, if the creative task involves producing a sonically pleasing guitar solo, focus might be switched from intense concentration to areas more involved in emotional content and auditory processing, [245] involving either of the dual models of thinking described above, either by conscious or unconscious thinking patterns based on the self and executive functioning. (Refer Review Table No.3.3), When focused on mental activity, the brain's default mode network is also known as self-referential network. [246]

Figure 3.5 – Default Mode Network and its Brain Areas

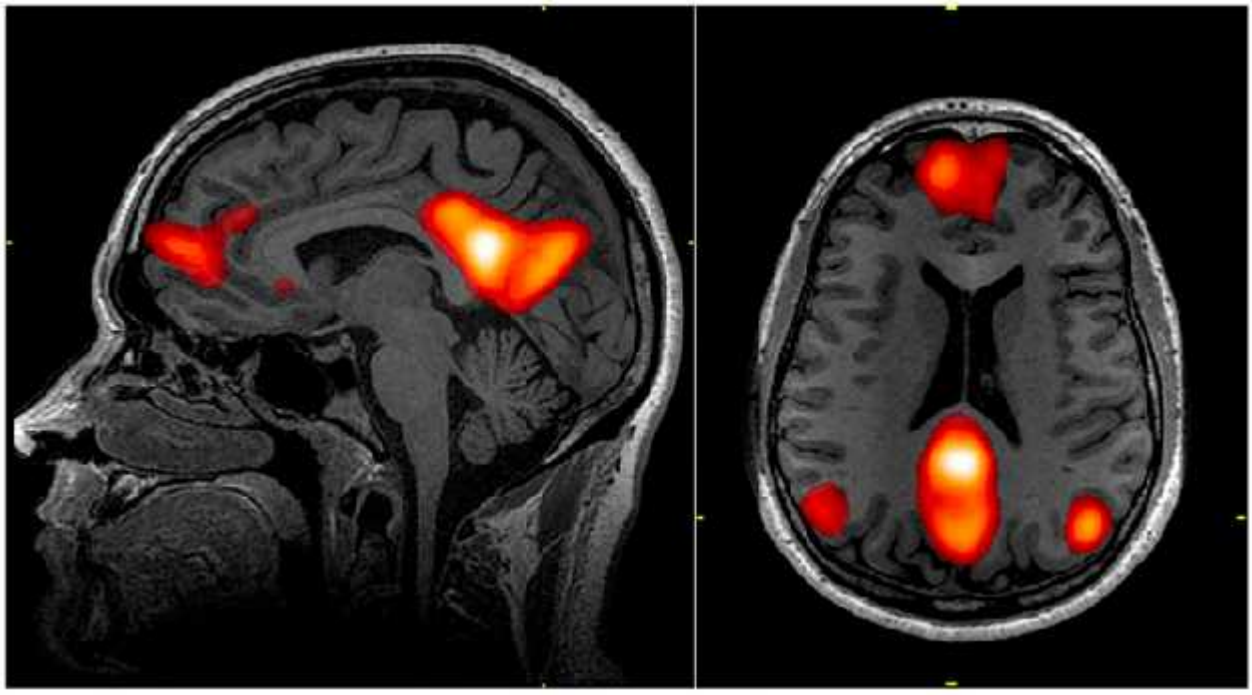

Figure 3.5 depicts the core areas where the default mode network comes online, such as in prefrontal cortex, Temporal regions and the connecting nodes in the parietal regions.

3.9.5 THE SELF REFERENTIAL NETWORK (SRN)

The brain has to organize, recognize and differentiate and process endless amounts of information and store and retrieve this information as per the need. This information is organized and encoded based on the self concept, self esteem and personal identity.[247] Self reference suggests that individuals interpret information in relation to themselves, using background information about their self concept, such as attributes of personality traits to oneself and identify recollected episodes of personal memories from the past.

Brain regions involved in this process are termed the self referential network; research includes investigations of self-concept, self-awareness and self-schema as foundations for self-reference and its role in memory, to understand the processes involved.[248] The information stored is known as schemata or schema, categorized as personal or social. Self functions on the concept of self-awareness in terms of self-focused attention, suggesting the encoding of information refers to self-awareness; wherein the behavior gets shaped up accordingly. The associations between self-referential encoding, self consciousness and self-knowledge happen in unison, wherein the above discussed networks such as the EAN, SN, and DMN, function in unison in the process of information retrieval based on the stimulus. The self awareness and focus in the present moment gives the flow to this information from memory into the working memory system. Meanings and associations are added to the information drawn from memory with reference to one's self knowledge and self consciousness.[249] Knowledge relating to self is activated by self consciousness and process of self reference happens based on the self awareness out of the information drawn in thinking pattern. Autobiographical self referential processing, mind-wandering and default mode network activity influenced the divergent thinking in creativity. In a study conducted by Berkovich-Ohana, it was found that gamma power influenced the interhemispheric connectivity by silencing the activity of DMN and SRN, improving fluency and flexibility in the creative cognition [250] (Refer Review Table No.3.3)

3.10. BRAIN WAVES AND SYNCHRONY - (EEG) APPROACH

In 1929, Hans Berger discovered EEG when he attached sensitive voltage measuring devices to the scalp and observed electrical activity mentioned in the table above. Since then, the scope and abilities of EEG have vastly broadened to include the study of different spectral ranges, as well as both synchrony and entrainment or coherence of cortical and subcortical electrical oscillations occurring at up to 256 different sites over the scalp. Even with the invention of other imaging technologies like MRI, some more spatially accurate (e.g., fMRI), EEG retains its usefulness due to its precise temporal accuracy. [251] Brainwaves span a spectrum of five kinds of frequencies, ranging from 0.1 Hz to well over 100 Hz by long convention. The five bands of human brain activity are: 1. The Delta Band, 2. The Theta Band, 3. The Alpha Band, 4. The Beta Band and 5. The Gamma Band. (Refer Figure 3.6)

Figure 3.6 – Spectrum of Brainwave patterns in frequency range and associated states

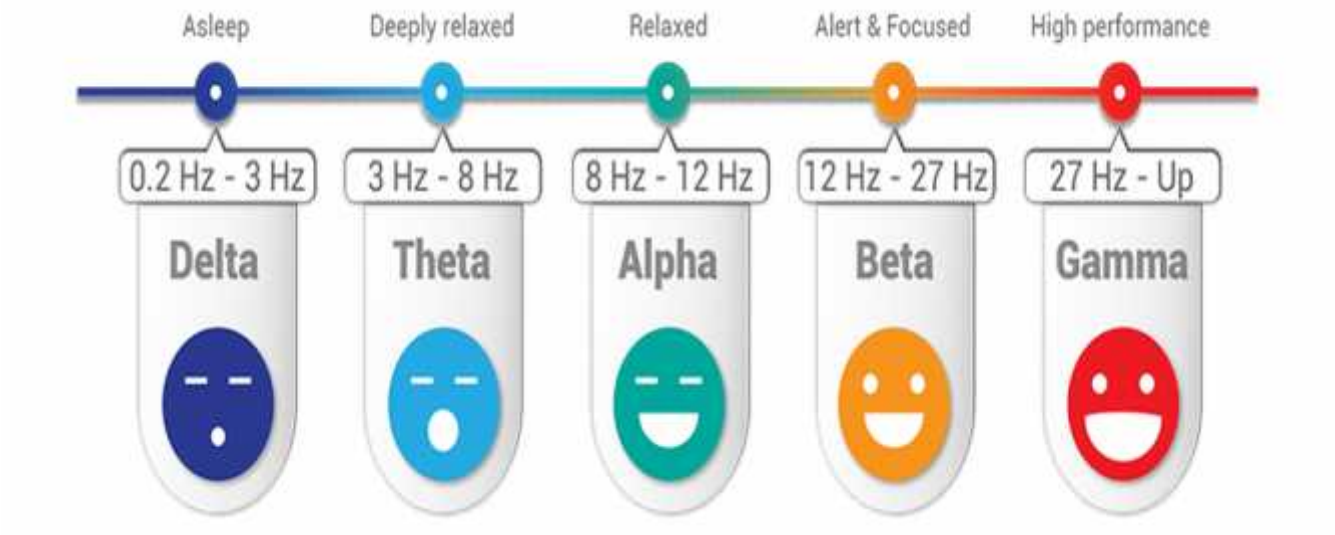

Figure 3.6 depicts the spectrum of brainwave patterns in the frequency range and the associated mental states during specific EEG band.

Spectral analysis is used to identify brain-wave characteristic frequency ranges, dominant amplitudes being emphasized (Refer Table 3.4). More recently, frequency ranges have been delineated further with alpha frequencies divided into low alpha (8-10 Hz) and high alpha (11-13 Hz), and beta frequencies into beta 1 (13-16 Hz), beta 2 (16-20 Hz), and beta 3 (20-30 Hz).[252, 253] The lower the brainwaves cps, the more is awareness turned towards the subjective experience, inner world and use of power of mind to create changes in the body.[162] The technique of Electroencephalography (EEG) is used to measure changing electrical potential of the brain. The apparatus used to measure this electric potential of the brain is called electroencephalograph (EEG), and the tracing or printout of the measured brainwave forms is called the electroencephalogram. Frequency is the number of complete repetitive waves that occur in a given unit of time. Frequency is measured in Hertz (Hz) or cycles per second (cps). According to their frequency brainwaves are divided into five main groups, for details refer EEG and Brain States Table (Refer Table 3.2 & 3). [252, 253]

The underlying assumption of EEG imaging for cognitive neuroscientific study is that variation in activity in a specific brain region is an indication of task-relevant recruitment of the particular region. Post-synaptic potentials in the grey matter of the cerebral cortex vary continuously; this variable activity is what is recorded at sites on the scalp by EEG. These are then described as amplitude or power values in designated spectral frequency ranges, alpha, beta, delta, theta, gamma, some now subdivided further.[252, 235]

With each lower state one becomes fully aligned with the source of energy and power residing within the unconscious reserve. Generally, in Beta states, the attention is focused outward (Refer Table No. 3.8). In alpha, it begins to turn inward; in theta and delta,(Refer Table No. 3.5,3.6,3 .7) it goes further inward; and in gamma, it begins to refine attention and awareness. The deeper one goes, the more depth into the subconscious is experienced. (Refer Table No.3.9)

On the border between Gamma and Alpha states is a doorway into subconscious mind, and into criticality. The alpha and beta ranges are most commonly associated with conscious wakeful activity, with alpha activity associated with relaxed states (i.e., altered states of consciousness, intuitive states), and beta activity associated with logical reasoning, i.e., rational thought, critical analysis.[254] The current study used EEG to determine brain-wave changes during cyclic meditation and creativity in comparison to less creatively demanding tasks. The Methods section below provides detailed information on EEG procedures used. In the following section the studies pertaining to EEG and Brain connectivity discusses the activation of specific networks and brain regions involved in the process of creative cognition.

3.10.1 SYNCHRONIZATION

The technique of measuring brainwave synchronization provides a scientific understanding of the above mentioned brain states in specifics. This area further develops an answer to understand and develop an access to higher states of consciousness and extraordinary abilities such as Creativity and higher cognitive faculties through brainwave entrainment or synchrony.[254, 255] Synchronization works on the principle of entrainment. Entrainment is the process where vibrations of one object cause vibrations of another object to oscillate at the same rate, i.e. synchronization.[256,257] External rhythms can cause distortions in such entrainment, thereby having a direct effect on the prana and mind, and thus the individual's physiology and psychology. [259]

3.10.2 PRINCIPLE OF FREQUENCY, RESONANCE AND SYNCHRONY

In nature, such kind of synchronization can be observed and felt. Everything is made up of energy, which resonates at specific frequencies.[260] Examples of such synchrony are clocks with several pendulums swinging in unison, women sleeping in same dormitory, whose periods would otherwise occur at different times of the month, tend to synchronize their periods; people who live together for many years tend to come to look alike, their energies becomes synchronized, telepathic ability between them increases, as thought patterns harmonize; even using the same words.

Principles of entrainment and synchrony are applied to alter states of mind; such as different forms of chanting used in different cultures to create patterns stimulating development of higher states of consciousness. [261]

A profound example is SVYASA University's 'Morning Prayer' session with Om chanting in the daily morning assembly; where a subjective sense of singular vibration and powerful synchrony is created by resonance with the frequency by the Omkaar Sound. Many scientists are turning to brainwave and human connectome research to test this technique is a powerful means to create well being and synchronization in mind-body healing and pain-cum-stress relief. [262]

3.10.3 BRAIN WAVES, CONSCIOUSNESS AND CREATIVE COGNITION

Three of the bands have been reliably shown to be related to higher level of synchrony and cognitive processes, they are Theta, Alpha and Gamma.[263] The theta frequency band, which is typically defined as the band of activity between 4-7 Hz, is known to be indicative of inhibitory processes, (Refer Table No.3.6) such as selective attention.[263] It is also involved in memory and recall, particularly short term, or working, memory,[177]and during working memory tasks for a language, where the left frontal and temporal lobes were more active; and also spatial and visual reasoning tasks, where the right frontal and temporal lobes were active.[264] These findings suggest that groups of task-specific neurons hold information for short term storage by oscillating at theta frequency (between 4 Hz and 7 Hz); and that such activity is an important part of memory storage and recall,(Refer Review Table 3.3) important in the preparatory and incubation stages of creativity.[265] The alpha frequency band, is identified as a sign of inhibitory activity.[266] It tends to represent slightly different inhibitive activity from theta waves: neurons in all lobes constantly put out a small steady alpha rhythm pattern, which keeps neurons across the entire brain in as state of perpetual readiness to activate. When a portion of the brain is activated, the alpha rhythms in that focal section de-synchronize their rhythm with the rest of the brain. (Refer Table No.3.7)

The gamma frequency band of brainwaves has been found to correlate reliably with mental activity and awareness.[267] There has been a massive amount of research conducted on gamma waves which are associated with cross modal sensory processing; the processing responsible for combining information from two or more senses.[268-270] Gamma band activity has also been found to be related to memory matching,[271] in which gamma wave activity was highest when a stimulus picture matched a target in short term memory.

This reveals that such an effect holds for long term memory as well: line drawings of real objects elicit more induced gamma responses than distorted pictures of the same object. These two categories of findings wrt gamma band activity, in cross modal processing and memory matching, indicate the importance of gamma in combining and integrating different brain processes to achieve a single cognition. (Refer Tables No.3.2, 3.3 & 3.9)

This theory is supported by research on schizophrenic patients, who display a significantly lower level of gamma activity, due to the disconnect between the areas of brain, than do normal people; further illustrating the importance of gamma activity in the proper organization of brain process. The importance of this finding is that it illustrates the top-down nature of gamma-band activity. The finding indicates that gamma activity is more likely to occur during object interpretation, after perceptual processes have taken place, which is indicative of higher level cognitive processing of sensory information and useful in the first three stages of creativity. This finding supports a growing body of evidence which suggests that the role of activity in the gamma band is to combine different cognitive processes, and to integrate information in order to form a single higher level cognitive behavior in the process of creative cognition. [272, 273]

3.11 EEG AND MEDITATION

Brain states in meditation have been studied for almost 50 years, but results lack a clear consensus on underlying neurophysiological changes.[274] Several different kinds of meditation technique have been studied for their influence on alpha, gamma and theta, and on creative cognition and thinking styles, it is pertinent to observe that three different basic styles of meditation process are now well identified.[67] Given that regulation of attention is the central commonality across the many divergent methods. [275, 276] Meditative styles into three categories and classified as 1.Open Monitoring (OM), 2. Focused Attention (FA) and 3. Self Transcending (ST) depending on how the attentional processes are directed.[67] It is always possible that some techniques may fall between these, but these three, conceptually different, approaches are all well understood in terms of their brain co-relates and neural effects on EEG in different regions of the brain (Refer Review Table No.2 & 3). The questions that arise are, 'What are their effects on creativity and various kinds of problem solving?', and how these two kinds of data set can be compared to generate hypotheses about brain mechanisms involved in different processes. One common parameter of the meditative experience is the expansiveness in the experience of self, which includes agency, autobiographical self and memory referencing.[277-279] However, neurophysiological studies of meditative practice are absent, because of difficulties in quantifying dimensions of self and self-experience.

3.11.1 CREATIVITY AND MEDITATION – EEG FINDINGS IN THE DMN

This section contains a review of EEG studies along with brain correlates during meditation and creativity. Functional magnetic resonance imaging (fMRI) studies on important networks such as the default mode network (DMN),[7, 38]executive attention network (EAN),[182] self referential network (SRN),[5]and cortical midline structures (CMS) [234] are beginning to refine the neuro-electric data by suggesting possible neural loci for meditation effects; (Refer Fig. 1.1) although how, when and where such practices may alter the central nervous system (CNS) have not yet been well characterized . The word meditation is used to describe practices that self-regulate the body and mind, thereby affecting mental events and enhancing cognition by engaging specific attentional sets. As regards creative cognition[4], offer an operational definition: ***the production of something both novel and useful***. Similarly, Heilman follows Helmholtz[6,12] in his work on creative innovation, and suggests creativity is the discovery of 'unity in the variety in what is called diversity of nature'. From this starting point, we may note that most studies of creativity have used mindfulness, with 3 smaller studies on the Transcendental Meditation technique; [280-282] in understanding and finding the deep structures in the brain which creates this functional connectivity leading to integration of information, in the creative process.

Figure 3.7 – Networks Active during Meditation and Creativity Tasks at rs (FC)

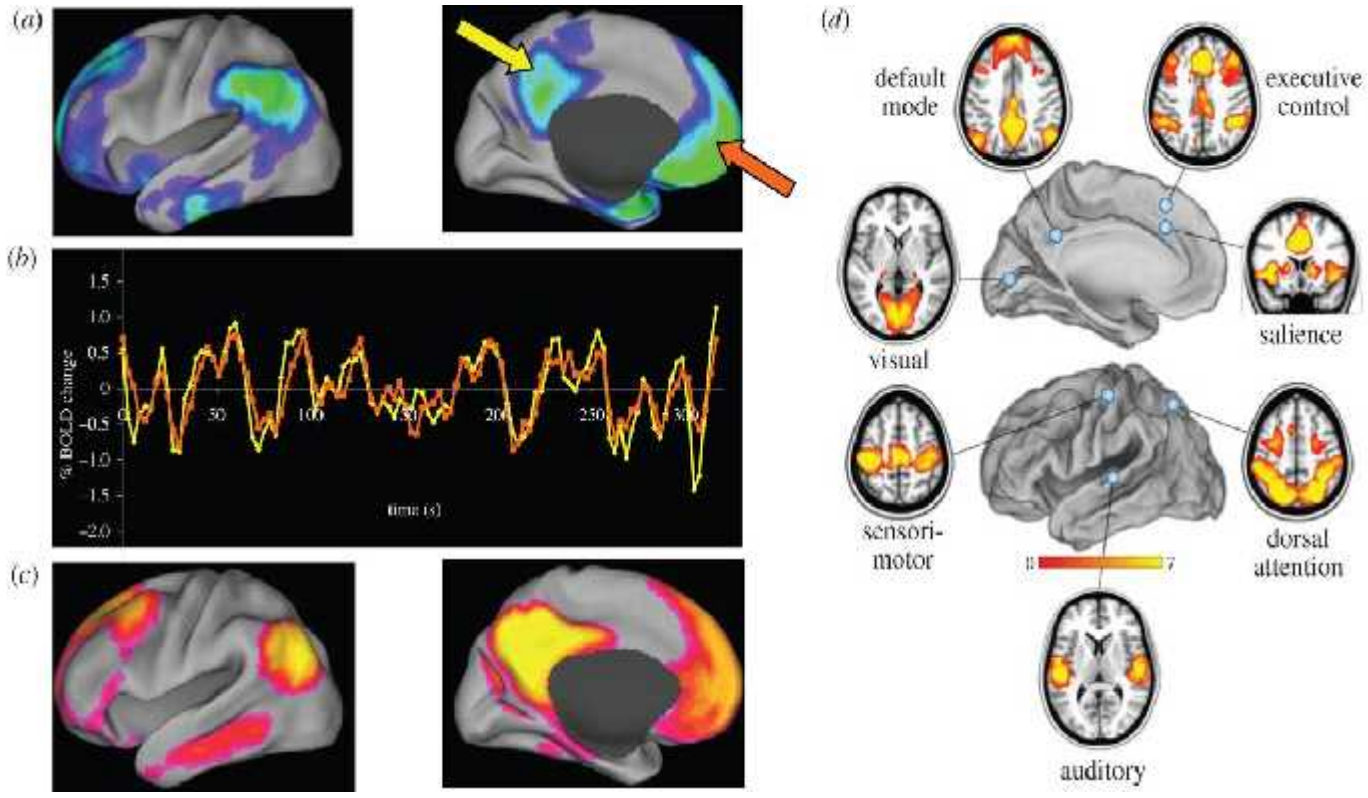

Figure 3.7, depicting the three important networks such as DMN, SRN, and EAN the resting state functional connectivity, in meditation and creativity tasks.

Froelinger et al.(2012) studied the effects of mindfulness on networks such as the DMN and the dorsal attentional network (DAN) [283], concluding that functional connectivity is strengthened within the DAN (Refer Review Table No.3.2 & 3). Attention strengthens coupling between self-referential processes and affective responses. This is of importance in the processes of divergent thinking and varied responses involved in creativity. [283] Christoff et al., (2009) showed that experience sampling during fMRI identified DMN and executive network contributions to mind wandering. While this indicates problems that may arise in convergent thinking, it may also suggest modes of free thinking; expansion of focus allows new ideas to arise, and flexibility in the process of cognition [284] (Refer back to Review Table No. 3.2 & 3).

Jang et al. found increased connectivity in cortical midline areas, but said that causal connections were not established, and that further work was needed to determine subtle differences between inhibition and disinhibition in different meditation techniques.[285]Another paper [216](Brewer, 2011), in PNAS, emphasized changes in DMN and brain region connectivity accompanying meditation techniques, indicating decreased mind wandering in ways that could lead to a full theory. [286] A 2012 study (No. 6) also concluded that meditation (OM type Mindfulness) decreased DMN activation, with lower gamma frequency activity in frontal and midline regions, with implications for the DMN network, self-reference and attention. [287](Refer back Review Table No. 3.3).

Three smaller studies on TM observed correlations between creative cognition scores on Torrance tests, and coherence between different brain regions. [280-281] TM results in higher alpha1, frontal log-power rest, lower beta and gamma frontal and parietal log-power; higher frontal and parietal alpha1 interhemispheric and higher frontal and frontal-central beta 2 intrahemispheric coherence. These observations are significant, in that we report changes in gamma EEG following CM practice and creativity.[3] Travis and Shear (2010) noted that frontal and parietal interhemispheric coherence are associated with focusing and attention.[67] Other earlier studies of TM by Dilbeck and Orme-Johnson observed slow wave alpha1 coherence in frontal and occipital lobes, and in concept learning, a cognitive process, which may well correlate with creative cognition [280-281]. (Refer back Review Table No. 3.2 &3). Ostafin and Kassman (2012) reported that open monitoring, mindfulness, practice improves insight problem solving i.e. requiring input from the creative imagination, but not non-insight problem solving, not requiring it. [288] Hikaru et al. (2012) found that increases in functional connectivity at rest between medial pre-frontal cortex and other regions of the brain were correlated with divergent thinking kinds of creative cognition.[289]

In a first study of corpus callosum activity during creative thinking tasks, Moore et al (2009) observed that decreased interhemispheric connectivity enhances hemispheric specialization, benefiting incubation of ideas, while lesser levels of cortical coherence reflect selective developmental pruning, facilitating efficient functional connectivity. [36] R.E. Jung et al (2013) observed that dynamic interplay between inhibitory and excitatory networks may correspond to various components of Creative Cognition, suggesting that investigation of the role of cortical hubs in the DMN might refine our understanding of creative cognition.[45]Takeuchi et al. (2012) observed associations between functional connectivity in the resting state, and performance on divergent thinking.[289] Vilareal et al. (2013) noted associations between activation in prefrontal and insular areas, and creativity levels, particularly, positive correlation between anterior insula activation, and both the capacity to integrate information and the creativity level. [290] (Refer back to Review Table No.3.2 & 3)

3.11.2 ROLE OF 3 A'S – ATTENTION, AROUSAL AND AWARENESS IN MEDITATION AND CREATIVE COGNITION

Sanyama, dharana, dhyana and samadhi, correlated to arousal, attention and awareness, [11] as explained in chapter two, has a special significance with the cortical inter and intrahemispheric integration and synchronization [292,293] within the EEG spectral bands discussed in the above sections of both literature review chapters. Sanyama, the technique of attentional focus and defocus, leads to expansion, and has an essential role in the processes of meditation and creative cognition.[61]

William James declared that volition is important for creation. [294] Volition is a power, power of attention, will and Higher Self. [295,296] This ability is essential to transcend information processing boundaries, including consciously directed, sustained attention and subconscious goal-directed attention, [297-299] which is integrated with the sense of Self, sense of being someone with a point of view. [299,300] The volition, the will, and the sense of self to transcend the informational boundaries and integrate one's identity into the higher power (higher Self) [294] is at the heart of meditation. Horan referred to this state as vacuous, pure consciousness and intelligence essential for creative cognition. [301] Attention, awareness and optimum arousal at the cortical and sub-cortical levels of brain regions are seen as a single process of synchronized neural activity. [301] They are considered defocused attention and expansive awareness [302, 303] and are all associated with efficient processing of information and organization, both in creativity, and during meditation. [274]

3.11.3 GAMMA BAND, MEDITATION AND CREATIVE COGNITION

Complex central nervous system activity such as recognition of ambiguous figures, forms, patterns and gestalts involved in cognitive and sensory processes have been correlated with 40 Hz gamma wave electrical activity.[263] Information binding at different levels of brain organization in sensory-cognitive processes correlates with gamma activity reflecting the brain's fundamental orientation and complexity of the integration process. [263]

Focusing and concentration within the executive attention network in the frontal regions of the brain was interpreted by Shear, [67] and Goldberg as indicating increased frontal gamma activity, higher arousal, alertness and attention.[304, 305]

During the creative process shifts to heightened awareness reflect gamma activity, followed by deep states of absorption.[8,30] Optimum cortical arousal is the essential signature of gamma activity; this condition creates highly absorbed states and heightened awareness during creative tasks.[4,179] The investigators suggested that gamma bursts reflect 'the sudden transition of solution-related cognitive processing from an unconscious to a conscious state'. [31,182,208] Although the process by which knowledge shifts from an unconscious state to a conscious state is thought to occur in stages, [31,182,208] it remains one of the fundamental unanswered questions in consciousness studies.[308] The movement from unconscious to conscious states, in terms of the parameters that they define, can be considered a form of heightening of awareness. Gestalt perception is the outcome of gamma activity synchrony and associative memories. [309-311] Lutz et al. (2004) observed robust gamma activity (25-42 Hz), bilaterally over the parieto-temporal and mid-frontal electrodes, as well as long-distance gamma phase synchrony, 30 times greater than controls. (Refer back to Review Tables 3.2 & 3.3)

Gamma baseline activity also increased over alpha/theta with years of practice, suggesting gamma band synchrony 'reflecting a change in the quality of moment-to-moment awareness, as claimed in many models of consciousness'.[312] Tolle (1999) referred to this heightened awareness as 'Living in the Now'.[313,314] It is also a component of flow. [315] According to Kris, the initial, inspirational, stage happens at low levels of cortical arousal, whereas the subsequent, elaboration, stage is one of high arousal. Martindale and Hasenfus's experiments found no significant gender differences in creativity dimensions, exhibiting low levels of arousal during the initial, preparation, stage, going on to elaboration. [265, 292 ,303]

3.11.4 HEMISPHERIC CO-ORDINATION AND INFORMATION PROCESSING

The work of Paul Broca (1863) it has repeatedly been demonstrated using lesion method, laterality studies (dichotic listening and visual half field), electrophysiological studies and functional imaging, that the brain is organized in modular fashion.[316-318] Thus, the understanding, development and expression of orderly relationships might require communication between these modules.[318] Perhaps the strongest evidence for brain modularity is hemispheric specialization, the left hemisphere being dominant for language, even in majority of left-handed people, motor control of skilled movement, and categorical processing.[319] In contrast, the right hemisphere appears to be important in spatial imagery [320] face recognition[321] and coordinate coding.[318] The right hemisphere also appears to be important in emotional communication, and might also be dominant for mediating many primary emotions.[322] Whereas the right hemisphere appears to have global attentional perspective the left hemisphere has a more focused attentional perspective. Many other right-left hemisphere dichotomies have been described that cannot be fully addressed in this paper. (Refer back to Review Table 3.2)

Works of scientific or artistic creativity often require that one uses skills and knowledge mediated by both hemispheres. For example, the novelist who is writing about an emotional response of a character must use the knowledge of facial emotional expressions stored in the right hemisphere together with the verbal lexicon stored in left hemisphere. The sculptor must imagine the rotation of spatial images mediated by the right hemisphere while he uses the motor skills mediated by the left hemisphere. The astronomer must combine the spatial computations mediated by the right hemisphere with arithmetic skills mediated by the left hemisphere. Thus, interhemispheric communication might be important for combining the knowledge and skills that are important for creative innovation.[6] Creativity and response of right-left hemisphere requiring interhemispheric communication. [323]

James Austin (1990) suggested that creativity requires an ‘unheard combination of elements and the sublest associations.’[324] Spearman (1931) suggested that creative ideas result from the combination of two or more ideas that have been previously isolated. Because the right and left hemispheres store different forms of knowledge and mediate different forms of creativity activity, different neuronal architectures probably exist within the association cortices of each hemisphere. [324,325] A possible method of resolving a previously unsolved problem is to see the problem in a new light. Then one can use a different form of knowledge, employing a different cognitive strategy that might be mediated by the opposite hemisphere to the one previously used.[6,34,36]

Connections between the two hemispheres which might effect this change are carried by the Corpus Callosum, the largest structure connecting these two independent modular systems responsible for coordination and integration of the two hemispheres, important for creativity. [326]

Bogen and Bogen (1988) noted that although the Corpus Callosum transfers high level information, normally such interhemispheric communication is incomplete. [327] They posited that incomplete interhemispheric communication permits hemispheric independence and lateralized cognition, important in the incubation of ideas.[327] These authors mention Fredric Bremer, who suggested that the corpus callosum subserves the highest and most elaborate activities of the brain, in a word, creativity. They also suggest that the momentary suspension of this partial independence accounts for the stage of illumination; but they did not state what might account for this momentary suspension of their independence. [6,34,36]

The corpus callosum is primarily comprised of myelinated axons whose cells bodies are in the pyramidal layers of the cerebral cortex. The cerebral connectivity important for creativity may not only be inter-hemispheric; it could have intra-hemispheric contributions. [34] In addition to the myelinated axons carrying information between the hemispheres, from the thalamus and basal ganglia to the cortex, and from the cortex to the basal ganglia, thalamus, brain stem and spinal cord, myelinated axons also carry information between cortical regions in the same hemisphere. These intrahemispheric connections facilitate intrahemispheric communication, coordination and integration, which might also be important for creative innovation; because widespread connectivity allows creative people to combine representations of ideas that have been previously isolated, meditated by the brain waves and the electrical firings of the neurons. [6,34,36] In Einstein's brain, it appeared that his parietal lobe had extremely well-developed subcortical white matter; a finding that suggests that Einstein's extraordinary creativity was related to his enhanced intra and interhemispheric coordination and connectivity. [6,34,36]

3.11.5 CLASSIFICATION OF MEDITATIONS BASED ON NEURONAL ACTIVITY

Travis and Shear (2010) and Lutz-Davidson (2008) are responsible for the most recent and authoritative classification of different kinds of meditation.[66,67] They showed that combining process descriptions with EEG characteristics of most popular kinds of meditation led to definitions of three classes: i. Focused Attention characterized by beta2 and gamma, ii. Open Monitoring, characterized by mid-line theta, and iii. Self-Transcending, characterized by global alpha. These were substantiated by published studies of each kind.(Refer back Table No.1.1)

They may also be correlated with awareness; arousal and attention in specific cortical networks (see Chapter 8). The first, *Focused Attention*, keeps the attention focused on an object (e.g. in *Mantra Japa*, a mantra is continually repeated), while the second, *Open Monitoring*, keeps the awareness involved in a monitoring process (e.g. in Vipassana the awareness scans stress sensations along the spine). In the third, *automatic self-transcending*, techniques are designed to transcend the activity required to start them. In this category, Travis and Shear gave seven examples of studies, six from TM, and one from Qigong. (Refer Review Table No.3.3)

3.12 SCIENTIFIC STUDIES ON CYCLIC MEDITATION (CM)

The studies described below were all carried out at the Swami Vivekananda Yoga Research Foundation, Bangalore, India, where the technique was devised. As of now this is the first study in the field of creativity and brain mechanisms employing meditation technique called as CM.

3.12.1 STUDIES ON AUTONOMIC AND RESPIRATORY VARIABLES

Sarang & Telles (2006) compared effects of cyclic meditation (CM) and supine rest (SR) on heart rate variability (HRV) in forty-two male volunteers. HRV high frequency (HF) power increased during both CM and SR practice, which suggested increased vagal tone.[332] However, there was substantially greater increase during CM (4.4%) than during SR (1.0%). Low frequency (LF) power, which correlates with sympathetic activity, decreased during both CM (1.8%) and SR (0.3%). The study therefore found that parasympathetic response to CM dominated. The exact mechanism underlying these effects on the autonomic nervous system (ANS) is not yet determined. It may be brought about by reduced cortical activity, which in turn could modify activity in the hypothalamus. An earlier study (Vempati & Telles, 2002) on thirty-five male volunteers aged 20 to 46 yrs, found a significant changes in oxygen consumption and in breath volume after 10 minutes guided relaxation compared to an equal duration of supine rest.[333] During guided relaxation HRV LF power reduced, whereas HF power increased, indicating reduced sympathetic activity. A previous study by Vempati & Telles, 1999, [334] on forty male volunteers aged 16 to 46 yrs found that one minute's practice of an isometric relaxation technique (IRT) reduced signs of anxiety and physiological stress. More recently, a study on thirty male volunteers aged 20 to 33 yrs observed decreases in heart rate (HR), LF power and LF/HF ratio, and an increase in pNN50, the ratio of the number of pairs of Normal to Normal RR intervals differing by more than 50 ms to the total number of all NN intervals, following practice of cyclic meditation a study by Patra & Telles, in 2009,[335] suggests a shift towards sympatho-vagal balance in favour of parasympathetic dominance during sleep. (Refer Review Table 3.1)

3.12.2 STUDIES ON OCCUPATIONAL STRESS LEVELS

In another study by Vempati & Telles, 2000 of CM and HRV, a two-day Yoga program that included CM was observed to decrease occupational stress levels and baseline autonomic arousal in twenty-six asymptomatic, male, middle managers,[336] suggesting significant reduction in sympathetic activity. The decrease in occupational stress levels may be due to associated decreases in autonomic arousal (sympathetic activation) as well as psychological factors, though this requires further investigation. (Refer Review Table 3.1)

3.12.3 STUDIES ON METABOLISM AND OXYGEN CONSUMTION

A first study found significantly reduced oxygen consumption during CM (-32.1%) than a comparable period of supine rest.[337] A study found a decrease in oxygen consumption of 19.3% during CM compared to SR (4.8%),[332] also suggesting that after, but not during, practice there was deeper physiological relaxation following CM than SR. This study assessed energy expenditure (EE), respiratory exchange ratio (RER) and heart rate (HR) of 50 male volunteers before, during, and after the sessions of CM and SR. CM reduced energy expenditure more than SR alone. The above studies used self-as-control design. The reason why the practice of CM reduces oxygen consumption was attributed to decreased oxygen consumption by both brain and skeletal muscles, which are probably more relaxed during practice of CM. (Refer Review Table 3.1)

3.12.4 STUDIES ON ATTENTION AND ELECTROPHYSIOLOGY

Sarang and Telles (2006) [332] showed that, despite the changes suggestive of parasympathetic dominance following CM, P300 peak latency decreased while P300 amplitude increased when obtained using an auditory oddball paradigm. P300 components of event-related potentials (ERPs) are generated when persons attend to and discriminate stimuli differing in a single aspect. More recently, examination of middle latency auditory evoked potentials (0-100ms range) generated within the cerebral cortex in forty-seven male volunteers before and after practice of CM observed prolonged latencies, supporting the idea of cortical inhibition after CM.[338] These studies were also conducted using self-as-control design. The mechanism by which CM improves attention while reducing sympathetic tone may relate to increased proprioceptive input to the Reticular Activating System (RAS) during *asana* practice, which in turn keeps cortical areas receptive and active in accordance with principles expounded in Kandel, Schwartz and Jessel (2000).[339] This is contrary to the usual association between increased alertness and vigilance and increased sympathetic tone. (Refer Review Table 3.1)

3.12.5 STUDIES ON PERFORMANCE IN A CANCELLATION TASK

In a previous study the effect of CM practice on the performance in a letter cancellation task, was assessed in sixty-nine male volunteers (whose ages ranged from 18 to 48 years). There was improved performance in the task which required selective attention, concentration, visual scanning abilities, and a repetitive motor response following CM.[340] The results were interpreted to suggest that the improved performance after CM suggests that the practice not only globally enhances performance but also selectively reduces the probability of being distracted. Again it is difficult to understand how CM practice which is associated with reduced sympathetic activity, increases the performance in an attention task. As described above this may be via increased proprioceptive input to the Reticular Activating System.[339] (Refer back Review Table 3.1)

3.12.6 A STUDY ON MEMORY AND ANXIETY

In a study, on fifty-seven male volunteers (group average age ± S.D., 26.6 ± 4.5 years) the immediate effect of CM and SR were studied on memory and state anxiety. A cyclical combination of yoga postures and supine rest in CM improved memory scores immediately after the practice and decreased state anxiety more than rest in a classical yoga relaxation posture (*shavasana*). Like the P300 event-related potential and the letter cancellation task, performance in the memory task requires increased alertness. The mechanism (as described above) remains speculative. (Refer back Review Table 3.1)

3.12.7 A STUDY ON POLYSOMNOGRAPHY

In a study, whole night polysomnography measures and the self-rating of sleep were assessed on the night following a day in which thirty-male volunteers practiced CM twice (approximately 22:30 minutes each time). This was compared to another night when they had two, equal duration sessions of supine rest (SR) on the preceding day. In the night following CM practice the percentage of slow wave sleep (SWS) was significantly more than the night following SR, whereas the percentage of rapid eye movement (REM) sleep and the number of awakenings per hour were less. The practice of CM during the day time has been shown to increase the percentage of slow wave sleep in the subsequent night. [335] CM has a number of components which may facilitate sleep, such as increased physical activity, muscle stretching, and introspection. (Refer back Review Table 3.1)

3.13 SUMMARY

This Chapter of the Thesis has reviewed three areas of scientific or modern literature related to the experimental areas and their aspects within the domain of creativity sciences, they are:

i. Phenomenological and philosophical studies of creativity sciences and self,
ii. Descriptive studies of experimental aspects of creativity process and
iii. Neuroscientific studies (imaging) brain wave synchronization and brain networks

The chapter focused on the scientific and modern literature review starting with the concepts of creativity such as, definition, meaning and approaches to creativity. It considered current status of creativity research, mainly the areas emphasized are cognitive neurosciences, philosophy and psychology. The chapter reviewed all existing studies covering the areas such as creativity, cognition, brain waves, synchrony and meditation pertaining to the important brain areas and networks active during the processes of meditation and creativity. Some reflections concerning the theoretical and conceptual foundations of the disciplines were also dealt with.

The studies of creativity, meditation and brain waves or synchronization in order to provide a backdrop to the current research were systematically reviewed and shortlisted as the highlights and foundations of this chapter. Then, attention was drawn to the constructs which have relevance to the scientific experiential aspects of the creativity process and four important stages, and their implications in the neuroscience and specifically the important brain networks. Finally, a brief review of the Cyclic Meditation studies is done, which is an intervention of the current study, though these studies are not directly related to the creativity research.

Table 3.1: Studies on Cyclic Meditation

Sr. No.	Reference	Sub	Design of Experiment and Variables Studied	Findings
1	Telles, S., Reddy, S.K. & Nagendra, H.R. (2000). *Applied Psychophysiology and Bio feedback,* 25(4), 35-41.	40	All alternately practiced Cyclic meditation and *śavāsana*. Self as controlled trial 5 min baseline → 23 min CM → 5 min rest in sitting position Variables: before and after (i) Oxygen consumption.(ii) Breath rate (iii)Breath volume	(i) Significant ↓ in amount of OC and in breath rate and increased in breath volume was observed in both groups. (ii) O2 consumption decreased 32.1% after CM compared with 10.1% after *śavāsana*. (iii) Breath rate reduced by 3.6 c/min after CM, and by 1.9c/min after SH (iv)Breath amplitude increased 28.8% after CM and 15.9% after *śavāsana*.
2	Sarang, S.P., & Telles, S. (2007). Perceptual and Motor Skills,105(2), 379-85	69	Self as control design Variable: Six letter cancellation task	(i) After both practices, the net scores were significantly higher, although the magnitude of change was more after Cyclic Meditation than after Supine Rest (24.9% versus 13.6%). (ii) Reduction in scores for wrong cancellations after Cyclic Meditation and not after Supine Rest.
3	Sarang, S.P., & Telles, S. (2006). Applied Psychophysiology and Biofeedback. 31(2), 143-53.	50	Self as control design, Variables: Oxygen consumption, minute ventilation, tidal volume breath rate	(i) 19.3 % decrease in oxygen consumption after cyclic meditation. (ii) 4.8 % decrease in oxygen consumption after Shavasana.,
4	Sarang, S.P., & Telles, S. (2006). International Journal of Neuroscience, 116(12), 1419-30.	42	Self as control design Variable: P300	(i) Reduction in the peak latencies of P300 after cyclic meditation at Fz, Cz, and Pz compared to the "pre" values. (ii)) Reduction in the peak latencies of P300 after supine rest at Fz, Cz, and Pz compared to the "pre" values, but magnitude of change is less.

Table 3.2: Studies on Creativity

Sr. No.	Reference	Sub	Design of Experiment and Variables Studied	Findings
1	Valeria Drago, Glen R. Finney, Paul S. Foster, Alejandra Amengual , Yong Jeong, Tomoiuki Mizuno , Gregory P. Crucian, Kenneth M Heilman	159	Two Groups – Experimental & Control Functional Connectivity at Rest (rFC) / FMRI , Creativity – Divergent Thinking (DMN)	(i). The strength of rFC (functional connectivity at rest) with the mPFC significantly and positively correlated with creativity as measured by the DT (divergent thinking) test in the posterior cingulated cortex (PCC). (ii).These results showed that higher creativity measured by DT is associated with rFC between the mPFC (medial prefrontal cortex) and the PCC (posterior cingulated cortex), the key nodes of the DMN. (iii)Association of creativity with the key nodes of DMN. (iv)Findings comparable to the previously reported psychological association in schizotypy & creativity.
2	HikaruTakeru,Yasuyuki,Hiroshi Hashizume,Yuko Sassa,Tomomi Nagase,Rui Nouchi,Ryuta (2012)	48	Two Groups – Experimental & Control, Mindfullness Meditation, Problem Solving & Creativity.	(i)Direct relation between mindfulness and creativity. (ii) Trait mindfulness predicts better insight but not non-insight problem solving (both studies) (iii) Mindfulness training improves insight but not non-insight problem solving, partially mediated by state mindfulness.
3	Brian D. Ostafin, Kyle T. Kassman (2012)	19	Two Groups – Experimental & Control , practitioners of FA / OM meditation & Control Group	(i) FA meditation and OM meditation exert specific effect on creativity. (ii) OM meditation induces a control state, promotes divergent thinking, a style of thinking that allows many new ideas being generated. (iii) The enhancement of positive mood induced by meditating has boosted the effect in the first case. (iv) Analysis of thinking styles i.e. Convergent & Divergent Thinking.

4	Judson A.Brewer, Patrick D. , Worhunsky, Jeremy R. Gray, Yi-Yuan Tang, Jochen Weber and	17	Two Groups – Experimental & Control , Attentional Bias (RTP)-Right Temporal-parietal region (spatial attention) and Creativity (Visual Art)	(i) Evocative impact & allocation of Attention (ii)Lesion studies demonstrate that the right temporal-parietal region (RTP) is important for mediating spatial attention (iii) Normal people vary in their ability to allocate spatial attention, thus, people who can better allocate attention might also be more influenced by the emotional messages of the paintings (evocative impact).
5	Taylor VA, Daneault V. , Grant J., Scavone G, Breton E., Roffe Vidal S., Courtemanche J, Lavarenne AS, Marrelec G., Benali H., Beauregard M.,	13	Two Groups – Experimental (Creativity) & Control , Resting Brain Activity, Cognition, Psychometric – General Intelligence & Creativity.	(i) Mean gray and white matter rest-CB, significantly & positively correlated with individual psychometric intelligence. (ii)Mean white matter rest-CBF significantly and positively correlated with creativity. 3. The left superior temporal gyrus and insula and individual psychometric intelligence was found. 4. Regional rest- CBF in the precuneus was significantly and negatively correlated with individual creativity. Significance of these results of regional rest-CBF did not change when the effect of regional gray matter density was corrected. .
6	Liad Uziel, Bar-Ilan University, Psychology Department, Ramat-Gan	168	Two Groups – Experimental (Creativity) & Control Expression of Greater Creativity , Task performance, Positive Implicit Affect, Self Control & Impression Management	(i)High impression management score was associated with performance facilitation in social presence, expressed in greater creativity, positive implicit affect, and high self-control (ii) The results reveal previously unnoticed constructive effects of impression management, supporting the reframing of the trait as reflecting interpersonally oriented self-control.
7	Lorenza S. Colzato*, Ayca Ozturk and Bernhard Hommel 18th April 2012)	19	Three Groups – Om Meditation Group, FAM Group & Control Group Cognitive Control States, Convergent & Divergent Thinking, Information Processing (Top-Down / Bottom-Up)	(i)OM meditation induces a control state that promotes divergent thinking, a style of thinking that allows many new ideas of being generated. (ii) FA meditation does not sustain convergent thinking, the process of generating one possible solution to a particular problem. (iii) Enhancement of positive mood induced by meditating has boosted the effect in the first case and counteracted in the second case.

8	Brain D. Ostafin, Kyle T. Kassman, 2012,	157	Two Groups - Problem Solving, Insight & Non Insight , Affect (Positive & Negative) , Mindfullness & Creativity	Trait Mindfullness predicts better insight, but not non insight problem solving (both studies), Improvement partially mediated by state mindfulness.
10	R. Ishii, L. Caniet, T. Ishihara, et al, 2014,	6	Arithmetic Calculation, Frontal Activity, Focused Attention , Creativity	Frontal theta is generated in medial prefrontal cortex & dorsal anterior cortex (ACC) during cognitive tasks requiring focused attention & working memory process. Gamma ERS underlying source of neural activity of the parietal sources.
11	Marily Oppezo, Daniel L. Schwartz, 2014,	48	Within-subject, Creativity, Convergent & Divergent Thinking	Walking produced novel and highest quality analogies. Walking open the for Free Flow of ideas, resulting in increase in creativity.
12	David W. Orme-Johnson & Christopher Haynes,	22	Two Groups, Creativity, Coherence	Information Processing, measured by ideational fluency is enhanced with clear experiences with the practice of TM Siddhi program, with highest coherence of alpha in frontal cortex.
13	D. Moore, R.A.Bhadelia, R. L. Billings et al., 2009,	21	Two Groups, Creativity, Divergent Thinking, Visual Spatial, White Matter Corpus Callosum, MRI	Decreased callosal connectivity enhances hemispheric specialization, benefiting the incubation of ideas, decreased CC size reflect selective developmental pruning facilitating efficient functional connectivity
14	R. E. Jung, B. S, Mead, J. Carrasco & R. A. Flores, 2013,	30	Three Groups, Creativity, cognition, DMN, PFC.	The results indicate a dynamic interplay between inhibitory and excitatory networks corresponding to the components of Creative Cognition.
15	H.Takeuchi, Y.Taki, et al., 2012,	170	Two Groups, Creativity, Functional Connectivity, DMN.	Strong association between individual creativity measured by divergent thinking test and resting state functional connectivity. .Study to investigate association between rFC and Creativity.
16	R.E.Jung, C.Gasparovic, R.S.Chavex et al., 2009,	56	Two Groups, Creativity, Divergent Thinking, Grey & White Matter.	Strong relationship between intelligence and creativity, between brain chemistry and creative cognition as measured with divergent thinking.
17	C.T.Haynes et al., 1976,	23	Multivariate, Alpha band, EEG coherence, Creativity, Divergent thinking.	Strong correlation found between creativity and coherence, establishing basis for understanding functional brain organization, underlying

				creativity
18	M.F.Vilarreal,D. Cerqetti et al., 2013,	24	Two Groups, Creativity, Music, Prefrontal Lobe activation, MRI.	Demonstration of activation in prefrontal & insular areas associated with creativity levels. Positive correlation between anterior insula activation and creativity level, capacity to integrate information and creativity level. First study to establish relationship between Prefrontal Lobe activation and anterior Insula, capacity for integration of information.
Sr. No.	**Reference**	**Sub**	**Design of Experiment and Variables Studied**	**Findings**
19	T. Shen, J C Lai, 2014,	54	Two Groups, Creativity, Divergent Thinking,	Positive correlation between creativity scores especially in flexibility, elaboration of creative thinking, trending of emotional and instrumental shunt with that of the abbreviated Torrance tests for adult creativity. Study reflects subjective dimensions of creativity and the personal traits / roles.
20	X. Ding, Y. Y. Tang, M. Posner, 2014,	40	Two Groups, Creativity, Mood, Affect. correlation between meditation, mood, emotion and creativity.	Emotion-related creativity promoting mechanism attributed to short term meditation. Creative performance on divergent thinking task and emotion were correlated with mood regulation and positive affect, establishing relationship between meditation, emotion and creativity.
21	Fred Travis, 1976,	93	Two group pre-post test, Creativity, Divergent thinking.	Relatively greater improvement in creativity suggests than the practice of TM technique particularly marked the effect on “primary process of creativity”. Study provides basis for 4 processes of creative stages .
22	M Zvyagintsev et al., 2013.	15	Two Groups, Creativity & Cognition (Auditory / Visual Information), fMRI, DMN, Frontal, Parietal Cortex.	The present fMRI study investigated supramodal & modality specific neural activity underlying mental-visual imagery & auditory information; supramodal network activated attention.
23	Valeria Drago, Glen R. Finney, Kenneth Heilman et al., 2008	17	Two Groups, Creativity (Visual Artistic), Attention (Spatial & Global), Line Bisection.	Research has indicated right hemisphere involvement in perceptions of emotions, individuals with reduced attentional bias experience greater emotional arousal viewing a visual of arts, evidence that greater evocative impact when viewing a series of paintings.

Table 3.3: Studies on Meditation and Brain Networks

Sr. No.	Reference	Sub	Design of Experiment and Variables Studied	Findings
1.	Fred Travis & Jonathan Shear, 2010,	20	Two Groups, Brain Waves, Coherence, Meditation, Frontal Cortex (mPFC)	Tibetan Buddhist, Buddhist & Chinese traditions characterized open monitoring category, characterized by theta activity. Self transcending meditations included Vedic and Chinese meditations, characterized by alpha1 activity.
2.	Fred Travis et al, 2010,	50	Two Groups, Brain Wave Coherence, Alpha, Meditation, Beta1	Significant brain wave differences were seen between groups, TM practice led to higher frontal alpha1 & low beta1 & gamma frontal & parietal.
3.	Michael C. Dillbeck, 1981,	15	Two Groups, Brain Wave Coherence, TM, Alpha (Frontal),	Study reports on the effect of the TM technique in contrast to relaxation on EEG alpha coherence in bilateral frontal and occipital areas, on slow alpha power in these findings. TM technique is characterized by higher values as compared to mere relaxation.
4.	David W. Orme-Johnson, 1981,	25	Two Groups, Brain Waves, Concept Learning, Focus, TM	Flexibility of Concept Learning was found to be frontal bilateral EEG coherence and H-reflex recovery; the presence of relationship between performance on the concept learning task & EEG bilateral coherence.
5.	B.Froelinger, E.L.Garland, et al., 2012,	7	Two Groups, BWC, Resting State – DMN, PFC, DAN, Salience, Executive Network.	Strengthened functional connectivity within dorsal attentional network (DAN), the coupling between networks involved in attention, self-referential processes and affective response.

7.	J.H.Jang, et al., 2011,	35	Two Groups, Resting State functional Connectivity, (fMRI), DMN, Frontal Cortex, FA(Brain Wave Vibration)	Meditators show heightened functional connectivity in the areas of cortical midline activity, the seed regions of the medial prefrontal cortex and the default mode network.
8.	J.A.Brewer et al., 2011,	12	Two Groups, Resting State, DMN, Self referential processing, Focused Attention,	Findings demonstrate differences in the default mode network that are consistent with decreased mind-wandering, as such provide unique understanding of possible neural mechanisms of meditation vis-à-vis DMN , SRN etc.
9.	A Berkovich-Ohana, J. Glicksohn, A. Goldstein, 2012,	36	Two Groups, DMN, Self-reference, Attention. Gamma power, meditation	Mindfulness meditation practitioners show lower frontal gamma activity, related to DMN and narrative self-reference. DMN deactivation was identified during transition from resting state to a time production task, as lower gamma (25-45 Hz) power over frontal & midline regions.

Table 3.4 - Brainwaves, Frequency and Brain States Representation

Sr. No.	EEG Brainwave	Brainwave Frequency	States of Consciousness and its Associates
1	**Delta**	**< 4 hz** **(0.5-3.5) cps**	Restful Sleep, Deep State, Vague Dream State, Generally associated with no thinking, Unconscious & Superconscious Access to non-physical states of existence – a key state for Regeneration & Rejuvenation
2	**Theta**	**4-7 Hz**	Light sleep, Hypnagogic Imagery, Visual Imagery, Deeply Relaxed, Dreaming, Generally associated with right-brain thinking activity – deeper subconscious to superconscious Access to insights, bursts of creative ideas – a key state for 'reality creation' through vivid imagery
3	**Alpha**	**7 – 13** **Low Alpha** **(7-10) Hz** **High Alpha (11-13) Hz**	Awake, Non-focused, Relaxed, Drowsy, Non-Vigilant, Low Level of environmental stimulation, Daydreaming Generally associated with right-brain thinking activity – Subconscious Mind – A key state for Relaxation, in Eyes closed condition.
4	**Beta**	**13 – 39 Hz** **Beta-1(13-16) cps** **Beta-2(16-20) Hz**	Fully Awake and Alert, Focused Attention, Problem Solving, Dream , REM sleep, High Level of Environmental Stimulation, Generally associated with left-brain Thinking Activity and Conscious Mind
5	**Gamma**	**>30 Hz** **(30-50)**	Conscious Awareness and Attention.

Table No.3.4 gives brief overview showing normal frequency ranges in which they operate and their primary functional associates

Table 3.5 - The Effects of Delta Brain Waves (0.5 Hz – 4 Hz)

Sr. No.	Delta Brain Waves	Effects of Specific Brain Waves
1	**0.5 Hz**	Complete relaxation and headache relief
2	**0.5-1.5 Hz**	Natural pain relief through stimulating endorphin release
3	**0.9 Hz**	Euphoric state
4	**1 Hz**	Feeling of well-being; stimulation of pituitary gland to release growth hormones, helps recover from injuries, rejuvenate, and develop muscles.
5	**2 Hz**	Nerve regeneration
6	**2.5 Hz**	Further pain and migraine relief from production of endogenous opiates, natural sedative effect.
7	**1-3 Hz**	Restorative sleep and profound relaxation
8	**3.4 Hz**	Restful sleep
9	**3.5 Hz**	Feeling of calmness reducing anger and irritability. Retention of languages.
10	**4 Hz**	Enkephalin release for natural stress and pain reduction. Improved memory, subconscious learning and problem solving.

Table No. 3.5, showing the effects of delta brain waves from (0.5 hz – 4 hz), and their normal frequency ranges in which they operate along with their primary functions.

Table 3.6 - The Effects of Theta Brain Waves (4 Hz – 7 Hz)

Sr. No.	Theta Brain Waves	Effects of Specific Brain Waves
1	**4.5 Hz**	Brings what is referred to as "the Tibetan state of consciousness", a state of meditation.
2	**4.9 Hz**	Induced relaxation, meditation, introspection, and a deeper sleep.
3	**5 Hz**	State of unconscious problem solving. Less sleep is needed due to the Theta waves replacing the need for extensive dreaming. Beta endorphin release as a natural pain killer.
4	**5.35 Hz**	Deeper breathing, relaxing the lungs.
5	**5.5 Hz**	Giving the feeling of intuition, your inner guidance, and "gut feeling".
6	**5.8 Hz**	Reduce fear, absent-mindedness, and dizziness.
7	**6 Hz**	Improves long-term memory and motivation; reduces procrastination and unwillingness to work.
8	**4.5-6.5 Hz**	Waking dreaming (day dreaming) with vivid images.
9	**6.5 Hz**	Activates the frontal lobe which controls creativity.
10	**6.2 – 6.7 Hz**	Activates Frontal Mid-line, engaged in cognitive activity, solving math problems, playing Tetris, or other similar types of quick passive problem solving tasks.
11	**6.88 Hz**	Effects balance and stability.
12	**3 Hz – 8 Hz**	Deep relaxation, meditation, lucid dreaming, increased memory, focus, and creativity.
13	**4 Hz – 7 Hz**	Inner peace and emotional healing which lowers mental fatigue.
14	**6 Hz – 10 Hz**	Creative visualization, starts at 6Hz and moves up to 10Hz.

Table No. 3.6, showing the effects of theta brain waves from (4 hz –7 hz), and their normal frequency ranges in which they operate along with their primary functions.

Table 3.7 - The Effects of Alpha Brain Waves (7.5 Hz – 13 Hz)

Sr. No.	Alpha Brain Waves	Effects of Specific Brain Waves
1	**7.5 Hz**	Creative thought is activated for music, art, invention, and problem solving. Overcoming troublesome issues or problems due to ease in finding solutions through re-evaluation. This is a type of inter-awareness of self purpose.
2	**7.83 Hz**	The Schumann Resonance. Very grounding as it is the same frequency as the magnetic field of the earth.
3	**7.5 – 8 Hz**	For treating addictions, drug, alcohol, food, etc. Gives the person the "satisfied" feeling that they would normally get from their addiction.
4	**8 Hz – 14 Hz**	Qi Gong.
5	**8.3 Hz**	Heightens clairvoyance around visual images and metal objects.
6	**8 – 10 hz**	Reduced stress and anxiety.
7	**9 Hz**	Brings awareness of body imbalances.
8	**10 Hz**	Increased serotonin release bringing mood elevation, arousal; relives headaches and stimulates the body. Will bring clarity to the mind and give subconscious correlation.
9	**10 – 12 Hz**	Improves the mind, body connection.
10	**10.5 Hz**	Lowers blood pressure. Associated with the Heart Chakra which is related to the Thymus, heart, blood, and circulatory system.
11	**10.6 Hz**	Relaxed and alert.
12	**11 Hz**	Brings relaxed & awake state, lucid state (day dreaming) but not tiredness. Thoughts & emotions may pleasantly, bringing mind to be calm. Bridge between conscious & unconscious mind. Gives stress reduction.
13	**12 Hz**	Gives mental stability
14	**12 – 14 Hz**	Improves learning by absorbing information when you plan to think about it later.
15	**12.3 Hz**	Improves visualization.

Table No. 3.7, showing the effects of alpha brain waves from (7.5 hz –13 hz), and their normal frequency ranges in which operate along with their primary functions.

Table 3.8 - The Effects of Beta Brain Waves (13 Hz – 39 Hz)

Sr. No.	Beta Brain Waves	Effects of Specific Brain Waves
1	**13-27 Hz**	Focus with attention toward external stimuli. The normal waking consciousness, active thought process, and alert mental activity.
2	**13-30 Hz**	Processing outside data, brain takes in, problem solving and active conscious thinking. A very wakeful state which combats drowsiness.
3	**14 Hz**	An awake, alert state. Allows you to focus and concentrate on tasks.
4	**15 - 18 Hz**	Increases mental abilities including focus, alertness, attentiveness and IQ. Awareness of one's self and surroundings, alert but not agitated.
5	**16 Hz**	Stimulates oxygen/-calcium release into cells.
6	**18 – 24 Hz**	Euphoria and ecstasy, similar to a runners high with serotonin release around 22Hz.
7	**20 – 40 Hz**	A fully awake state with normal alertness. Significant improvements can be seen in memory, reading, spelling, math, and planning. Stimulation of the pineal gland. The frequency can help with tinnitus. Ideal meditation frequency for stress release.
8	**31 Hz**	Release of growth hormone, can help to develop muscles and recover from injuries (rejuvenation effects).
9	**32 Hz**	Enhanced vigor and alertness.
10	**33 Hz**	Pure consciousness and the Pyramid frequency.
11	**35 Hz**	Balance of all chakras.
12	**38 Hz**	Endorphin release.

Table No. 3.8, showing the effects of beta brain waves from (13 hz –39 hz), and their normal frequency ranges in which they operate along with their primary functions.

Table 3.9 - The Effects of Gamma Brain Waves (40 Hz and above)

Sr. No.	Gamma Brain Waves	Effects of Specific Brain Waves
1	**40 Hz**	Having efficient 40Hz activity creates a good memory also dominant in problem solving. Important for information and high-level information processing. A lack of this frequency can create learning disabilities. The learning frequency range; will help maintain alertness when actively studying or thinking. Related to the pre-piriform cortex and amygdala. Coordinates processing of information in different areas of the brain simultaneously.
2	**40 – 60 Hz**	Can stimulate the release of beta-endorphins and give anxiolytic effects.
3	**55 Hz**	Tantric yoga which stimulates the "kundalini".
4	**62 Hz**	Feeling of physical vigor.
5	**72 Hz**	The emotional spectrum.
6	**40 + Hz**	The higher gamma frequencies are less specific occurring over larger ranges and are mostly related to intelligence, problem solving, focus, memorization, concentration, etc. They can be looked at as an enhancement for a lot of the benefits of the beta frequencies.

Table No. 3.9, showing the effects of gamma brain waves from (<40 hz & above), and their normal frequency ranges in which they operate along with their primary functions.