Original Article

Association between Cyclic Meditation and Creative Cognition: Optimizing Connectivity between the Frontal and Parietal Lobes

Abstract

Background: Important stages of creativity include preparation, incubation, illumination, and verification. Earlier studies have reported that some techniques of meditation promote creativity but have not specified which stage is enhanced. Here, we report the influence of cyclic meditation (CM) on creative cognition measured by a divergent thinking task. Our aim was to determine the degree of association between the two. **Methods:** Twenty-four university students were randomly assigned to an experimental group (CM) and controls (Supine Rest), 35 min/day for 7 days. Creativity performance was assessed pre and post using Abbreviated Torrance Test for Adults (ATTA), while 64-channel electroencephalography (EEG) was used to measure brain activity during both CM/SH and the creativity test. **Results:** Results indicated that CM training improved creativity performance, producing a shift to predominant gamma activity during creativity compared controls who showed delta activity. Furthermore, the experimental group showed more activation of frontal and parietal regions (EEG leads F3, F4 and P3, P4) than controls, i.e., the regions of the executive network responsible for creative cognition, our particular regions of interest where specialized knowledge is being stored. **Conclusion:** Improvement on creativity test performance indicates that CM increases association and strengthens the connectivity between frontal and parietal lobes, the major nodes of default mode network and executive attention network, enhancing the important stages of creativity such as preparation, incubation, and illumination.

Keywords: *Attention, cognition, creativity, cyclic meditation, default mode network, divergent thinking, electroencephalography, executive network, gamma waves*

Reshma Madhukar Shetkar, Alex Hankey, H. R. Nagendra[1], Balaram Pradhan[2]

Yoga and Physical Sciences, S-vyasa University, [1]Chancellor, S-vyasa University, [2]Division of Yoga and Humanities, S-vyasa University, Bengaluru, Karnataka, India

Introduction

During the past several decades, there has been tremendous increase in understanding the process of creativity and its associates in the brain.[1,2] Creativity has been defined as the capacity to generate novel, socially valued ideas (Mumford)[3] or as an ability to produce work that is novel, original, and appropriate (Sternberg).[4] Helmholtz (1826) and Wallas (1926) suggest that creativity has four stages of conscious and unconscious brain activity and they are (i) preparation, (ii) incubation, (iii) illumination, and (iv) verification.[5,6] During the preparation stage, the problem is investigated in all possible directions as the thinker readies the mental soil for sowing the seeds. In the preparation stage, accumulation of intellectual resources takes place out of which new ideas could emerge. Next, a period of subconscious processing known as incubation takes place, during which no direct effort is exerted upon the problem at hand – this stage is where the combinatory play takes place wherein the development of new thought processes arises. In the third i.e., incubation stage, two divergent process takes place and series of unconscious, involuntary background events happen. This being termed as 'fore-conscious' and 'fore-voluntary' Wallas. 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 and the subliminal self 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 and spontaneous state of mind which cannot be forced. It is accompanied by the final flash or click, which is the culmination of a successful train of association and thinking. These trains of associations are the connections

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Address for correspondence:
Dr. Reshma Madhukar Shetkar, C/O. Dr. Alex Hankey and Dr. Nagendra H. R. Swami Vivekananda Yoga Anusandhana Samsthana, Vivekananda Yoga University, Eknath Bhavan, 19 Gavipuram Circle, Kempegowda Nagar, Bengaluru - 560 019, Karnataka, India.
E-mail: rashmishetker@gmail.com

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between seemingly unconnected areas within the brain. In the last stage, conscious and deliberate effort of testing the validity of idea and reducing the idea into form happens; hence, this last stage does the scientific verification of the concept or idea taken place during the first three stages, i.e., preparation, incubation, and illumination.

Creativity is measured and verified by divergent thinking tasks, wherein many possibilities develop from one starting point, which produces creative thinking resulting in new answers, forms, ideas, or new patterns. Divergent thinking is an important and measurable aspect of creativity. According to Guilford, divergent production pertains to information retrieval and the number of varied responses.[7] Pfenninger and Shubik (2001) suggest that creativity is the innate ability to "associate novel contexts with principles of order."[8] Heilman defines creativity as the discovery of "unity in the variety in what is called diversity of nature."[9]

The Torrance tests of creativity are among the most widely used assessments of creativity.[10] These tests use divergent thinking and yield scores for fluency, flexibility, originality, and elaboration, examining the stages of creativity such as preparation, incubation, and illumination, which can be corelated to the activity of different areas of frontal and parietal regions[11] of the brain. Electroencephalographic (EEG) studies of healthy controls suggest interhemispheric as well as intrahemispheric communication of neuronal networks providing evidence of communication and connectivity between brain areas important for divergent thinking.[12] Wechsler Adult Intelligence Scale and Torrance tests, respectively, found that creative individuals had more inter- and intra-hemispheric EEG coherence than those who were less creative.[13,14] Overall, these EEG studies support a relationship between divergent thinking and physiological interactions, associations and connections between brain regions.[15]

Clinical as well as functional imaging studies suggest that the frontal lobes are important for divergent thinking and specialized knowledge. The domain-specific and specialized knowledge is stored in specific portions of the parietal lobes.[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 goal-directed attention and rest.[17] The coactivation and communication between these regions are normally not strongly established; however, meditation studies reveal that these associations can be triggered by alterations during meditation, a goal-directed activity and focusing of attention and by the role of neurotransmitters such as norepinephrine during meditation.[18] Hence, our attempt is to search for this association with one of the most powerful techniques of yoga meditation called *Avartan Dhyan* or cyclic meditation (CM).[19]

The purpose of this study was to understand whether CM can enhance the associations, connection, and communication between the frontal and the parietal lobes, especially specific regions such as F3-F4 and P3-P4, where specialized and domain-specific knowledge of an individual responsible for creative cognition is stored.[11,16,17] Further, it is hypothesized that CM could optimize connectivity of the frontal and the parietal lobes, thereby enhancing creative stages such as preparation, incubation, and illumination as tested by Torrance tests of creativity[20] and EEG in comparison to the controls.

Materials and Methods

Subjects

Twenty-four healthy controls (mean age: experimental - 27.92 ± 6.95 years, control - 27.17 ± 8.30 years) were recruited. One group was undergoing regular training sessions for CM as an experimental intervention and another group for *Shavasana* as a control intervention for 7 days, 35 min each day from 8.00 am to 8.35 am. The inclusion criteria were right handedness;[21] no history of neurological illness as assessed by GHQ questionnaire;[22] no present medication for medical disorders that could have deleterious effects on EEG morphology, as well as neurological, and/or cognitive functioning consequences; and no hearing, vision, or upper body impairment relevant for neuropsychological function.[23] Before the EEG experiment, a brief neurocognitive assessment aimed to assess verbal intelligence quotient[24] (M = 119.4, standard deviation [SD] = 12.21), and a brief clinical assessment ruled out the presence of psychopathological symptoms[25] (M = 1.26, SD = 0.26). None of the participants had total scores that indicated the presence of clinical symptoms. Participants were not paid for the study; only a free 1 week daily training of CM for experimental group and *Shavasana* training to control group were given for 35 min. All participants provided written informed consent for the experimental protocol approved by the Institute's Ethical Committee.

Study design

Participants were assessed in two separate sessions pre- and post-intervention, in the EEG laboratory of DRDO (Defence Research and Development Organisation), Delhi, where the study was conducted [Figures 1 and 2]. The order of the recording and assessment was randomized as per the online random number generator log table. On both the recording days pre and post for CM and SH, participants were asked to avoid all other physical activities (e.g. walking, jogging, or other yoga practices). However, they continued with the rest of their routine (e.g. listening to lectures in their usual schedule) since all of them were students at a local university wherein their routine was relatively comparable.

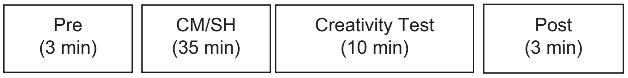

Figure 1: Schematic representation of the study

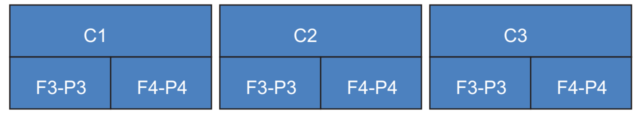

Figure 2: Regions of interest (ROI) and dimensions of creativity in two groups

Apparatus and procedures

Intervention-cyclic meditation

CM also called as "*Avartan Dhyan"* technique is a "moving meditation," which combines the practice of yoga postures with guided meditation as introduced by one of the authors (HRN). CM has its origin in an ancient Indian text named Mandukya Upanishad.[26] It is interesting to note that CM induces a quite state of mind, which is compatible with the description of meditation, namely, dhyana or effortless expansion, according to Patanjali. The description states "Tatra pratyayaikatanata dhyanam" (Patanjali's Yoga Sutras, Chapter 3: Verse 2).[27] This means that an uninterrupted flow of the mind toward the object chosen for meditation is dhyana. There are three categorizations of meditation: open monitoring, focused attention, and self-transcending[28] which may include varieties of techniques of meditations practiced worldwide. The above categorization is based on the neural mechanism, and its neural correlates in the brain. All meditations irrespective of the strategies involved are believed to help reach a higher state of silence and bliss. The verse on which CM is based states: "in a state of mental inactivity awaken the mind; when agitated, calm it down; between these two states realize the possible abilities of the mind. If the mind has reached states of perfect equilibrium do not disturb it again." The underlying idea is that, for most persons, the mental state is routinely between the extremes of being "inactive" or of being "agitated" and hence to reach a balanced and relaxed state; the most suitable technique would be one which combines "awakening" and "calming" practices like that of CM.

In CM, the period of practicing yoga postures constitutes the "awakening" practices, while periods of supine rest comprise "calming practices." An essential part of the practice of CM is being aware of sensations arising in the body.[19,29] This supports the idea that a combination of stimulating and calming techniques practiced with a background of relaxation and awareness (during CM) may reduce psychophysiological arousal more than just resting in a supine posture for the same duration. The practice of CM includes yoga postures (asanas) which involve muscle stretching and this has diverse benefits. The effects, benefits, and possible mechanism underlying CM were further discussed by Subramanya and Telles, which is not mentioned in detail here.[29]

Procedure

Participants sat in the chair during baseline and creativity testing and on the floor on mats during intervention of CM and *Shavasana*. Throughout the CM practice, the participants kept their eyes closed and followed the instructions of the CM trainer. The instructions emphasized carrying out the practice slowly, with awareness and relaxation. The practice began by repeating a verse (40s) from Mandukya Upanishad,[26] followed by isometric contraction of the muscles of the body ending with supine rest (1 min), slowly coming up from the left side and standing at ease (called *Tadasana*), and "balancing" the weight on both feet (called centering) (2 min). The first actual posture consists of bending to the right (*Ardhakati chakrasana*, 80s), a pause of 70s in *Tadasana* with instructions regarding relaxation and awareness, bending to the left (*Ardhakati chakrasana*, 80s), a pause (70s), backward bending (*Ardhakati chakrasana*, 80s), a pause (70s), forward bending (*Padahastasana*, 80s), another pause (70s), backward bending (*Ardhakati chakrasana*, 80s), and slowly coming down to supine posture with instructions to relax different parts of the body, followed by QRT, i.e., Quick Relaxation Technique in sequence (5 min). This is followed by sitting and forward bending posture, namely, *Shashankasana*, 80s and camel posture (*Ustrasana* 80s), followed by the deep relaxation technique (Deep Relaxation Technique for 12 min). In all these, awareness is focused and sensation felt on each part of the body step by step from toes to the tip of the head. The total duration of the practice was 35 min.[19] The key features of CM are (i) postures interposed with relaxation, (ii) slowness of movements, (iii) continuity, (iv) inner awareness, and (vi) recognition of linear, surface, three-dimensional, and all pervasive awareness.

Shavasana for control

During *Shavasana*, the individuals lay in the corpse posture (*Shavasana*), with their legs 30° apart and arms from the side of the body with eyes closed.[30] This practice lasted 35 min so that the duration was the same as for CM.

Assessment of creative cognition – divergent thinking

The figural, visual/verbal, and artistic Abbreviated Torrance Test for Adults (ATTA) was used to measure the divergent thinking activity. This test comprised of three different phases of activities in which the participant is given verbal, figural, and artistic questionnaire along with the shapes and lines for assessing creativity.[20] Furthermore, the individuals were instructed to make abstract, unusual pictures, and tell us story. Individuals had to title their creativity tasks, introducing a small verbal component to the task. The streamlined scoring system was used,[31] which scores the test performance for fluency, originality, elaboration, and flexibility, all of which contribute to the index score, which are given for a number of other creative strengths such as emotional expressiveness, storytelling, articulateness, movement, synthesis of figures, humor, richness of imagery, and fantasy.[32] The reliability for this test was adopted from the test-retest reliability and scorer reliability. The numerical value in the test-retest reliability is 0.340–0.682 ($P < 0.01$), and in scorer reliability, it is 0.311–0.975 ($P < 0.01$). The linguistic parts of correlational coefficient in criterion-referenced creativity indicators is 457 ($P < 0.01$) whereas that in figure parts is 368 ($P < 0.05$).[32] Raw ATTA scores for the subscales were converted to age-normalized standard scores using the technical manual (Torrance, 1998).[32] Total ATTA index scores are calculated by adding bonus points to the average of these subscales standard scores. Percentile equivalents of the total index scores are provided in the technical manual. The existing normative data for the ATTA were established predominantly among elementary and university students. While there are normative data for adults, they are not stratified by age or education. For the purpose of this study, the general reference group of all adults over the age of 20 was used to calculate total index scores and percentiles, and age and education were analyzed as potential confounding variables during data preanalysis. To establish inter-rater reliability, ATTA tests of three individuals were scored by two separate raters, the primary investigator and a trained researcher, both of whom were unaware (blinded) of the EEG results. Both raters were trained through careful reading of the figural TTCT manual. An acceptable level of inter-rater reliability was obtained for scoring of the ATTA ($r = 0.82$). Only the primary investigator scored the remainder of the tests, and the primary investigator's scores were used in final analysis.

Electroencephalographic recording, data acquisition, and analysis

EEG data acquisition: the experimental room was sound proof and the floor was electrically shielded and grounded.[33] To ensure good quality EEG signals, participants were asked to wash their hair before attending the recording session, and for nonscalp electrodes, their skin was carefully cleaned using an alcohol solution. All electrodes were kept within 50 mV offset of the BIOSEMI system metric for measuring impedance. EEG data were recorded using a 64-channel Active Two Biosemi system (Biosemi, Amsterdam, Netherlands), in a continuous mode at a digitization rate of 512 Hz, with a bandpass of 0.01–100 Hz, and stored on disk for later analysis. Eye blinks and movements were monitored through electrodes placed on both temples (horizontal electrooculogram) and another one below the left eye (vertical electrooculogram). Following steps were taken in data processing: (a) filtering and removal of excess noise from data; (b) independent component analysis (ICA) for artifact removal; (c) segmentation of data into different brainwave frequencies; and (d) calculation of energy and power for different frequency segments for all events (baseline-pre-post, creativity test, CM).

Data processing and artifact rejection

Data processing was carried out using the EEGLAB open source software version 12[33] running on Matlab R2009b (The Matworks Inc.) under a Linux operating system (Ubuntu 12.04). EEG data were first referenced to the right mastoid and downsampled from 1024 to 256 Hz. A high-pass filter at 1 Hz using an infinite impulse response filter with a transition bandwidth of 0.3 Hz and an order of 6 was applied. We automatically removed portions of the signals presenting nonstereotyped artifacts using *pop_rejcont* function of the EEGLAB software (The Matworks Inc).[33] The data were first segmented in 1-s epochs with 0.5 s overlap. Segments of 8 contiguous epochs in which the 0–10 Hz frequency band and the 35–128 Hz frequency band had amplitude higher than 17 and 14 decibels, respectively, were labeled as artifactual. We used this rejection procedure to ensure that artifact rejection was uniform for all individuals. Rejection of low-frequency segments helped remove signals related to individuals' head and body movements. Rejection of high frequency activity helped reject data portions of muscular activity. Finally, we used Infomax ICA on the pruned data to reject eye movement related and muscle artifacts.[34]

Statistical analysis

Analysis of variance (ANOVA) was first used to assess significance of the EEG spectral power across groups and conditions using one-way Welch's ANOVA.[34,35] The final statistical analysis was using SPSS Version 20.0 (IBM, Armonk, NY, USA). Between- and within-group comparison for creativity and EEG using independent *t*-test to determine whether scan protocol affected the creativity and EEG measurements on our regions of interest (ROI) measurements and their scores. Descriptive statistics were used to identify outliers and normality of distribution for variables of interest. For significant relationships that were found between creativity total scores and ROIs, correlations were determined *post hoc* between the areas of frontal F3, F4 and parietal P3, P4, following a significant relationship between the experimental and control groups practicing CM and *Shavasana* (SH) and the total scores in each group.

Results

Tables 1 and 2, Figure 3 and 4 shows that there was significant difference between CM and SH groups in Creativity Scores, namely, CRS ($P < 0.020$), C1F ($P < 0.001$), C1P ($P < 0.001$), C2F ($P < 0.001$), C2P ($P < 0.001$), C3F ($P < 0.004$), C3P ($P < 0.025$), and TOTAL ($P < 0.001$).

Table 1: Creativity scores pre-post with percentage change in two Groups

Creativity variables	CM			SH		
	Pre	Post	%	Pre	Post	%
Fluency	19.75±1.05	26.66±1.43***	34.99	18.75±2.53	18.25±2.09	2.67
Originality	9.33±1.72	16.83±3.80***	80.39	13.17±4.24	9.17±1.40 *	30.37
Elaboration	19.41±2.19	25.25±1.91***	30.09	18.50±3.53	18.92±2.97	2.16
Flexibility	8.66±1.55	9.75±2.34**	12.59	8.50±1.00	12.08±3.18 **	42.12
Total Scores	65.91±5.26	77.66±2.49***	17.83	60.42±6.35	59.92±8.17	0.83
Level	3.58±0.66	5.33±0.49***	48.88	3.67±1.30	2.58±1.08 ***	29.70

Values are expressed as *n* (%) change, mean and standard deviations

Table 2: EEG data asymmetry and synchrony - scores in creativity

Creativity dimensions	ROI	CM mean±SD	SH mean±SD	Independent '*t*' test *P*
Fluency	F3, F4	85.67±12.54	18.50±28.29	0.001
	P3, P4	71.33±25.82	10.17±9.34	0.001
Originality	F3, F4	62.67±20.80	10.33±14.77	0.001
	P3, P4	72.83±29.08	8.33±15.30	0.001
Elaboration	F3, F4	74.63±33.25	46.33±8.07	0.004
	P3, P4	66.50±43.312	16.33±17.17	0.025

Values are expressed as mean and SD = Standard deviations, CM = Cyclic Meditation, SH = Shavasana

Discussion

The experiment described above shows that this deep meditation and relaxation technique such as CM could enhance access to creative cognition and thought processes. When effect sizes are compared to experiments on deep meditation, we find relaxation alone performed in accordance with Gaudapada's principle of alternating excitation and relaxation has comparable effect sizes (Control and Exp 0.28–0.56, 0.28–77). CM practice improved performance on Torrance tests of creativity, presumably because CM can help participants enter deeper states of awareness, where arousal is in perfect equilibrium, alertness increased, and attention functions from deeper levels.

The results provide evidence that while CM training increases performance on tests of creative cognition, *Shavasana* training does not. Creative processes are held to occur in three stages, i.e., preparation, incubation, and illumination; so which of these are affected? As has previously been shown, the frontal and parietal lobes of the brain play special roles in above-mentioned stages of creativity. Brain regions of the interest F3, F4 (frontal) and P3, P4 (parietal) electrodes, which represent core regions of executive attention networks and where specialized, domain-specific knowledge important for creativity is stored, and from where it is retrieved;[11,16] gets networked predominantly, by parallel activations. CM training seems to promote awareness and attention strengthening connections in the frontal lobe and associations between these regions, presumably facilitating retrieval of required information from the parietal lobes.[11]

Before the intervention, baseline data showed dominant delta wave activity during eyes closed periods in both groups. During intervention, a shift from delta to gamma activity was observed in the CM group, whereas in the control group, delta activity remained dominant. This seems to suggest a mechanism behind CM's effect of increasing ATTA scores. Delta wave activity is associated with mental activity in dullness while gamma wave activity is associated with refined levels of awareness, presence, alertness, and positive feeling. Results suggest that the experimental group's levels of attention, alertness, awareness, and subtle positive feeling (gamma) increased, while controls failed to release stress and remained in dullness (delta). As discussed in this paper, increased levels of awareness, alertness, and subtle positive feeling may be reasonably expected to be connected to creative intuition and to increase creative cognition.

This result should be compared with the observations of periods of peak creativity and Buddhist compassion meditation, both of which are characterized by gamma waves. More speculatively, we may also suggest that by better connecting mind and body, CM practice may shift consciousness from gamma toward alpha during practice and performance on tasks assessing creative cognition. Another dimension to the regions of brain activation concerns the various brain networks active during different tasks or activities: the executive network,[36] the self-referential network,[37] and the default mode network (DMN).[38-41] Observed connection between frontal and parietal lobes in the CM group suggests that CM facilitates connections between the first two networks, which are both important for creative cognition.

The last stage of CM practice is *Nadanusandhana*, chanting the mantra, Aum, first as three separate sounds, Aaaa…, Uuu…, and Mmm…, and finally "Om," as a

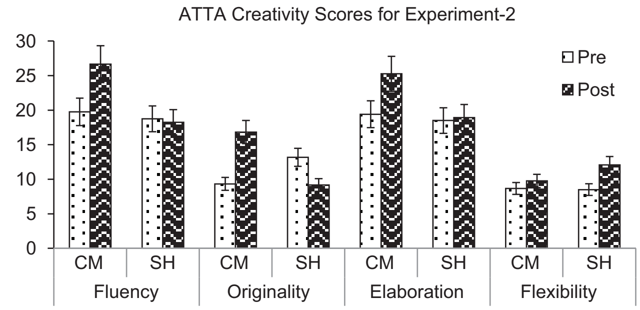

Figure 3: ATTA Creativity Scores for Pre-Post testing between two groups

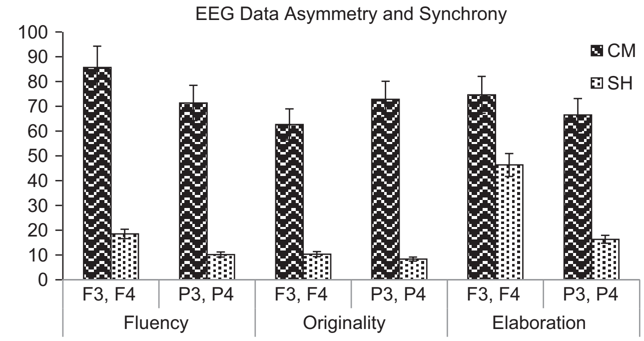

Figure 4: Differences between groups within the ROI

single phoneme. EEG waves may be modified by the sound; this may be mediated through the midbrain, from which the parasympathetic nervous system signals the heart through the vagus nerve. At least one published study has been conducted on the Om sound and its significant impact in deactivation was observed within the nodes of DMN mainly in limbic system and anterior cingulate, as seen in a fMRI study.[42] "OM" chanting indicates limbic deactivation particularly the parietotemporal node of DMN in comparison to the resting brain state within the specific regions of orbitofrontal, anterior cingulate, parahippocampal gyri, thalami, and hippocampi mainly active in the depression and relaxation states of the brain.[42] In terms of the Panchakoshas, the increased connectivity of the subtle, Manomaya, and gross, Annamaya-koshas, represents integration between the five koshas, improving harmony between the conscious and unconscious spectra of the mind, i.e. higher connectivity within the brain resulting in increased creativity, freedom and expansion.

Recommendations for future research

The study has limitations so that more studies are needed. Combined studies using EEG and fMRI with longer intervention duration and larger sample sizes would better define brain regions involved; also, a variety of tools could be used to assess creative cognition; for example, one based on South Asian lifestyle and cognitive style or ones aimed at better understanding relationships between various other parts of the brain and styles of creativities associated with left and right hemisphere function. Further studies might also investigate functional connectivity measures in other regions of the brain and correlate scores with different kinds of creativity.

Conclusions

In summary, the data demonstrate that CM improves creativity measured by the ATTA test, while *Shavasana* practice failed to produce a measurable effect. They also show that CM practice produces changes in EEG activity, improving connectivity between frontal and parietal lobes in the gamma frequency bands of the EEG. We conclude that research using EEG-based associations and connectivity patterns among the brain regions may offer a fruitful direction for future research on creative cognition. CM may enhance the brain's potential in that area. The future journey of this research will depend on what can be shown to be scientific and what can be proven. It should build on our understanding of the biophysics of meditation,[43] its relationship to self-organized criticality,[44,45] subjective accounts of meditation from the first person perspective,[46] building the Panchakosha model,[47] and similar reasoning to show how meditation benefits mental health[45,44] enhancement of higher brain faculties such as an emotional intelligence,[48] redefining social consciousness through human excellence,[49] and cognition of pure consciousness, by the application of its structure in the Vedic sciences.[50]

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Conflicts of interest

There are no conflicts of interest.

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