SpARC
Research Program and Publications

Spiritual Applications Research Centre

SpARC Wing of
Rajyoga Education & Research Foundation
Prajapita Brahma Kumaris Ishwariya Vishwa Vidyalaya,
Mount Abu Rajasthan (India)

Table of Content

Table of Content

Preface

The current world is leading towards technological advancement at the fastest pace each day. In this world running so fast, stillness is bliss and can provide the ultimate relaxation and energy to start again. Spiritual qualities among us are demanding for this stillness and emptiness for a moment. Meditation is one of the practice to easily achieve and rejuvenate with the degrading effects of worries and negativity. Rajayoga meditation with its versatility and easy to practice is becoming popular among different performance domains. Many individuals from different age, race, profession, education background and sufferers of different mental disorders across the globe have got benefitted from the practice of Rajayoga. Many research institutions have identified the need to explore the effects of Rajayoga meditation and lifestyle of Brahmakumaris through proper scientific tools. SpARC wing has also envisioned the importance of scientific research and provided the best possible facilities at Mt. Abu Headquarters as well as supported wholeheartedly the scientists and researchers from recognized research institutes.

Currently, with the Psychophysiology Lab established at SpARC, many objectives for mental and spiritual well-being are planned. In this direction, SpARC has established Memorandum of Understanding with labs of international as well as of national repute.

SpARC is currently working to understand different mental states related to emotions, and cognition reflected during different stages of meditation. With different techniques of data recording, SpARC has its prime focus to understand the psychological and physiological mechanisms behind conscious experiences during meditation as well as in resting state. Also, the noble question related to the correct method of meditation practice as well as its self-verification is also considered to work upon.

At, the national and international level many posters were presented by researchers and scientists which were based on experiments conducted and data collected at SpARC lab as well as various centers across the country. Some peer-reviewed journal articles were also published in international journals. This book is a collection of these research experiments, their results, and impact on society.

Research Collaborations

National Collaborations

- India International Multiversity, Pune
- Medical Intelligence and Language Engineering (Mile),IISc, Bangalore
- DRDO (Defense Research Development Organization)
- Defence institute of Physiological and allied sciences(DIPAS)
- Defence institute of Physiological research (DIPR)
- Institute of Nuclear medicine and allied sciences (INMAS)
- NIMHANS (National Institute of Mental Health & Neuro Sciences)
- AIIMS (All India institute of Medical Sciences)
- NDMA (National Disaster Management Authority)
- KMIO (Kidwai Memorial Institute of Oncology)
- ISIC (Indian Spinal Injuries Centre)

International Collaborations

MoU with The KEY institute for Brain-Mind Research, Univ. of Zurich, Switzerland
Protocol designing
EEG data analysis
Prof Achermann and Prof. Pascal Faber

In process of formulating MoU with
Coma science Group, Université de Liège, Belgium
Universiti Teknologi PETRONAS, Kualalumpur, Malaysia
University of Groningen Bernoulliborg, The Netherlands

Original Article

The Effectiveness of Rajyoga Meditation as an Adjuvant for Panic Anxiety Syndrome

Kamlesh Jha, Pankaj Kumar, Yogesh Kumar, C. P. Ganashree, Chandrabhushan Tripathi[1], B. K. Shrikant[2]

Department of Physiology, All India Institute of Medical Sciences, Patna, Bihar, [1]Department of Biostatistics, IHBAS, New Delhi, [2]Natinal Co-ordinator, pARCWing of BKWSU, Mount Abu, Rajasthan, India

Abstract

Objective: One of the most prevalent psychiatric conditions that affect a person's quality of life, ability to function and productivity, and consequently the loss of national income, are anxiety disorders. Rajyoga meditation (RM) is a form of meditation that is performed without rituals or mantras and can be practiced anywhere at any time. In this study, we attempted to evaluate the modulation of psycho-physiological parameters in panic disorder patients by a technique of short-term on RM. **Methods:** In this prospective randomized control study, 110 patients with panic disorder were randomized into two groups, Group A (standard treatment + RM) and Group B (Standard treatment). The participants of both group participants were subjected to sleep quality score, Physical Health Questionnaire-9 score, Panic Disorder Severity Scale (PDSS), and Hamilton Anxiety Rating Scale (HAM-A) questionnaires before starting the study (baseline) and at the end of the 8th week. Study groups were compared at baseline and at the end of 8 weeks. **Results:** We found that the PDSS/HAM-A was not statistically different among the study groups at baseline ($P > 0.05$); however, there was a statistically significant difference in mean z-scores of PDSS and post-HAM-A scores among the study groups at 8 weeks ($P < 0.001$). The composite score was created by adding the z-scores of pre- and post-PDSS and HAM-A. We found a statistically significant difference in postcomposite scores between the study groups ($P < 0.001$). Analysis of co-variance for PDSS and HAM-A among study groups showed statistical significance ($P < 0.001$). **Conclusion:** When used in conjunction with pharmaceutical treatments for the treatment of panic disorder, RM is a successful therapy. The key factors are adherence and motivation while being supervised by a licensed therapist.

Keywords: *Composite score, Hamilton Anxiety Rating Scale, panic anxiety syndrome, Panic Disorder Severity Scale, Rajyoga meditation, z-score*

Introduction

One of the most prevalent psychiatric conditions that affects a person's quality of life, ability to function and productivity, and consequently, the loss of national income, are anxiety disorders (ADs). According to the World Mental Health Survey, the lifetime prevalence of ADs varies between 3% and 19% among nations.[1] According to the Global Burden of Disease 2015 report, ADs contributed to the sixth-highest number of years with a disability.[2] Despite the enormous disease burden, ADs are generally underdiagnosed and undertreated, which results in significant health damage and financial loss.

Panic disorder (with or without agoraphobia), agoraphobia without panic, social phobia (social AD), specific phobia, generalized AD (GAD), acute stress disorder, posttraumatic stress disorder, obsessive–compulsive disorder, and AD not otherwise specified are the major categories of ADs listed in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-IV) (American Psychiatric Association).[3]

Panic attacks happen frequently and without warning in people with panic disorder. Even when there is no obvious threat or trigger, these attacks are distinguished by a rapid wave of panic, discomfort, or a sense of losing control. Not everybody who has a panic episode goes on to have a panic disorder.

One of the most prevalent ADs is panic disorder, with lifetime prevalence rates in the general population estimated to range between 2.1% and 4.7%.[4,5] Since panic disorder is frequently accompanied by a

Address for correspondence:
Dr. C. P. Ganashree, Department of Physiology, All India Institute of Medical Sciences, Patna, Bihar, India. E-mail: drganashree1979@gmail.com

Access this article online

Website: https://journals.lww.com/IJOY

DOI: 10.4103/ijoy.ijoy_149_23

Quick Response Code:

How to cite this article: Jha K, Kumar P, Kumar Y, Ganashree CP, Tripathi C, Shrikant BK. The effectiveness of Rajyoga meditation as an adjuvant for panic anxiety syndrome. Int J Yoga 2023;16:116-22.

Submitted: 04-Aug-2023 **Revised:** 01-Oct-2023
Accepted: 04-Oct-2023 **Published:** 21-Nov-2023

chronic progression that causes financial hardship and a loss of quality of life, it is crucial to properly prevent and treat panic disorder.

Psychological and pharmaceutical therapies are two of the main strategies for treating panic disorder. Cognitive-behavioral therapy is a type of psychological intervention. There are elements of their therapy regimens that may additionally improve their corresponding medical illnesses in patients with a panic disorder and concurrent comorbid medical ailments.

Meditation is usually defined as a form of mental training that aims to improve an individual's psychological capacities. Meditation encompasses a family of complex practices that include yoga meditation, mindfulness meditation, mantra meditation, and tai chi.[6] Rajyoga meditation (RM) is a form of meditation that is performed without rituals or mantras and can be practiced anywhere at any time. Rajyoga word has been derived from Raja, meaning king, and yoga, meaning union between soul (spiritual energy) and supreme soul (ocean of spiritual energy).[7]

The objective of this study was to evaluate the modulation of psycho-physiological parameters in panic disorder patients by a technique of short term on RM.

Methods

In this prospective randomized control Study, 110 patients with panic disorder, as defined by the DSM-5 criteria,[8] were selected by consecutive sampling from the Psychiatry Department at the All India Institute of Medical Sciences, Patna. The same control group design was applied.

All the participants were subjected to the preapproved demographic questionnaire and Physical Health Questionnaire-9 (PHQ 9), which were used for screening purpose.

Patients in the age group of 18–60 years of either gender diagnosed according to the DSM-5 criteria for Panic AD with comorbid depression and PHQ 9 score <20 were included in the study. Patients with a history of comorbid psychiatric syndrome, subjects with a history of neurological trauma, vascular disease, and organic brain disorder, and patients with alcohol addiction were excluded from the study.

All the study subjects have been explained about the study protocol in their language of communication and were asked to sign the informed consent before beginning of the study. Prior ethical approval has been taken from the Institute Ethical Committee vide letter number AIIMS/Pat/IEC/2019/411 dated November 30, 2019. The study has also been registered on the trial registry portal of Government of India vide Registration Number CTRI/2020/12/029462 before starting the study.

The study participants were randomized into two groups using computer-generated block randomization tables. The two groups were defined as follows:

- Group A: Experiment (standard treatment + RM) group: $n = 55$
- Group B: Control (standard treatment) group: $n = 55$.

Standard treatment

Selective serotonin re-uptake inhibitor (SSRI) as well as cognitive behaviour therapies (CBT) as per psychiatric advice and clinical psychologist supervision was given as standard treatment.

Rajyoga meditation

The RM technique from the Brahma Kumaris school of thought, which emphasizes the cultivation of positive thoughts for oneself and others through guided technique, was used in the RM practice in the current study. With a focus on the idea of the ultimate soul, a hypothetical primary source of energy for each and every person, particularly emphasizes the intentional transfer of cognitive process from a body-conscious to the soul-conscious state.

The intervention arm of the study population has been subjected to supervised RM sessions tailored specifically for the purpose of anxiety spectrum disorder by a team of long-term (>10 years) Rajyoga meditators. The RM session protocol (6 domains) was practiced sequentially by all the intervention group participants 25–30 min each morning and evening daily for 5 days or more every week for 8 weeks.

Meditation quality was assessed by subjective and objective feedback.

Subjective feedback

Each fortnight, the six components of the meditation practice were assessed for the self-reported effectiveness by the participants on 0–10 scale with a score of 0 if the participants could not attain any focus for the meditation practice most of the time during the fortnight and a score of 10 if he could attain desired focus most of the time during the fortnight. The maximum possible score could be 60 for the fortnight and the maximum possible total score for the complete duration would be 240.

Objective feedback

Each fortnight, the six domains were scored between 0 and 4 for the level of understanding of the concept of meditation by the participants. A score of 0 was given if a participant could not understand the domain and 4 if the participant could be able to make a very good understanding of it. The maximum score could be 28 for the fortnight, and 140 for the total period [Table 1].

The participants of both the group participants were subjected to the following before starting the study (baseline) and at the end of 8th week.

Table 1: The quantitative scores for the individual components of meditation based upon subjective feedback of the participants

Domains	Score				
	0	1	2	3	4
I. Knowledge of self	No understanding	Little understanding	Reasonable understanding	Good understanding	Very good understanding
II. Knowledge of supreme	No understanding	Little understanding	Reasonable understanding	Good understanding	Very good understanding
III. Knowledge of universal flow of energy	No understanding	Little understanding	Reasonable understanding	Good understanding	Very good understanding
IV. Yoga					
Morning (30 min)	Felt nothing	Felt somewhat	Felt reasonably	Good feeling	Very good feeling
Evening (30 min)	Felt nothing	Felt somewhat	Felt reasonably	Good feeling	Very good feeling
V. Dharana (quality of traffic control)	Felt nothing	Felt somewhat	Felt reasonably	Good feeling	Very good feeling
VI. Service/good wishes and gratitude (quality of practice)	Felt nothing	Felt somewhat	Felt reasonably	Good feeling	Very good feeling

1. Preapproved demographic and clinical questionnaire
2. Sleep quality score: Subjective feedback: 0-Complete loss of sleep to 10-Perfectly sound sleep
3. PHQ-9 score
4. Panic Disorder Severity Scale (PDSS) questionnaire
5. Hamilton Anxiety Rating Scale (HAM-A) questionnaire.

Data analysis

The data have been compiled using Microsoft Excel [Internet] (Microsoft Corporation, 2010). The data have been further analyzed using SPSS version 27.0 (IBM Corp. (2020). IBM SPSS Statistics for Windows). All the normally distributed continuous variables have been compared, computing mean and standard deviation with a 95% confidence interval. Nonparametric tests have been used for nonnormally distributed variables; the outcome is presented as proportions. Pearson's correlation has been used for assessing the associations. A value of $P < 0.05$ has been taken as the level of significance.

Results

Sociodemographic characteristics

The sociodemographic data of the participants of the two groups are presented in Table 2. The two study groups were comparable in terms of sociodemographic variables ($P > 0.05$).

Table 3 shows the comparison of comorbidities among study groups. The two study groups were comparable in terms of mean sleep hours, diagnosis, mean duration of untreated period, family history, and comorbidities ($P > 0.05$). Figure 1 shows panic disorder and panic attacks with anxiety was distributed equally among study groups ($P > 0.05$).

We calculated individual z-score for pre- and post-PDSS/HAM-A. We found that the pre-PDSS/HAM-A were not statistically different among the study groups ($P > 0.05$); however, there was a statistically

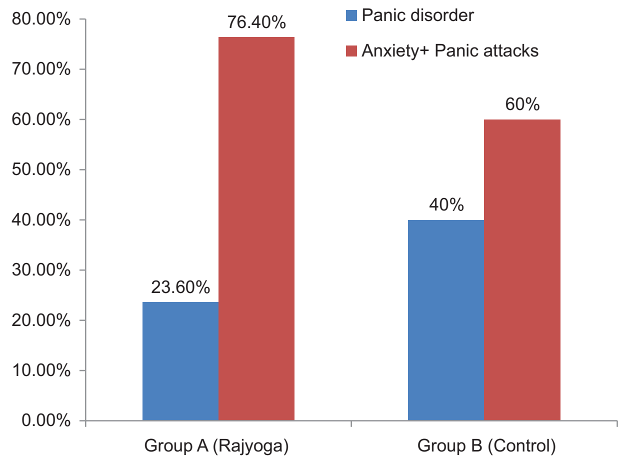


Figure 1: Bar graph showing diagnosis of study groups

significant difference in mean z-scores of post-PDSS and post-HAM-A scores among the study groups ($P < 0.001$).

The composite score was created by adding the z-scores of pre- and post-PDSS and HAM-A. We found a statistically significant difference in postcomposite scores between the study groups ($P < 0.001$) [Table 4].

We used preintervention PDSS/HAM-A as a covariate when comparing the postintervention PDSS/HAM-A between Group A and Group B. Therefore, we ran a one-way ANCOVA with: (a) Postintervention PDSS/HAM-A as the dependent variable; (b) The control and two intervention groups as levels of the independent variable, and (c) The preintervention PDSS/HAM-A as the covariate.

Tables 5 and 6 show whether there was an overall statistically significant difference in postintervention PDSS/HAM-A between the study groups once their means had been adjusted for preintervention PDSS/HAM-A.

The data have further been evaluated for the possible correlation between the difference in clinical scores of the

Table 2: Sociodemographic variables among study groups

	Group A (Rajyoga), *n* (%)	Group B (control), *n* (%)	*P*
Age (years), mean±SD	34.49±8.3	34.36±11.1	0.946*
Gender			
Males	38 (69.1)	27 (49.1)	0.052#
Females	17 (30.9)	28 (50.9)	
Type of family			
Nuclear	22 (40)	22 (40)	1#
Joint	33 (60)	33 (60)	
Education			
Uneducated	2 (3.6)	5 (9.1)	0.215#
Elementary school	4 (7.3)	1 (1.8)	
High school	17 (30.9)	25 (45.5)	
Graduation	24 (43.6)	19 (34.5)	
Postgraduation	7 (12.7)	3 (5.5)	
Higher qualification	1 (1.8)	2 (3.6)	
Occupation			
Unemployed	13 (23.6)	6 (10.9)	0.344#
Housewife	12 (21.8)	17 (30.9)	
Self employed	9 (16.4)	8 (14.5)	
Government job	6 (10.9)	5 (9.1)	
Student	2 (3.6)	0	
Agriculture	6 (10.9)	10 (18.2)	
Others	7 (12.7)	9 (16.4)	
SES			
Upper	4 (7.3)	3 (5.5)	1#
Upper middle	4 (7.3)	4 (7.3)	
Lower middle	28 (50.9)	29 (52.7)	
Upper lower	19 (34.5)	19 (34.5)	
Dietary pattern			
Vegetarian	12 (21.8)	13 (23.6)	1#
Nonvegetarian	43 (78.2)	42 (76.4)	
Tobacco use	5 (9.1)	5 (9.1)	1#
Alcohol use	0	1 (1.8)	0.315#

*t-test, #Chi-square test. SD: Standard deviation, SES: Socioeconomic status

Table 3: Comparison of panic anxiety syndrome among study groups

	Group A (Rajyoga), *n* (%)	Group B (control), *n* (%)	*P*
Mean hours of sleep	7.4±1.1	7.3±2.1	0.714*
Diagnosis			
Panic disorder	13 (23.6)	22 (40)	0.101#
Anxiety + panic attacks	42 (76.4)	33 (60)	
Mean duration of untreated period from onset of illness (months)	18.65±13.9	17.3±15.9	0.629*
Family history			
Yes	6 (10.9)	5 (9.1)	1#
No	49 (89.1)	50 (90.9)	
Co-morbidities			
Nil	45 (83.3)	43 (78.2)	0.647#
Anxiety	1 (1.9)	4 (7.3)	
Depression	2 (3.7)	2 (3.6)	
Agoraphobia	6 (11.1)	5 (9.1)	
Dissociative symptoms	1 (1.8	1 (1.8)	

*t-test, #Chi-square test

severity of the condition before and after intervention and the total meditation quality scores among study participants using Pearson's correlation after testing for Levine's test for the equality of variance. There was a positive correlation

Table 4: *Z*-score and composite score for Panic Disorder Severity Scale and Hamilton Anxiety Rating Scale among study groups

Clinical scores	Mean±SD		Effect size	*P*
	Group A	Group B		
PDSS (*z*-score)				
Pre	−0.136±1.02	0.136±0.96	0.27	0.155*
Post	−0.72±0.68	0.72±0.71	2.07	<0.001*
HAM-A (*z*-score)				
Pre	−0.64±0.98	0.064±1.02	0.704	0.503*
Post	−0.73±0.56	0.73±0.79	2.13	<0.001*
Composite score PDSS and HAM-A				
Pre	−0.1±8.75	0.1±0.88	0.032	0.234*
Post	−0.72±0.52	0.72±0.63	2.49	<0.001*

**t*-test. PDSS: Panic Disorder Severity Scale, HAM-A: Hamilton Anxiety Rating Scale, SD: Standard deviation

Table 5: Analysis of co-variance for Panic Disorder Severity Scale and Hamilton Anxiety Rating Scale among study groups

ANCOVA	Group A	Group B	*F*	*P*
PDSS	11.53±3.5	4.38±3.4	145.84	<0.001*
HAM-A	17.4±5.44	7.33±3.89	161.64	<0.001*

*Statistically Significant. PDSS: Panic Disorder Severity Scale, HAM-A: Hamilton Anxiety Rating Scale, ANCOVA: Analysis of co-variance

Table 6: Repeated measures ANOVA for Panic Disorder Severity Scale and Hamilton Anxiety Rating Scale among study groups

Variable	Group, mean±SD		Partial eta square	*P*
	Control	Experimental		
ZD				
Pre	0.068±0.50	−0.067±0.79	0.016	0.192
Post	−0.038±0.58	0.038±0.74		
PDSS				
Pre	15.31±4.96	13.91±5.92	0.322	<0.001
Post	11.53±3.53	4.38±3.40		
HAMA				
Pre	26.35±6.64	25.51±6.40	0.406	<0.001
Post	17.40±5.44	7.33±3.90		

Two-way RMANOVA. PDSS: Panic Disorder Severity Scale, HAM-A: Hamilton Anxiety Rating Scale, SD: Standard deviation, ZD: Z-score for difference in scores

between clinical score and meditation quality; however, it was not statistically significant ($P > 0.05$) [Table 7].

Discussion

To improve a patient's total health and well-being, complementary treatments or alternative medicines are utilized in conjunction with traditional medical management.[9] Yoga, massage therapy, progressive muscle relaxation, acupuncture, acupressure, reflexology, aromatherapy, music therapy, guided imagery, and meditation are a few examples of these treatments. Normally, medications are used to treat anxiety before and after surgery, but mounting research supports the value of complementary therapies in the healing process. These treatments are used to lessen stress, headaches, the length of hospital stays, and the need for sedatives, and to improve patients' relaxation, sleep, satisfaction, and overall health.[10,11]

Our study found that the z-scores of PDSS and HAM-A were not statistically different among the study groups ($P > 0.05$) during preintervention period; however, there was a statistically significant difference in mean z-scores of PDSS and post-HAM-A scores after intervention among the study groups ($P < 0.001$). Our study also found a statistically significant difference in postcomposite scores between the study groups ($P < 0.001$). We also found that there was an overall statistically significant difference in postintervention PDSS/HAM-A between the study groups once their means had been adjusted for preintervention PDSS/HAM-A.

According to neuroimaging studies, meditation causes the prefrontal cortex, thalamus, and inhibitory thalamic reticular nucleus to become more active, as well as the functional differentiation of the parietal lobe.[12] Anxiolytic effects may result from neurochemical changes brought on by meditation, enhanced parasympathetic activity, decreased locus ceruleus firing with decreased noradrenaline, enhanced GABAergic drive, increased serotonin, and lower levels of the stress hormone cortisol are the elements that reduce anxiety during meditation. The anti-anxiety effects of meditation are also influenced by the elevated levels of endorphins and arginine-vasopressin.[12]

According to a study by Parmentier *et al*.,[13] mindfulness meditation lessens anxiety and depressive symptoms by regulating emotions, reducing concern, and decreasing thinking rumination.

Another study, a randomized clinical trial by Hoge *et al*. (2013) on a subset of participants with GAD, found that although both the intervention group had shown a significant reduction in the HAM-A score after an 8-week

Table 7: Correlation between meditation quality and clinical improvement

Clinical scores	Meditation quality score from baseline (n=300)		Meditation quality score from 1st fortnight (n=240)	
	Correlation co-efficient (r)	P	Correlation co-efficient (r)	P
D1: (Pre-HAM-Post-HAM)	0.090	0.513	0.011	0.917
D2: (Pre-PDSS-Post-PDSS)	0.150	0.273	0.038	0.713
Composite PDSS and HAM	0.135	0.325	0.031	0.760

PDSS: Panic Disorder Severity Scale, HAM-A: Hamilton Anxiety Rating Scale

intervention of mindfulness-based stress reduction (MBSR) and stress management education, the group that had received the MBSR intervention had a significantly lower stress score and better tolerability.[14]

The prefrontal cortex and amygdala are crucial for controlling emotions and the stress response. The prefrontal cortex is known to focus more on the positive handling of similar inputs, whereas the amygdala is known to attribute meaning to unpleasant emotional stimuli. The cortical brain region's inverse relationship to a person's behavior in a stressful circumstance appears to be modulated by meditation. According to studies, during meditation, prefrontal activity surpasses amygdala reaction.[15,16]

RM is a term that is frequently used in relation to meditation and has references in numerous traditional Indian literary works, such as the Bhagwadgeeta and Patanjali's Yoga Sutras. According to some recent studies, RM boosts happiness through neuroplasticity. In one study, it was found that RM practices were linked to a significant increase in the grey matter volume in the brain regions related to emotion regulation, happiness, and reward centers, the right insular cortex, and the left inferior orbitofrontal cortex.[17] It is widely established that the etiology of panic disorder is directly related to both the orbitofrontal cortex and the insular cortex.[18] The neural plasticity brought on by the guided meditation practice of the intervention group members may have contributed to the short-term meditation intervention's success in reducing anxiety symptoms and the severity of the condition in the current study.

According to a study by Kiran *et al.*,[19] patients who practiced Rajyoga also had elevated blood cortisol levels on the 2nd postoperative day, but the increase was markedly less than in the control group. On the 5th postoperative day, the Rajyoga group's cortisol levels generally returned to normal range as the stress was resolved. In addition, Creswell *et al.* discovered that practicing mindfulness meditation for a brief amount of time changes how the brain and body react to stress.[10] Similarly to this, Turakitwanakan *et al.* have found that practicing mindfulness meditation lowers blood cortisol levels, which suggests that it can reduce stress.[20] Gainey *et al.* found that in diabetic patients, meditation decreased glycated hemoglobin and cortisol levels.[21]

Conclusion

When used in conjunction with pharmaceutical treatments for the treatment of panic disorder, RM is a successful therapy. The key factors are adherence and motivation while being supervised by a licensed therapist. The results of the current study indicate that RM techniques can improve sleep quality and lower clinical panic AD scores. We conclude that irrespective of the quality of meditation, mere meditation practice for the long term would help alleviate the anxiety and panic disorder symptoms.

Ethical approval

The work has been approved by the Institutional Ethical Committee of AIIMS, Patna, in which it was performed and that subjects gave informed consent to the work. The study has also been registered on the trial registry portal of the Government of India vide registration number CTRI/2020/12/029462. Name of the ethics committee: IEC, AIIMS Patna. Approval number and date: AIIMS/Pat/IEC/2019/411 dated November 30, 2019.

Acknowledgment

The authors acknowledge Department of Science and Technology, Government of India for the funding support for the study under DST-SATYAM initiative (research grant no DST/SATYAM/255/18). The authors express their gratitude toward the patients, facilities, scientific and technical assistance provided by Department of Physiology and Psychiatry in completing this work.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Kessler RC, Aguilar-Gaxiola S, Alonso J, Chatterji S, Lee S, Ormel J, *et al.* The global burden of mental disorders: An update from the WHO World Mental Health (WMH) surveys. Epidemiol Psichiatr Soc 2009;18:23-33.
2. World Health Organization. Depression and Other Common Mental Disorders: Global Health Estimates. Geneva: World Health Organization; 2017.
3. American Psychiatric Association. Diagnostic and Statistical Manual for the Assessment of Mental Disorders. 4th ed. Washington, DC: American Psychiatric Association; 1994.
4. Baxter AJ, Vos T, Scott KM, Ferrari AJ, Whiteford HA. The global burden of anxiety disorders in 2010. Psychol Med 2014;44:2363-74.
5. Carta MG, Moro MF, Aguglia E, Balestrieri M, Caraci F, Dell'Osso L, *et al.* The attributable burden of panic disorder in

the impairment of quality of life in a national survey in Italy. Int J Soc Psychiatry 2015;61:693-9.
6. Ospina MB, Bond K, Karkhaneh M, Tjosvold L, Vandermeer B, Liang Y, *et al.* Meditation practices for health: State of the research. Evid Rep Technol Assess (Full Rep) 2007;155:1-263.
7. Telles S, Desiraju T. Autonomic changes in Brahmakumaris Raja yoga meditation. Int J Psychophysiol 1993;15:147-52.
8. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders. 5th ed. Washington, D.C: American Psychiatric Association; 2013.
9. Hart J. Complementary therapies before and after surgery. Altern Complement Ther 2009;15:184-8.
10. Creswell JD, Pacilio LE, Lindsay EK, Brown KW. Brief mindfulness meditation training alters psychological and neuroendocrine responses to social evaluative stress. Psychoneuroendocrinology 2014;44:1-12.
11. Kiran U, Behari M, Venugopal P, Vivekanandhan S, Pandey R. The effect of autogenic relaxation on chronic tension headache and in modulating cortisol response. Indian J Anaesth 2005;49:474-8.
12. Tang YY, Hölzel BK, Posner MI. The neuroscience of mindfulness meditation. Nat Rev Neurosci 2015;16:213-25.
13. Parmentier FB, García-Toro M, García-Campayo J, Yañez AM, Andrés P, Gili M. Mindfulness and symptoms of depression and anxiety in the general population: The mediating roles of worry, rumination, reappraisal and suppression. Front Psychol 2019;10:506.
14. Hoge EA, Bui E, Marques L, Metcalf CA, Morris LK, Robinaugh DJ, *et al.* Randomized controlled trial of mindfulness meditation for generalized anxiety disorder: Effects on anxiety and stress reactivity. J Clin Psychiatry 2013;74:786-92.
15. Keng SL, Smoski MJ, Robins CJ. Effects of mindfulness on psychological health: A review of empirical studies. Clin Psychol Rev 2011;31:1041-56.
16. Creswell JD, Way BM, Eisenberger NI, Lieberman MD. Neural correlates of dispositional mindfulness during affect labeling. Psychosom Med 2007;69:560-5.
17. Babu MG, Kadavigere R, Koteshwara P, Sathian B, Rai KS. Rajyoga meditation induces grey matter volume changes in regions that process reward and happiness. Sci Rep 2020;10:16177.
18. Martin EI, Ressler KJ, Binder E, Nemeroff CB. The neurobiology of anxiety disorders: Brain imaging, genetics, and psychoneuroendocrinology. Psychiatr Clin North Am 2009;32:549-75.
19. Kiran U, Ladha S, Makhija N, Kapoor PM, Choudhury M, Das S, *et al.* The role of Rajyoga meditation for modulation of anxiety and serum cortisol in patients undergoing coronary artery bypass surgery: A prospective randomized control study. Ann Card Anaesth 2017;20:158-62.
20. Turakitwanakan W, Mekseepralard C, Busarakumtragul P. Effects of mindfulness meditation on serum cortisol of medical students. J Med Assoc Thai 2013;96 Suppl 1:S90-5.
21. Gainey A, Himathongkam T, Tanaka H, Suksom D. Effects of Buddhist walking meditation on glycemic control and vascular function in patients with type 2 diabetes. Complement Ther Med 2016;26:92-7.

Mindfulness
https://doi.org/10.1007/s12671-023-02163-y

ORIGINAL PAPER

High Theta–Low Alpha Modulation of Brain Electric Activity During Eyes-Open Brahma Kumaris Rajyoga Meditation

Kanishka Sharma[1,2] · **Peter Achermann**[3] · **Bhawna Panwar**[4] · **Shrikant Sahoo**[4] · **Roberto D. Pascual-Marqui**[3] · **Pascal L. Faber**[3] · **Ramakrishnan Angarai Ganesan**[1,5]

Accepted: 31 May 2023

Abstract
Objectives The objective was to analyze EEG recorded during Brahma Kumaris Rajyoga meditation (BKRYM) using eLORETA applied in the frequency domain for localizing sources during meditation vis-à-vis baseline condition. Unlike many other popular meditation practices, BKRYM is practiced with open eyes. To our knowledge, there has been no study of the changes in the brain's activity during the practice of BKRYM using source localization. Furthermore, this seed-stage meditation goes through specific stages, and the corresponding changes in the brain activity, including the different brain networks, were explored.
Method EEG recorded during Brahma Kumaris seed-stage meditation was studied in 52 long-term meditators. The meditation comprised three stages, namely focusing on peace, imagining being a soul, and communion with the Supreme Soul. Brain electric source localization in the frequency domain was used on multichannel EEG recordings to establish activation differences between meditation and open-eyed, task-free resting. Additional exploratory analyses were performed for the differences between initial rest, meditation, and final rest.
Results After 5000 randomized statistical tests of significance ($p < 0.05$), meditation showed reduced activity in delta and increased activity in low alpha frequencies. The brain networks altered in their activation during meditation are the following: central executive network, mirroring network, and task-positive and task-negative networks.
Conclusions The observed changes in activity reflect the main cognitive-affective and behavioral specifics of seed-stage meditation: attention modulation, self-related processing, visual imagery, extra corporeal experience. Future studies need to distinctly differentiate between the stages of the meditation.

Keywords Rajyoga meditation · EEG · Source localization · eLORETA · Frequency domain · Central executive network · Mirroring network · Task-positive network · Task-negative network · Default mode network · Soul consciousness · Non-dual awareness

Brahma Kumaris (BK) Rajyoga is a modern revival of the Indian Rajyoga system. Unlike most other Rajyoga systems, BK Rajyoga (BKRY) is not based on Patanjali's yoga system and has little to do with it (Birch, 2013). Rajyoga as taught

✉ Ramakrishnan Angarai Ganesan
agr@iisc.ac.in

1 Medical Intelligence and Language Engineering (MILE) Lab, Electrical Engineering Department, Indian Institute of Science, Bengaluru, India

2 NeuroOscillations Lab, Center for Neuroscience, Indian Institute of Science, Bengaluru, India

3 Department of Psychiatry, Psychotherapy and Psychosomatics, The KEY Institute for Brain-Mind Research, University Hospital of Psychiatry, Zurich, Switzerland

4 Spiritual Applications Research Centre (SpARC), Rajyoga Education and Research Foundation (RERF) Brahma Kumaris, Mount Abu, India

5 Centre for Neuroscience, Indian Institute of Science, Bengaluru, India

Published online: 15 June 2023

by the Prajapita Brahma Kumaris World Spiritual University is said to be a way for self-realization and the realization of the Supreme almighty. It does not rely on rituals or mantras and can be practiced without rigorous training. The most common meditation practice within this tradition is *seed-stage meditation*. Practitioners believe that through this practice they seek the intellectual and loving communion of the soul with the Supreme Soul (Brahmakumaris, 1986). This meditation follows several steps and moves through different stages (Ramesh et al., 2013; Telles & Desiraju, 1993). Sitting with eyes open, in a comfortable posture, for example, in an armchair, the practitioner gazes at a meaningful symbol (such as a picture depicting the Supreme Soul as a radiating point of light) or faces a neutral wall and visualizes the soul in between the two eyebrows.

The meditation itself goes through the following stages using appropriate autosuggestions (see the supplementary material for some sample autosuggestions used) to keep the mind focused on the task and avoid it from wandering. Practice begins with sitting quietly and relaxed, followed by the stage of concentration, when the practitioner uses autosuggestions to settle into a feeling of peace. The practitioner may either create the feeling of peace in the moment or bring forth this feeling through recalling it from an autobiographical memory. This feeling of peace is the foundation for the next stage, namely soul consciousness. The practitioner reminds him-/herself that he/she is a soul, a sparkling light visualized between his/her eyes. The last stage is described by the practitioners as the connection (a conversation) of the soul with the Supreme Soul, a bodyless light source with peace. The practitioner imagines receiving these qualities from the Supreme Soul and letting them permeate her/his soul. When successful, this culminates in absorption. The practitioner's mind is totally calm and absorbed, and there is little to no active guiding of the intellect. Soul consciousness is a progression away from everyday concerns, away from the body, towards the realization of being a soul and the connection of this soul with the Supreme Soul and ultimately the absorption within it.

Several ideas have been put forth in the literature to categorize meditation practices. The most common classification systems distinguish among focused attention, open monitoring, and automatic self-transcendence practices (Lutz et al., 2008; Raffone & Srinivasan, 2010; Travis & Shear, 2010). Josipovic (2010) proposed non-dual awareness as a defining characteristic of some practices. Nash and Newberg (2013) categorized practices into three classes: fostering enhanced (i) cognitive, (ii) affective, or (iii) non-cognitive/non-affective state. To allow for a better understanding of how the different practices might foster well-being, Dahl et al. (2015) proposed a classification distinguishing between attentional, constructive, and deconstructive families of practices, i.e., practices that cultivate meta-awareness, enhance cognitive and affective patterns which increase well-being, or focus on self-inquiry, respectively.

Rajyoga meditation has strong elements of focused attention, since it needs focus to guide the mind through the different stages, focusing on the soul and the qualities of the Supreme Soul. This process of observing one's own soul as an entity distinct from the body can be categorized as self-monitoring. Following the classification of Nash and Newberg (2013), this self-monitoring belongs to the cognitive domain. It also has a strong affective component with the practitioner seeking the feeling of peace and other positive qualities such as purity, love, joy, bliss, and knowledge. Within the classification of Dahl et al. (2015), BK Rajyoga meditation (BKRYM) fits into the constructive family of practices, since it targets a change in perspective, a cognitive reappraisal of oneself as a soul that is pure in its qualities as are the souls of all human beings (see also Nair et al., 2017).

Let us briefly review the benefits of meditation in general, and BKRYM in particular. Regular practice of any meditation technique has many potential benefits (for a review, see Keng et al., 2011) such as increased subjective well-being, reduced psychological symptoms and emotional reactivity, and improved behavioral regulation. Meditation yields stronger effects than relaxation practices and other alternative treatment types provided (Sedlmeier et al., 2018). Pilot studies on meditation suggest downregulation of epigenetic pathways related to inflammation, cell aging, and depression (Kaliman, 2019). Meditation intervention may possibly be utilized as an adjunct to guideline-directed cardiovascular risk reduction (Levine et al., 2017). The following are the specific benefits reported from the practice of BKRYM: improved basic cardio-respiratory functions (Sukhsohale & Phatak, 2012); higher self-satisfaction and happiness in life than the non-meditators (Ramesh et al., 2013); less neurotic symptoms and higher scores on hope and happiness (Misra et al., 2013); and significant increase of IQ in a group of 42 ADHD children after 3 months of practice (Naik et al., 2016). BK Rajyoga is thought to help generate resilience through the cultivation of meaning and self-transformation based on the respective spiritual guidelines (Ramsay & Manderson, 2011).

Few researchers have explored the brain electrical mechanisms sub-serving the different states of the practice of BKRYM. In a study, a popular 1-min meditation was explored in long-term BK Rajyoga practitioners, short-term practitioners, and meditation-naïve subjects. This study reported increased theta and alpha band-power in the EEG for long-term and short-term practitioners, respectively, during meditation compared to resting (Nair et al., 2017). Also, long-term meditators reliably shifted between resting and meditation states, while short-term meditators less reliably, and controls were unable to do so. Another study exploring a 10-min practice of meditation found changes in theta and lower alpha band and higher alpha asymmetry in meditators during meditation compared to controls during resting (Sharma et al., 2018a). The activity of the default mode network during BKRYM and resting compared to resting in control subjects was studied by Panda et al. (2016) using simultaneous EEG-fMRI recordings. Increased occurrence and duration of the EEG microstates corresponding to default mode network activation were reported as well as an increase in EEG spectral power in the alpha, theta, and beta bands (Panda et al., 2016). Increase in gray matter volume of reward processing centers was found in long-term meditators practicing Rajyoga as well as strong positive correlation found between practice years and the gray matter volume (Babu et al., 2020). An enhancement of white matter microstructural properties was reported in all the regions of corpus callosum fibers as investigated by diffusion tensor imaging (Sharma et al., 2018b).

To prepare the ground for future investigations on how physiological and psychological health benefits might be associated with the brain electrical activity of the BKRYM practice, we investigated the brain electrical underpinnings of this meditation practice compared to task-free resting within a large group of experienced practitioners. Based on the above description of the cognitive and affective particulars of this practice, we expected brain areas involved in attention modulation as well as emotion and memory processing to show alterations in electrical activity. Consequently, we expected the central executive network (CEN) and the task-positive network to show increased activation and the task negative or default mode network to show decreased activation.

To study the above, we needed to know the electrical activity of the brain at the subcortical level. Since the EEG data we have recorded corresponds mainly to the cortical activity, we needed to use the mathematical technique of source localization to inverse map from the scalp EEG data to the electrical activity at each voxel (*three-dimensional pixel*) in the entire volume of the brain. In our work, we first converted the EEG data of each channel into frequency domain by taking the discrete Fourier transform of the data. Then, we performed source localization in the frequency domain to obtain the activity of each voxel of the brain at different frequencies starting from 0.5 and going up to 64 Hz. The resulting data were used to detect intracortical electrical activity changes during meditation occurring at different frequencies.

Method

Participants

Fifty-two meditators (mean age: 42.0 ± 10.1 years, range: 25–59; mean meditation experience: 17.5 ± 10.8 years, range: 4–43; 14 females) were recruited and recorded during a winter season when followers from across the world visited the headquarters of Brahma Kumaris. Meditation experience was calculated based on the year of learning the first course of BKRYM and practiced regularly.

Procedure

EEG Recordings

The EEG recordings took place at the International Centre for Higher Learning, Brahma Kumaris, Gyan Sarovar, Mount Abu, India (1722 m above sea level). The recordings were performed in a small, normally lit room with the participants sitting upright cross-legged either on a couch or on the couch border with their feet on the ground. They faced a neutral, coffee-colored tapestry on the wall. The experimenter controlled the recording from a small adjacent room containing the recording computer and allowing easy view of the participant through a clear glass window. Based on the 10–10 electrode placement system (Nuwer et al., 1998), EEG was recorded at the following 61 locations: Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, POz, O1, O2, AF7, AF3, AF4, AF8, F5, F1, F2, F6, FC3, FCz, FC4, C5, C1, C2, C6, CP3, CP4, P5, P1, P2, P6, PO5, PO3, PO4, PO6, FT7, FT8, TP7, TP8, PO7, PO8, and Oz. All the channels were referenced to CPz, and AFz was used as ground. Since the EEG cap has only left EOG electrode, it was placed on the corner of the left eye to record horizontal eye movements. The recordings were performed using a 64-channel ANT neuro mylab system. EEG was recorded at 500 Hz sampling rate. Impedance for all the EEG and EOG channels was kept below 10 K ohms to ensure good data quality. The EEG amplifier and the acquisition system (laptop) were running on battery and were not connected to the mains during the data recording. Band pass filter was applied from 0.3 to 75 Hz in the recording software as was a 50-Hz notch filter.

Recording Conditions

The recordings adhered to the following protocol: (1) initial rest with eyes open (EO1): 3 min (instruction: "sit quietly without meditating"); (2) initial rest with eyes closed: 3 min (instruction: "close your eyes and sit quietly without meditating"); (3) Rajyoga seed-stage meditation with eyes open (Med): 30 min (shifting the awareness from the visible world to *the soul and its peaceful nature* and then connecting to the *Supreme Soul*); (4) final rest with eyes open (EO2): 3 min (instruction: "sit quietly without meditating"); (5) final rest with eyes closed: 3 min (instruction: "close your eyes and sit quietly without meditating").

Since this meditation is practiced with open eyes, we felt that it was appropriate to compare the brain activity during meditation with the activity during a baseline with eyes open. However, since it is standard practice in most EEG studies on meditation to use an eyes-closed baseline, we chose to record a second baseline with eyes closed as an abundant precaution in case it would be required later. This data can be used later in a comparative analysis of resting state networks with different meditation types. However, we did not use the eyes-closed baseline recordings in this study. The whole protocol was timed using a digital stopwatch to ensure proper durations of the different data segments. To ensure that the participants align with the practice variables, on days before the recording, they listened to recorded audio instructions from a senior meditator and followed the same steps during the actual session. During the meditation, the participants were presented an acoustic tone 4 to 5 times at random intervals to check if the meditators could later remember the total number of prompts given during the experiment. However, these data were not used for the current study.

This report compares the meditation (Med) state to the initial eyes-open (EO1) rest state. Additional analyses were performed to look for possible changes over time during the meditation. Also, meditation and initial rest (eyes open) were compared to final rest (EO2: eyes open).

Measures

The data was preprocessed using BrainVision Analyzer version 2.1.2 (www.brainproducts.com). The EEG data was first downsampled to 128 Hz using spline interpolation. The eye movement artifacts were corrected using independent component analysis where necessary, and then, the remaining eye, muscle, sweat, and other artifacts were marked through visual inspection. To remove the distraction that possibly occurred due to the acoustic prompts, 30 s data before and after each prompt was removed from the final analysis. The EEG was segmented into 2-s epochs and all artifact-free epochs were exported for further analysis. The meditation session was divided into three parts to study the effect of time elapsed since the meditation began (hereinafter referred to as the first, the middle, and the last tertiles). To account for the difference in the recording durations of meditation and rest sessions, a random selection of 50 artifact-free epochs were collected from the initial and final rest data as well as from the first, the middle, and the last tertiles of the meditation data. This resulted in a total of 150 epochs for the complete meditation session.

Data Analyses

The preprocessed, artifact-free 2-s epochs (50 for each rest condition and 150 for the three meditation segments) underwent source localization analysis using exact, low-resolution brain electromagnetic tomography (eLORETA; Pascual-Marqui et al., 2011), available at http://www.uzh.ch/keyinst/loreta.htm. eLORETA is a solution to the inverse problem that gives reliable localization even in the presence of measurement and structured biological noise (Pascual-Marqui et al., 2011). The analysis procedure follows the LORETA functional tomography analysis approach (Pascual-Marqui et al., 1994, 1999). Applying the procedure delineated in Frei et al. (2001), power spectra (128 discrete frequencies, from 0.5 to 64.0 Hz, at 0.5 Hz frequency resolution) were computed for all the available epochs and averaged per condition and participant and then transformed into eLORETA images (with 6239 cortical voxels at a spatial resolution of 5 mm^3). For all comparisons between and within conditions, paired t-statistics were computed on the log-transformed current density values at each voxel. Corrections for multiple testing were applied over all the 6239 voxels and 128 frequencies using nonparametric randomization (Nichols & Holmes, 2002). The Brodmann areas (BAs) corresponding to the voxels with significant changes are identified based on their coordinates in MNI space (Evans & Collins, 1993). Combined meditation data (of all three tertiles) was compared with the initial and final rest data separately (Tables 1 and 2). Meditation tertiles of 50 epochs each were separately compared (Table 3) to one another.

Results

Meditation vs Initial Rest

Table 1 lists the number of voxels in each Brodmann area with significant differences in the brain activity between the meditation, initial, and final rest states in pairwise comparison of conditions. Data from only those specific frequencies or frequency ranges with at least 15 significant voxels are included in the table. The counts of significant voxels are given in terms of their location in the left or right hemisphere, or along the midline. Increased activity in any frequency/frequency range with respect to an earlier condition is shown in italics. On the other hand, decreased activity is shown using numbers in normal font.

Significant differences were found between meditation (averaged across all the tertiles) and initial rest in several clusters with a total of at least 15 voxels in two frequency ranges: the delta range between 0.5 and 4.0 Hz and the range between 7.0 and 9.5 Hz, which we consider as "high theta–low alpha." The number of voxels significantly

Table 1 Number of voxels per Brodmann area significantly differing among meditation, initial, and final rest states in specific frequency/frequency ranges showing at least 15 significant voxels in each associated frequency range. *LH* left hemisphere, *RH* right hemisphere, *M* midline voxels. Numbers in italics indicate increased activity in the respective frequency/frequency range and condition. Normal font numbers indicate decreased activity

	Meditation vs initial rest						Final rest vs meditation						Final rest vs initial rest					
	δ: 0.5–4.0 Hz			7.0–9.5 Hz			1.5–7.0 Hz			11.0–14.5 Hz			1.5–7.0 Hz			26 Hz		
	Decreases during meditation			Increases in meditation			Decreases in final rest			Decreases in final rest			Decreases in final rest			Decreases in final rest		
BA	LH	M	RH	LH	M	RH	LH	M	RH	LH	M	RH	LH	M	RH	LH	M	RH
1	9	-	9	-	-	-	7	-	9	4	-	2	9	-	8	1	-	-
2	40	-	27	-	-	*3*	42	-	46	18	-	13	43	-	42	6	-	-
3	66	-	41	-	-	-	67	-	56	49	-	31	72	-	54	17	-	-
4	63	1	56	-	-	-	59	1	66	40	1	42	69	1	70	8	-	-
5	20	1	8	-	-	-	40	9	41	40	9	41	40	9	41	14	-	9
6	173	1	153	-	-	*2*	185	12	122	163	13	150	261	13	275	15	-	-
7	9	-	-	*13*	*4*	*2*	186	25	189	98	10	85	186	25	198	15	-	78
8	9	-	63	-	-	-	23	8	36	10	7	9	74	9	91	-	-	-
9	34	-	93	-	-	-	38	3	9	-	-	2	124	9	134	-	-	-
10	30	-	46	-	-	-	-	-	-	-	-	-	56	-	51	-	-	-
11	4	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-
13	11	-	2	*30*	-	*66*	12	-	4	-	-	-	37	-	36	-	-	-
17	-	-	-	-	-	-	36	2	21	-	-	-	36	2	36	-	-	-
18	-	-	-	*8*	-	*9*	145	28	80	-	-	-	141	28	142	-	-	-
19	-	-	1	*41*	-	*26*	180	2	78	-	-	-	179	2	170	-	-	-
20	31	-	-	*8*	-	*11*	-	-	-	-	-	-	11	-	74	-	-	-
21	63	-	-	-	-	-	-	-	-	-	-	-	12	-	101	-	-	-
22	60	-	10	*3*	-	*8*	6	-	4	-	-	-	37	-	85	-	-	-
23	-	-	-	*12*	*15*	*19*	15	15	22	10	8	11	3	-	3	-	-	-
24	-	-	-	*4*	*5*	*15*	39	13	46	44	13	58	43	9	37	-	-	-
27	-	-	-	*7*	-	*9*	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	*3*	-	*1*	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	*5*	-	*4*	5	-	4	-	-	-	-	-	-	-	-	-
30	-	-	-	*30*	*3*	*35*	32	3	19	-	-	-	13	-	13	-	-	-
31	-	-	-	*56*	*16*	*53*	80	29	59	42	19	37	49	10	35	-	-	-
32	-	-	-	-	-	-	17	4	26	22	4	28	39	5	39	-	-	-
35	-	-	-	*5*	-	*1*	-	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	*10*	-	*10*	-	-	-	-	-	-	1	-	15	-	-	-
37	2	-	-	*28*	-	*15*	23	-	-	-	-	-	83	-	88	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-
39	3	-	8	*18*	-	*3*	70	-	29	-	-	-	77	-	60	-	-	-
40	164	-	101	*3*	-	*8*	174	-	147	59	-	43	189	-	180	4	-	6
41	11	-	-	*17*	-	*21*	-	-	-	-	-	-	13	-	27	-	-	-
42	19	-	4	-	-	*1*	2	-	2	-	-	-	11	-	20	-	-	-
43	10	-	1	-	-	-	-	-	-	-	-	-	12	-	11	-	-	-
44	22	-	8	-	-	-	-	-	-	-	-	-	22	-	15	-	-	-
45	25	-	15	-	-	-	-	-	-	-	-	-	14	-	27	-	-	-
46	20	-	21	-	-	-	-	-	6	-	-	-	18	-	26	-	-	-
47	14	-	1	-	-	-	-	-	-	-	-	-	1	-	28	-	-	-

differing between meditation and initial rest in these two frequency bands is given in the left-most columns of Table 1 as per the Brodmann areas they belong to.

Table 2 lists the number of voxels in each anatomical structure of the brain with activity significantly differing between meditation (averaged over the complete meditation data) and initial rest in two frequency ranges (delta: 0.5–4.0 Hz and high theta–low alpha: 7.0–9.5 Hz). Table 2 clearly shows that the activity in the delta band decreases during meditation compared to the initial rest condition,

Table 2 Number of voxels per anatomical structure significantly differing between meditation (averaged over the complete meditation data) and initial rest in two frequency ranges (0.5–4.0 Hz: decreases and 7.0–9.5 Hz: increases during meditation)

	Meditation vs initial rest					
	0.5–4.0 Hz			7.0–9.5 Hz		
	Decreases during meditation			Increases during meditation		
Anatomical structure	LH	M	RH	LH	M	RH
Inferior frontal gyrus	76	-	40	-	-	-
Medial frontal gyrus	9	-	20	-	-	-
Middle frontal gyrus	108	-	164	-	-	-
Superior frontal gyrus	50	-	107	-	-	-
Precentral gyrus	149	-	115	-	-	*2*
Postcentral gyrus	160	-	103	-	-	*5*
Paracentral lobule	6	3	8	-	-	-
Anterior cingulate	-	-	-	*6*	*6*	*22*
Posterior cingulate	-	-	-	*241*	*116*	*236*
Parahippocampal gyrus	-	-	-	*204*	-	*93*
Transverse temporal gyrus	12	-	-	*20*	-	*10*
Inferior temporal gyrus	27	-	-	*1*	-	-
Middle temporal gyrus	64	-	6	*8*	-	*2*
Superior temporal gyrus	77	-	18	*58*	-	*40*
Insula	8	-	1	*125*	-	*129*
Fusiform gyrus	9	-	-	*80*	-	*22*
Lingual gyrus	-	-	-	*70*	-	*37*
Precuneus	1	-	-	*92*	*30*	*38*
Cuneus	-	-	-	*19*	-	*14*
Inferior parietal lobule	146	-	86	*2*	-	*8*
Superior parietal lobule	10	-	-	*7*	-	-

LH left hemisphere, *RH* right hemisphere, *M* midline voxels. Numbers in italics indicate activity increases in the respective frequency range and condition. Normal font numbers indicate activity decreases.

Table 3 Number of voxels per Brodmann area significantly differing in activity between the first and the last tertiles (one-third time segments) of meditation period for frequencies/frequency ranges showing at least 15 significant voxels in each associated frequency

	Meditation data last tertile vs first tertile					
	1.5–4.5 Hz			26 Hz		
	Decreases in last tertile			Increases in last tertile		
BA	LH	M	RH	LH	M	RH
1	6	-	-	-	-	-
2	24	-	6	-	-	-
3	17	-	5	*1*	-	-
4	11	-	7	*1*	-	-
5	-	-	6	-	-	-
6	2	-	1	*7*	-	-
7	-	-	1	-	-	-
23	-	-	-	*5*	-	-
24	-	-	-	*18*	-	-
31	-	-	-	*13*	-	-
40	25	-	18	-	-	-

LH left hemisphere, *RH* right hemisphere, *M* midline voxels. Numbers in italics indicate activity increases in the respective frequency/frequency range and condition. Normal font numbers indicate activity decreases.

whereas it increases during meditation in the other frequency band. Figure 1 illustrates these findings with cortical slices through difference maxima between the two conditions per frequency in the same two frequency bands with a resolution of 0.5 Hz. The largest cluster of significant voxels was found at 1.5 Hz within the delta range and at 9.0 Hz within the low alpha range.

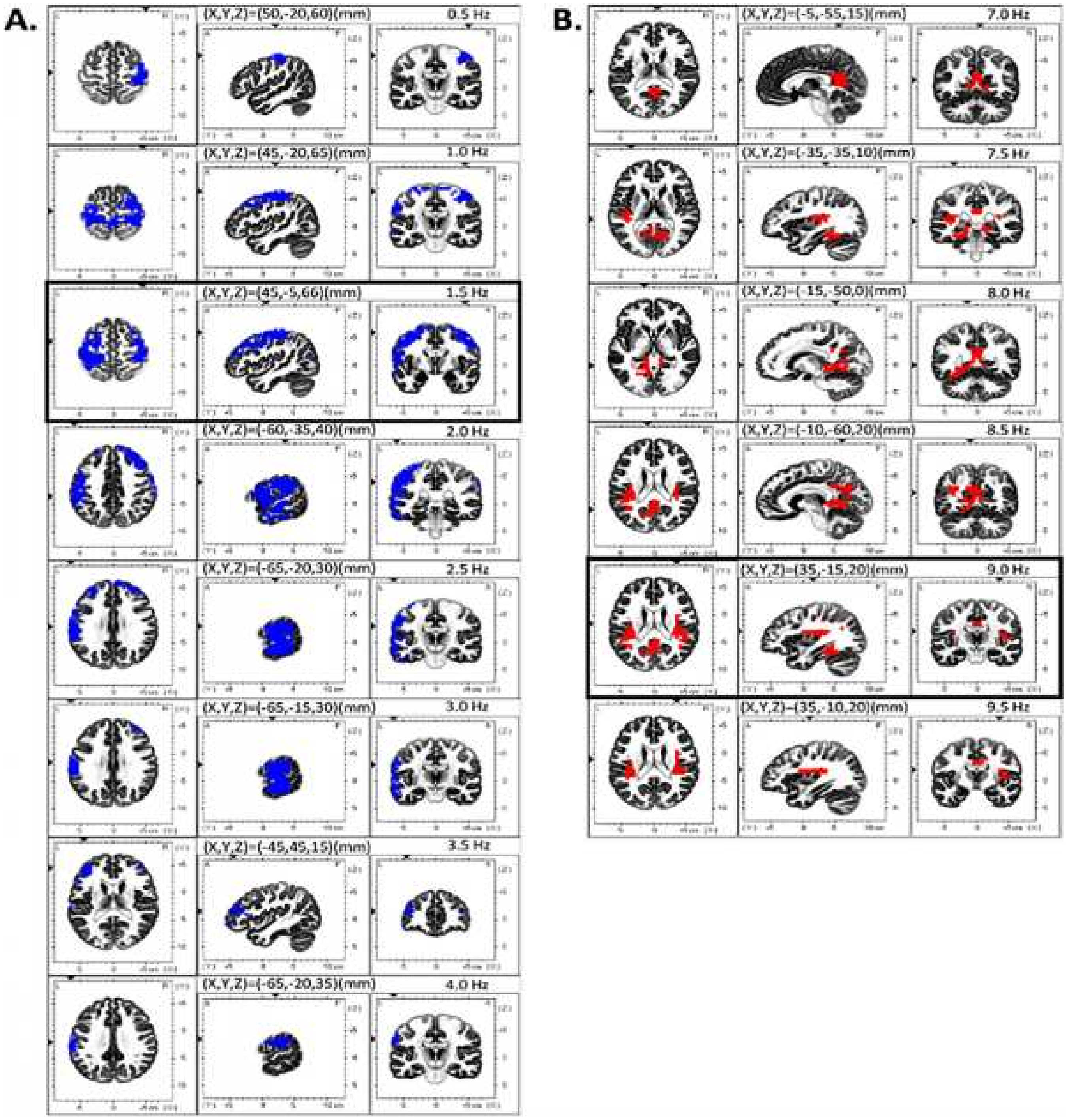


Fig. 1 Frequencies showing significant differences between meditation and initial rest. Decreases (blue) during meditation were seen in delta frequencies (Panel **A** on the LHS). Increases (red) during meditation were seen in low alpha frequencies (Panel **B** on the RHS). Shown are slices (transverse, sagittal, and coronal from left to right) through the voxel of maximal difference (indicated by black triangles on the axes) between meditation and initial rest per frequency. The MNI coordinates of the voxel of maximal difference are indicated on top of each sagittal slice, and the frequency on top of the coronal slice. Slices with bold borders indicate the frequency in each frequency range with the highest number of significant voxels

Compared to the initial resting state, meditation data showed decreased delta activity in a large cluster encompassing bilateral prefrontal (BAs 9, 10, 46), orbitofrontal (left BAs 11, 47), and dorsolateral areas (BA 46), the frontal eye fields (BA 8), Broca's area (BAs 45, 44), and extending to the premotor (BA 6), primary motor (BA 4), and the somatosensory (BAs 1, 2, 3) cortices, and the precuneus (BA 7) and parietal (left BAs 5, 40) areas, as well as the temporal areas (BAs 20, 21, 22, 41, 42, and 43).

In the high theta–low alpha range, meditation data revealed increased activity compared to the initial rest state. These increases were found bilaterally in the cingulate cortex (BAs 23, 24, 29, 30, 31), the parahippocampal and fusiform gyrus (BAs 27, 28, 36, 37), the superior and inferior temporal gyrus (BAs 22, 20), Wernicke's area (BAs 39, 40), the auditory cortex (BAs 41, 42 right), the insula (BA 13), the associative and secondary visual cortices (BA 18, 19), and precuneus (BA 7). No significant differences were present between meditation and initial rest in other frequency ranges, namely the low theta, upper alpha, beta, and gamma bands.

EEG Changes Across the Tertiles Within the Duration of Meditation

EEG activity did not differ significantly between successive tertiles (one-third segments) of meditation, i.e., the first from the middle, and the middle from the last tertile. However, compared to the first tertile, there were significant changes in the activity in the last tertile. Table 3 gives the counts of voxels in each Brodmann area, where the activity significantly differs between the first and the last tertiles (one-third segments) of meditation period for frequencies/frequency ranges showing at least 15 significant voxels in each associated frequency. The counts of significant voxels are given in terms of their location in the left or right hemisphere, or along the midline. Increased activity in any frequency/frequency range with respect to an earlier condition is shown in italics, and decreased activity is shown using numbers in normal font. Decrease was found in low frequencies (1.5–4.5 Hz) in the motor (BAs 4, 6) and somatosensory (BAs 1, 2, 3, 5) cortices as well as parietal areas (BA 40). However, a significant increase was observed at 26 Hz, in the posterior and anterior left cingulate cortex (BAs 23, 24, 31; Table 3).

Final Resting State Compared to the Meditation and Initial Resting States

The final rest state showed decreased brain activity compared to meditation (complete data—averaged over the tertiles) in two frequency ranges (1.5–7 Hz and 11–14.5 Hz) in large areas, and also decreased activity compared to initial rest in the frequency ranges of 1.5–7 Hz and 26 Hz (Table 1). For visualizing the relative number of voxels with significant changes, Fig. 2 shows bar graphs of the top five

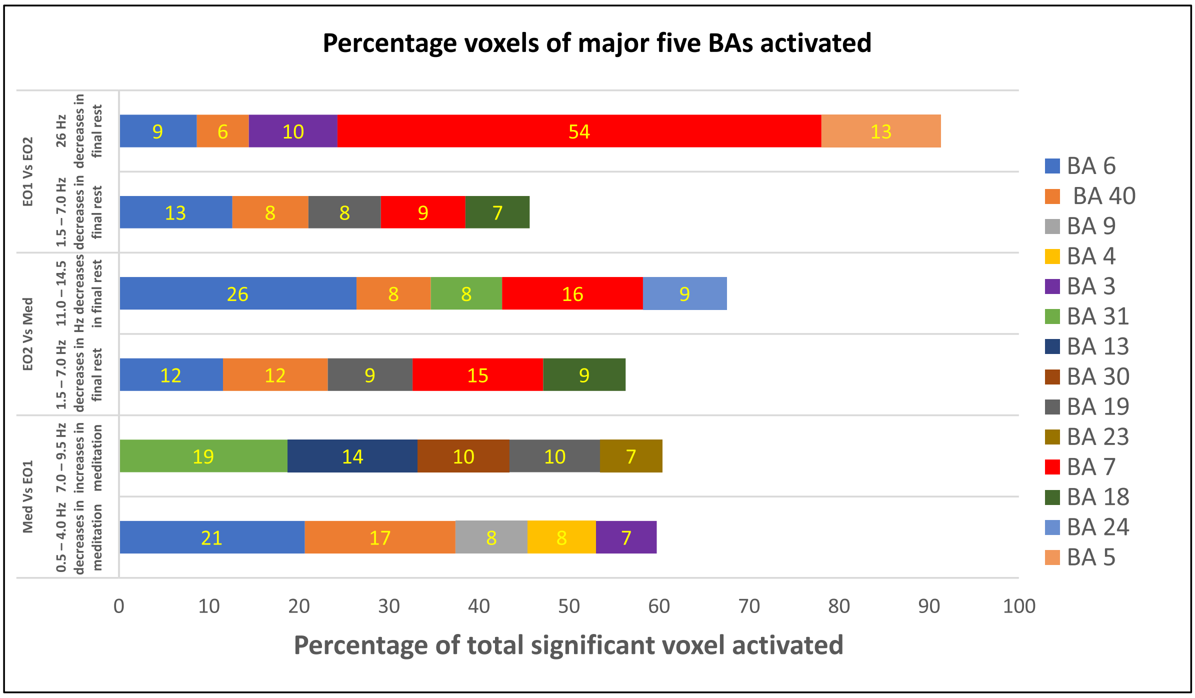


Fig. 2 Percentage of total voxels activated for the top five BAs contributing the largest activation or above 50% activation. *Y*-axis represents different comparisons between initial resting (EO1), meditation (Med), and final resting (EO2)

Brodmann areas contributing to the largest differences in activity between the initial rest, meditation, and the final rest conditions in pairwise comparisons.

A summarized account of the number of voxels in BAs having prominent change in activity is given in Fig. 2. For each BA, the number of activated voxels is calculated as a percentage of the total voxels of that anatomical region in each protocol comparison. Only five BAs with maximum activation for each comparison (Med vs EO1, EO2 vs Med, EO1 vs EO2) have been plotted in the graph.

Discussion

The main goal of the present study was to examine the changes in EEG sources (i.e., activity in specific brain areas) during BKRY meditation compared to the resting state. It is possible that the initial resting state before meditation (EO1) is closer to everyday resting than the final rest (EO2) immediately following the meditation session. This is because we expect that the brain of a long-term meditator may take some time to settle down to its normal activity after the practitioner stops meditating. Therefore, our focus was on the comparison of meditation with the initial rest. In an exploratory analysis, the final resting state was included to evaluate possible lingering effect of the meditation session. Furthermore, the meditation session data was partitioned into three segments of equal duration (tertiles), which were pairwise compared to find possible differences of arousal with increasing time into the meditation. First, we discuss the results of the comparison between meditation and initial rest.

Reduced Inhibition

During BKRY seed-stage meditation, the inhibitory delta band activity (Niedermeyer & Lopes da Silva, 1993) decreased in a large bilateral frontal and central cluster that extended into left-hemispheric temporal and parietal areas (Fig. 1; Table 1 (left) and Table 2). Thus, we see reduced functional inhibition, which likely implies increased activation (processing) in the above areas during meditation as compared to task-free rest. These areas sub-serve functions such as empathy (bilateral (pre) frontal: Seitz et al., 2006), behavioral inhibition/executive control (dorsolateral prefrontal cortex: Kübler et al., 2006; Van Oort et al., 2017), visuo-spatial cognition and spatial information processing (middle frontal, BAs 9/46: Leung et al., 2002), somatosensory processing (homunculus) (BAs 3, 1, 2), and semantic language processing (BAs 20, 21, 22, 44, 45, 6: Bookheimer, 2002). As hypothesized, we see an activation of the central executive network with decreased delta activity in the dorsolateral prefrontal cortex (BAs 9, 10, 46), the frontal eye fields (BA 8), and the posterior parietal cortex (BA 7). Sustaining attention during meditation has been reported to keep the dorsolateral prefrontal cortex (as part of the CEN) activated (Hasenkamp et al., 2012). Task-positive networks have been categorized into two: central executive network and the salience network. CEN is a dominant control network involved in higher cognition and information processing. Anatomically, frontoparietal regions are part of CEN. Anterior cingulate cortex, the inferior parietal lobe, and the posterior-most portions of the middle and inferior temporal gyri connect functionally to regulate emotions, cognitive traits, and behavior. It also acts in self-control mechanisms and suppressing the unpleasant thoughts. Individuals with high connectivity in CEN are found to be resilient and not manifesting cardiometabolic risk under high-violence conditions (Miller et al., 2018).

Our results fit well with the subjective experience involved in seed-stage meditation. The increased behavioral inhibition is expected since the meditators sit still and relaxed while having higher wakefulness (Cahn et al., 2010) during meditation. Increased semantic language processing could be the result of the auto-suggestive nature of the meditation process, since the meditators internally verbalize the steps involved in achieving each stage of the meditation. Activation of the left-side language areas (BAs 44/45 and 21/22) possibly reflects the logical reasoning involved in following the sequence of autosuggestive sentences (Bookheimer, 2002; Caplan & Dapretto, 2001).

We found increased activation in the somatosensory cortex (homunculus, BAs 3, 2, 1) during the first tertile of meditation, which decreased during the last tertile. One explanation for this finding is that during resting, the practitioners were actively inhibiting (higher delta activity) the somatosensory cortex, as they were instructed to sit quietly and not move during the experiment. Overall, during meditation, there was no longer any special focus on relaxation or on maintaining body posture and thus, the activity in the somatosensory cortex went back to more normal levels, i.e., resulting in reduced delta activity as compared to resting. On the other hand, the 20% of voxels showing the highest t-values for reduced delta activity were located in a small cluster with average MNI coordinates (44, 1, 51 mm) in the right hemisphere and (−60, −28, 32 mm) in the left hemisphere, corresponding to the face areas on the homunculus (Roux et al., 2018). This might be the result of focusing the attention between the eyes as an important step during the meditation. The increased visuo-spatial cognition and spatial information storage might result from having the eyes open during the meditation. This allows the meditator to keep an image of himself/herself in relation to the tapestry on the wall that he/she gazes at. It is even conceivable that the nature of the meditation itself fosters spatial processing. Indeed, the meditator is reported to become aware of himself/herself as a soul, a point of light between the eyes that becomes increasingly distanced to the material world. Also, the Supreme Soul is envisioned as separate from the soul before letting the qualities of the Supreme Soul permeate the soul, which implies a direction. This latter part of sensing the qualities of the Supreme Soul and attempting to let them permeate the self might explain the apparently enhanced empathic processing during meditation.

Increased Facilitation

Power in the high theta–low alpha frequencies (7.0 to 9.5 Hz) increased during meditation in a cluster of voxels with the largest cluster being at 9.0 Hz (Fig. 1). While upper alpha frequencies have been considered inhibitory and suppress potentially distracting sensory information, lower alpha is facilitatory and is involved during phasic alertness (Bazanova & Vernon, 2014; Bowman et al., 2017; Klimesch et al., 1998, 1999). This cluster encompassed the bilateral posterior (and to a lesser degree the right anterior) cingulate, extended bilaterally to the parahippocampal gyrus and the superior temporal gyrus, the bilateral insula, the fusiform gyrus, the inferior parietal lobule, and bilateral lingual gyrus, and occipitally and bilaterally to the cuneus and precuneus. The BA 19 bilaterally and left BA 37 have been implicated in mental imagery (D'Esposito et al., 1997), as were BAs 40 and 7 (Knauff et al., 2000) and 18 (De Volder et al., 2001). Seed-stage meditation has a strong focus on mental imagery since the practitioner imagines himself/herself as a point of light between the eyes, as distant from his/her body and the world and witnessing the light of the Supreme being. The involvement of the insula (BA 13) might result from feeling peaceful, since cortically the insula processes the states of feeling (Damasio et al., 2012). The perirhinal cortex (BA 36) processes semantic memory (Davies et al., 2004) as do other parts of the temporal lobe (BAs 20, 21, and 22) (Bookheimer, 2002) and their activation could reflect the meditators' focus on peace and related memories. One of these areas was activated by decreased delta (BA 21), another by increased low alpha (BA 36), and others by both frequency ranges (BAs 13, 20, 22).

Combined Activations

Across delta and low alpha, several networks were activated. The mirroring or experience-sharing network was activated in its classical regions (ventral premotor cortex, inferior frontal gyrus, inferior parietal lobule) and also in regions associated especially with mirroring emotional expression (insula and cingulate cortex) (Molenberghs et al., 2012). An important part of BKRY seed-stage meditation is the practitioner mirroring the peace perceived in the Supreme Soul and let it permeate his/her own soul. This could explain the activation of the mirroring network.

Thirty-five percent of all significant voxels across delta and low alpha belonged to the task-positive network (BAs 6, 19, 37, 40, 46) and 25% to the task-negative network (BAs 8, 10, 20, 21, 30, 31, 39) (Fox et al., 2005). Task-negative network, mostly referred to as default mode network, includes the precuneus/posterior cingulate cortex, the medial prefrontal cortex, and medial, lateral, and inferior parietal cortex. While the activation of the task-positive network confirms our hypothesis, the activation of the task-negative network was unexpected. These two networks are typically mutually exclusive (Fox et al., 2005; Fukunaga et al., 2006), except for states of non-dual awareness during deep meditation as proposed by Josipovic (2014). The task-negative network (Raichle et al., 2001) has been related to mind wandering (Mason et al., 2007), episodic memory processing (Buckner et al, 2008; Greicius et al., 2004), and conceptual processing (Binder et al., 1999). Clearly these processes are all important for maintaining the sense of self (Gusnard et al, 2001; Lou et al., 2004). Many meditation practices tend to weaken the sense of self and are accompanied by a deactivation of the default mode network (e.g., Brewer et al., 2011; Garrison et al., 2015). However, soul consciousness has a strong focus on the self, since it relates the self to the everyday world, its own body, the point between the eyes, and the Supreme Being during its different stages. Self-related processing is known to activate the default mode network (Buckner et al., 2008; Raichle et al., 2001).

The areas belonging to the task-positive network have been associated with different aspects of attention (Corbetta et al., 2008; Posner & Petersen, 1990). Shifting the attention back to the focus of meditation after noticing mind wandering as well as sustaining the attention on the focus of meditation has been associated with activation in the task-positive network (Hasenkamp et al., 2012). It is interesting that the two networks are both activated during BKRY seed-stage meditation. It is not clear whether this indicates that the subjects experience a state of non-dual awareness during some stage of the meditation; alternately, the two networks may be active at different times during the meditation, and the appearance of simultaneous activation may be due to the averaging over the different stages of meditation. This needs to be disentangled in future studies by delineating the different stages of meditation. Across all the states, BKRY seed-stage meditation seems to involve the task-negative network with its strong focus on self-referential processing and the task-positive network with its need to shift attention to and sustain it on the task of going through the different stages of meditation.

It is unclear why certain brain areas were activated by reduced delta activity and others by increased high theta–low alpha activity. A few regions showed activations in both frequency ranges (Table 1). Possibly, studying separately the different states of BKRY seed-stage meditation may shed some light on this issue.

It has been proposed that associative learning processes through imagination help promote mental well-being through reduced neural threat expression (Reddan et al., 2018). Therapies based on associative learning are usually applied to reduce symptoms of anxiety, phobias (Pittig et al., 2018), and addiction (Bevins & Palmatier, 2004). In the case of meditation, practicing imagination of pleasant stimulus or scene may mimic the process of associated learning and follow Hebb's rule (Hebb, 2002) to establish and strengthen new synapses. However, no direct measure of mental health was used in this study, and it requires a new study to explore the above possibility.

Probing for Time Effects

To probe for the effects (e.g., changes in arousal) of passing time over the 30-min meditation session, the meditation data was partitioned into three consecutive segments, each covering 10 min. The differences of the middle tertile from the first or last tertile were not significant. However, there were significant changes from the first to the last tertile of meditation. These changes were decreases in delta (1.5–4.5 Hz) activity in somatosensory, premotor, and motor cortices (BAs 1–6) as well as the inferior parietal lobule (BA 40) and increases at 26 Hz in the cingulate cortex (BAs 23, 24, 31) and the premotor and supplementary motor areas (BA 6). All these changes also show up when comparing the complete meditation session to the initial resting state. These changes thus slightly increase with the progression of time into the 30-min meditation session. However, when the activities of successive time segments (during meditation) are compared to each other, only a few voxels show significant differences. Subject variability and varying temporal progression across subjects during meditation might explain this.

Comparisons with the Final Rest State

Meditation shows different changes in comparison with the final resting state than it does to the initial resting state. Most noteworthy is the decrease of upper alpha (11.0–14.5 Hz) frequencies in the final rest, but also decrease of activity in the delta and theta (1.5–7.0 Hz) frequencies in many areas. Thus, it is apparent that coming out of meditation is different from the state before going into meditation. This has already been described in a study of EEG and eLORETA-based functional connectivity on meditators from 5 different meditation traditions (Lehmann et al., 2012). On a side note, the differential involvement of low alpha during meditation in comparison with initial rest and high alpha during final rest in comparison with meditation seems to imply that low and high alpha reflect different processes and caution should be applied when analyzing a single broad alpha band.

Activation in a single frequency bin of 26 Hz is increased in anterior and posterior cingulate cortices (BAs 24 and 23). The anterior cingulate area is active during the detection of conflicts and maintains attention by alerting the top-down systems involved in resolving the conflicts (Van Veen & Carter, 2002). Our findings contradict those of Faber et al. (2015) mentioning the posterior cingulate area deactivation in expert zazen meditators as resulting from the detachment from perceptions during the meditative state. Zazen is considered open mindfulness and reduced conceptual processing and self-referential. However, the seed stage of BKRY is a more involved practice with positive thoughts and requires self-related processing and visualizing the soul as distinct from the body. BK Rajyoga practice involves imagining oneself as a point of light, detached from one's physical body. This may give them an extracorporeal experience during meditation. The self-reported phenomenon of detachment of the soul from the body by most meditators of BKRY tradition can be supported by our findings of activation/deactivation in BA 6 (supplementary motor area) and BA 40 (supramarginal gyrus, inferior parietal lobe) (Fig. 2) in different frequency bands (Bünning & Blanke, 2005), also seen earlier in fMRI studies (Smith and Messier, 2014).

Similarly, the deactivations in the last tertile of meditation indicate decreasing requirement of networks involved in conflict monitoring and different sensory perceptions running during the beginning of meditation in order to initiate and maintain the meditative state. It seems reasonable that large parts of the brain show changes during this transition back to a normal state. To study in detail the changes in returning to rest after meditation, future studies should record EEG for a longer period after meditation or at periodic intervals for a couple of hours after meditation. This would help elucidate how the brain returns to its normal, everyday state of mind after an extended meditation session. The final resting data differs largely from the initial resting data in almost all the brain areas, thus possibly showing a lingering effect of the meditation session combined with a reorganization of brain activity in order to return to normal processing. Looking only at the first 3 min after the meditation practice without knowing when the return to the normal state is complete seems insufficient to draw any useful conclusions.

The current study attempted to find common brain networks activated in eyes-open meditation. To the knowledge of the authors, these have not been explored so far. The major areas of involvement of default mode network are common between seed-stage meditation and other meditation traditions. In a non-dual practice, where self-regulation is involved, no activation in frontoparietal network was found (Schoenberg et al., 2018), suggesting that this network plays no role in meditation. The anterior cingulate cortex, posterior cingulate cortex, precuneus, insula, and middle frontal gyrus are a few involved areas common to meditation practices in the current study and previous ones (Deolindo et al., 2020).

In summary, the BKRY seed-stage meditation with open eyes showed activations in brain areas sub-serving the subjective experience of the practitioners during the different stages of meditation. The modulated areas were part of the CEN and the task-positive and task-negative networks. They inhibit movement, foster and modulate attention to stay on the task of moving through the different stages of the meditation, reducing the requirement of distraction-inhibiting networks to maintain the meditative state, and enable self-related processing for experiencing the soul as a point of light between the eyes, and endowing it with the properties (i.e., peace) of the Supreme Soul (as taught in the Prajapita Brahma Kumaris World Spiritual University while learning meditation).

Limitations and Directions for Future Research

The eLORETA tool for source localization of EEG data provides brain activations with low spatial resolution. Our findings can be interpreted based on the previous literature of neuroimaging methods with high spatial resolution, where the subjects performed tasks based on defined instructions while the data was being recorded. However, since meditation is an activity with few known attributes while being practiced, it is challenging to fit in a prepared instructional order. A more robust study can be planned with subjective ratings or questionnaire-based scoring of cognitive traits to correlate with the EEG indices. The participants in the current study were all adept Brahma Kumaris meditators. As such, they practice a certain lifestyle that could very well have an influence on their general state of mind, irrespective of the seed-stage meditation studied here. This lifestyle includes maintaining celibacy, consuming vegetarian diet, and a rigorous daily routine (e.g., getting up early for morning meditation). Mount Abu is situated at 1722 m above sea level and the altitude could have influenced the EEG patterns. Also, the recordings were performed during a winter retreat. All the participants had at least 3 days of acclimatization before the recording. The intense meditation schedule during the retreat might also have reflected in the findings. However, these effects should all be mitigated by our intra-subject comparisons.

The recording protocol did not control the durations of the different stages of meditation and hence, each meditator might have followed his/her normal characteristic timing to advance from one stage of meditation to the next. Because of this, it is difficult to mark the timings of the various cognitive and emotional states of the subjects. To delineate the brain's electrical characteristics during the different sub-stages of meditation, these may need to be triggered by the experimenter in a controlled fashion in future studies. Furthermore, specific cognitive/psychological tests can be carried out to cross-validate the functional activation of brain regions relevant to our study. This information can then be used to better explain the changes to the activity occurring in each of those brain regions during meditation. A psychophysiological study is suggested to provide an idea of the effect of meditation practice on cognitive functions with evidenced source activation. To study how the brain activity returns to normal after an extended meditation session, future studies should record rest after meditation over a prolonged period. The high theta–low alpha (7–9.5 Hz frequency range) could be a new range to explore when experiments are designed for meditation involving multiple phenomenological components such as self-realization, positive thought inculcation, and out-of-body experiences.

Acknowledgements The authors would like to acknowledge the team members Ms. Priya and Ms. Manju Mohan, who supported in experimental data recording.

Funding The first author would like to acknowledge the support received as post-doctoral fellowship under the DST-Cognitive Science Research Initiative (DST-CSRI-87/2018). Members and decision-makers of the grant had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data Availability We are not in a position to make our EEG data public at this time since some of the other research work we have carried out on this data are yet to be published.

Declarations

Ethical Approval The study was approved by the Institutional Human Ethics Committee of the Indian Institute of Science. All the procedures performed in this study were in accordance with the ethical standards of the Institutional Human Ethics Committee of the Indian Institute of Science and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to Participate Individual informed consent was obtained from all the study participants.

Competing Interests The authors declare no competing interests.

References

Babu, M. R., Kadavigere, R., Koteshwara, P., Sathian, B., & Rai, K. S. (2020). Rajyoga meditation induces grey matter volume changes in regions that process reward and happiness. *Scientific Reports, 10*(1), 1–11. https://doi.org/10.1038/s41598-020-73221-x

Bazanova, O., & Vernon, D. (2014). Interpreting EEG alpha activity. *Neuroscience & Biobehavioral Reviews, 44*, 94–110. https://doi.org/10.1016/j.neubiorev.2013.05.007

Bevins, R. A., & Palmatier, M. I. (2004). Extending the role of associative learning processes in nicotine addiction. *Behavioral and*

Cognitive Neuroscience Reviews, 3(3), 143–158. https://doi.org/10.1177/1534582304272005

Binder, J. R., Frost, J. A., Hammeke, T. A., Bellgowan, P., Rao, S. M., & Cox, R. W. (1999). Conceptual processing during the conscious resting state: A functional MRI study. *Journal of Cognitive Neuroscience, 11*(1), 80–93. https://doi.org/10.1162/089892999563265

Birch, J. (2013). Rājayoga: The reincarnations of the king of all yogas. *International Journal of Hindu Studies, 17*(3), 399–442. https://doi.org/10.1007/s11407-014-9146-x

Bookheimer, S. (2002). Functional MRI of language: New approaches to understanding the cortical organization of semantic processing. *Annual Review of Neuroscience, 25*(1), 151–188. https://doi.org/10.1146/annurev.neuro.25.112701.142946

Bowman, A. D., Griffis, J. C., Visscher, K. M., Dobbins, A. C., Gawne, T. J., DiFrancesco, M. W., & Szaflarski, J. P. (2017). Relationship between alpha rhythm and the default mode network: An EEG-fMRI study. *Journal of Clinical Neurophysiology, 34*(6), 527–533. https://doi.org/10.1097/WNP.0000000000000411

Brahmakumaris. (1986). *Positive health - Rajyoga meditation for stress-free peaceful and healthy life*. Prajapitha Brahma Kumaris Ishwarya Vishwa Vidyalaya.

Brewer, J. A., Worhunsky, P. D., Gray, J. R., Tang, Y.-Y., Weber, J., & Kober, H. (2011). Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences, 108*(50), 20254–20259. https://doi.org/10.1073/pnas.1112029108

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences, 1124*(1), 1–38. https://doi.org/10.1196/annals.1440.011

Bünning, S., & Blanke, O. (2005). The out-of body experience: Precipitating factors and neural correlates. *Progress in Brain Research, 150*, 331–606. https://doi.org/10.1016/S0079-6123(05)50024-4

Cahn, B. R., Delorme, A., & Polich, J. (2010). Occipital gamma activation during Vipassana meditation. *Cognitive Processing, 11*, 39–56. https://doi.org/10.1007/s10339-009-0352-1

Caplan, R., & Dapretto, M. (2001). Making sense during conversation: An fMRI study. *NeuroReport, 12*(16), 3625–3632. https://doi.org/10.1097/00001756-200111160-00050

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron, 58*(3), 306–324. https://doi.org/10.1016/j.neuron.2008.04.017

D'Esposito, M., Detre, J. A., Aguirre, G. K., Stallcup, M., Alsop, D. C., Tippet, L. J., & Farah, M. J. (1997). A functional MRI study of mental image generation. *Neuropsychologia, 35*(5), 725–730. https://doi.org/10.1016/S0028-3932(96)00121-2

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences, 19*(9), 515–523. https://doi.org/10.1016/j.tics.2015.07.001

Damasio, A., Damasio, H., & Tranel, D. (2012). Persistence of feelings and sentience after bilateral damage of the insula. *Cerebral Cortex, 23*(4), 833–846. https://doi.org/10.1093/cercor/bhs077

Davies, R., Graham, K. S., Xuereb, J. H., Williams, G. B., & Hodges, J. R. (2004). The human perirhinal cortex and semantic memory. *European Journal of Neuroscience, 20*(9), 2441–2446. https://doi.org/10.1111/j.1460-9568.2004.03710.x

De Volder, A. G., Toyama, H., Kimura, Y., Kiyosawa, M., Nakano, H., Vanlierde, A., Wanet-Defalque, M.-C., Mishina, M., Oda, K., Ishiwata, K., & Senda, M. (2001). Auditory triggered mental imagery of shape involves visual association areas in early blind humans. *NeuroImage, 14*(1), 129–139. https://doi.org/10.1006/nimg.2001.0782

Deolindo, C. S., Ribeiro, M. W., Aratanha, M. A., Afonso, R. F., Irrmischer, M., & Kozasa, E. H. (2020). A critical analysis on characterizing the meditation experience through the electroencephalogram. *Frontiers in Systems Neuroscience*, *14*,53, https://doi.org/10.3389/fnsys.2020.00053

Evans, A. C., & Collins, D. (1993). A 305-member MRI-based stereotaxic atlas for CBF activation studies. *Journal of Nuclear Medicine, 34*(5), 70–71.

Faber, P. L., Lehmann, D., Gianotti, L. R., Milz, P., Pascual-Marqui, R. D., Held, M., & Kochi, K. (2015). Zazen meditation and no-task resting EEG compared with LORETA intracortical source localization. *Cognitive Processing, 16*(1), 87–96. https://doi.org/10.1007/s10339-014-0637-x

Fox, M. D., Snyder, A. Z., Vincent, J. L., Corbetta, M., Van Essen, D. C., & Raichle, M. E. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences, 102*(27), 9673–9678. https://doi.org/10.1073/pnas.0504136102

Frei, E., Gamma, A., Pascual-Marqui, R., Lehmann, D., Hell, D., & Vollenweider, F. X. (2001). Localization of MDMA-induced brain activity in healthy volunteers using low resolution brain electromagnetic tomography (LORETA). *Human Brain Mapping, 14*(3), 152–165. https://doi.org/10.1002/hbm.1049

Fukunaga, M., Horovitz, S. G., van Gelderen, P., de Zwart, J. A., Jansma, J. M., Ikonomidou, V. N., Chu, R., Deckers, R. H. R., Leopold, D. A., & Duyn, J. H. (2006). Large-amplitude, spatially correlated fluctuations in BOLD fMRI signals during extended rest and early sleep stages. *Magnetic Resonance Imaging, 24*(8), 979–992. https://doi.org/10.1016/j.mri.2006.04.018

Garrison, K. A., Zeffiro, T. A., Scheinost, D., Constable, R. T., & Brewer, J. A. (2015). Meditation leads to reduced default mode network activity beyond an active task. *Cognitive, Affective, & Behavioral Neuroscience, 15*(3), 712–720. https://doi.org/10.3758/s13415-015-0358-3

Greicius, M. D., Srivastava, G., Reiss, A. L., & Menon, V. (2004). Default-mode network activity distinguishes Alzheimer's disease from healthy aging: Evidence from functional MRI. *Proceedings of the National Academy of Sciences, 101*(13), 4637–4642. https://doi.org/10.1073/pnas.0308627101

Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of the National Academy of Sciences, 98*(7), 4259–4264. https://doi.org/10.1073/pnas.071043098

Hasenkamp, W., Wilson-Mendenhall, C. D., Duncan, E., & Barsalou, L. W. (2012). Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *NeuroImage, 59*(1), 750–760. https://doi.org/10.1016/j.neuroimage.2011.07.008

Hebb, D. O. (2002). *The organization of behavior: A neuropsychological theory*. Psychology Press. https://doi.org/10.4324/9781410612403

Josipovic, Z. (2010). Duality and nonduality in meditation research. *Consciousness and Cognition, 19*(4), 1119–1121. https://doi.org/10.1016/j.concog.2010.03.016

Josipovic, Z. (2014). Neural correlates of nondual awareness in meditation. *Annals of the New York Academy of Sciences, 1307*(1), 9–18. https://doi.org/10.1111/nyas.12261

Kaliman, P. (2019). Epigenetics and meditation. *Current Opinion in Psychology, 28*, 76–80. https://doi.org/10.1016/j.copsyc.2018.11.010

Keng, S. L., Smoski, M. J., & Robins, C. J. (2011). Effects of mindfulness on psychological health: A review of empirical studies. *Clinical Psychology Review, 31*(6), 1041–1056. https://doi.org/10.1016/j.cpr.2011.04.006

Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience Letters, 244*(2), 73–76. https://doi.org/10.1016/S0304-3940(98)00122-0

Klimesch, W., Doppelmayr, M., Schwaiger, J., Auinger, P., & Winkler, T. (1999). 'Paradoxical' alpha synchronization in a memory task. *Cognitive Brain Research, 7*(4), 493–501. https://doi.org/10.1016/S0926-6410(98)00056-1

Knauff, M., Kassubek, J., Mulack, T., & Greenlee, M. W. (2000). Cortical activation evoked by visual mental imagery as measured by fMRI. *NeuroReport, 11*(18), 3957–3962.

Kübler, A., Dixon, V., & Garavan, H. (2006). Automaticity and reestablishment of executive control—An fMRI study. *Journal of Cognitive Neuroscience, 18*(8), 1331–1342. https://doi.org/10.1162/jocn.2006.18.8.1331

Lehmann, D., Faber, P. L., Tei, S., Pascual-Marqui, R. D., Milz, P., & Kochi, K. (2012). Reduced functional connectivity between cortical sources in five meditation traditions detected with lagged coherence using EEG tomography. *NeuroImage, 60*(2), 1574–1586. https://doi.org/10.1016/j.neuroimage.2012.01.042

Leung, H. C., Gore, J. C., & Goldman-Rakic, P. S. (2002). Sustained mnemonic response in the human middle frontal gyrus during on-line storage of spatial memoranda. *Journal of Cognitive Neuroscience, 14*(4), 659–671. https://doi.org/10.1162/08989290260045882

Levine, G. N., Lange, R. A., Bairey-Merz, C. N., Davidson, R. J., Jamerson, K., Mehta, P. K., Michos, E. D., Norris, K., Ray, I. B., Saban, K. L., Shah, T., Stein, R., & Smith, S. C. (2017). American Heart Association Council on Clinical Cardiology; Council on Cardiovascular and Stroke Nursing; and Council on Hypertension. Meditation and cardiovascular risk reduction: A scientific statement from the American Heart Association. *Journal of the American Heart Association, 6*(10), e002218. https://doi.org/10.1161/JAHA.117.002218

Lou, H. C., Luber, B., Crupain, M., Keenan, J. P., Nowak, M., Kjaer, T. W., Sackeim, H. A., & Lisanby, S. H. (2004). Parietal cortex and representation of the mental self. *Proceedings of the National Academy of Sciences, 101*(17), 6827–6832. https://doi.org/10.1073/pnas.0400049101

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences, 12*(4), 163–169. https://doi.org/10.1016/j.tics.2008.01.005

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: The default network and stimulus-independent thought. *Science, 315*(5810), 393–395. https://doi.org/10.1126/science.1131295

Miller, G. E., Chen, E., Armstrong, C. C., Carroll, A. L., Ozturk, S., Rydland, K. J., Brody, G. H., Parrish, T. B., & Nusslock, R. (2018). Functional connectivity in central executive network protects youth against cardiometabolic risks linked with neighborhood violence. *Proceedings of the National Academy of Sciences, 115*(47), 12063–12068. https://doi.org/10.1073/pnas.1810067115

Misra, N., Gupta, A., Alreja, S., & Prakash, O. (2013). Effect of Raj Yoga meditation on affective & cognitive functions. *International Journal of Health Sciences and Research, 3*(2), 38–46.

Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: A meta-analysis of 125 human fMRI studies. *Neuroscience & Biobehavioral Reviews, 36*(1), 341–349. https://doi.org/10.1016/j.neubiorev.2011.07.004

Naik, A., Patel, S., Biswas, D., & Verma, M. (2016). Effect of Rajyoga meditation on intelligence quotient of attention deficit hyperactivity disorder. *Journal of Yoga and Physiotherepy, 6*(242), 1–2. https://doi.org/10.4172/2157-7595.1000242

Nair, A. K., Sasidharan, A., John, J. P., Mehrotra, S., & Kutty, B. M. (2017). Just a minute meditation: Rapid voluntary conscious state shifts in long term meditators. *Consciousness and Cognition, 53*, 176–184. https://doi.org/10.1016/j.concog.2017.06.002

Nash, J. D., & Newberg, A. (2013). Toward a unifying taxonomy and definition for meditation. *Frontiers in Psychology, 4,* 806. https://doi.org/10.3389/fpsyg.2013.00806

Nichols, T. E., & Holmes, A. P. (2002). Nonparametric permutation tests for functional neuroimaging: A primer with examples. *Human Brain Mapping, 15*(1), 1–25. https://doi.org/10.1002/hbm.1058

Niedermeyer, E., & Lopes da Silva, F. (1993). *Electroencephalography: Basic principles, clinical applications and related fields* (3rd ed.). Williams and Wilkins.

Nuwer, M. R., Comi, G., Emerson, R., Fuglsang-Frederiksen, A., Guérit, J.-M., Hinrichs, H., Ikeda, A., Luccas, F. J. C., & Rappelsberger, P. (1998). IFCN standards for digital recording of clinical EEG. *Electroencephalography and Clinical Neurophysiology, 106*(3), 259–261. https://doi.org/10.1016/s0013-4694(97)00106-5

Panda, R., Bharath, R. D., Upadhyay, N., Mangalore, S., Chennu, S., & Rao, S. L. (2016). Temporal dynamics of the default mode network characterize meditation-induced alterations in consciousness. *Frontiers in Human Neuroscience, 10*, 372. https://doi.org/10.3389/fnhum.2016.00372

Pascual-Marqui, R. D., Michel, C. M., & Lehmann, D. (1994). Low resolution electromagnetic tomography: A new method for localizing electrical activity in the brain. *International Journal of Psychophysiology, 18*(1), 49–65. https://doi.org/10.1016/0167-8760(84)90014-X

Pascual-Marqui, R. D., Lehmann, D., Koenig, T., Kochi, K., Merlo, M. C. G., Hell, D., & Koukkou, M. (1999). Low resolution brain electromagnetic tomography (LORETA) functional imaging in acute, neuroleptic-naive, first-episode, productive schizophrenia. *Psychiatry Research: Neuroimaging, 90*(3), 169–179. https://doi.org/10.1016/S0925-4927(99)00013-X

Pascual-Marqui, R. D., Lehmann, D., Koukkou, M., Kochi, K., Anderer, P., Saletu, B., Tanaka, H., Hirata, K., John, E. R., Prichep, S., Biscay-Lirio, R., & Kinoshita, T. (2011). Assessing interactions in the brain with exact low-resolution electromagnetic tomography. *Philosophical Transactions Royal Society, Series a, Mathematical, Physical, and Engineering Sciences, 369*(1952), 3768–3784. https://doi.org/10.1098/rsta.2011.0081

Pittig, A., Treanor, M., LeBeau, R. T., & Craske, M. G. (2018). The role of associative fear and avoidance learning in anxiety disorders: Gaps and directions for future research. *Neuroscience & Biobehavioral Reviews, 88*, 117–140. https://doi.org/10.1016/j.neubiorev.2018.03.015

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13*(1), 25–42. https://doi.org/10.1146/annurev.ne.13.030190.000325

Raffone, A., & Srinivasan, N. (2010). The exploration of meditation in the neuroscience of attention and consciousness. *Cognitive Process, 11*, 1–7. https://doi.org/10.1007/s10339-009-0354-z

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences, 98*(2), 676–682. https://doi.org/10.1073/pnas.98.2.676

Ramesh, M., Sathian, B., Sinu, E., & Kiranmai, S. R. (2013). Efficacy of Rajyoga meditation on positive thinking: An index for self-satisfaction and happiness in life. *Journal of Clinical and Diagnostic Research, 7*(10), 2265–2267. https://doi.org/10.7860/JCDR/2013/5889.3488

Ramsay, T., & Manderson, L. (2011). Resilience, spirituality and posttraumatic growth: Reshaping the effects of climate change. In *Climate Change and Human Well-being* (pp. 165–184): Springer. https://doi.org/10.1007/978-1-4419-9742-5_9

Reddan, M. C., Wager, T. D., & Schiller, D. (2018). Attenuating neural threat expression with imagination. *Neuron, 100*(4), 994–1005. https://doi.org/10.1016/j.neuron.2018.10.047

Roux, F. E., Djidjeli, I., & Durand, J. B. (2018). Functional architecture of the somatosensory homunculus detected by electrostimulation. *The Journal of Physiology, 596*(5), 941–956. https://doi.org/10.1113/JP275765

Schoenberg, P. L. A., Ruf, A., Churchill, J., Brown, D. P., & Brewer, J. A. (2018). Mapping complex mind states: EEG neural substrates of meditative unified compassionate awareness. *Consciousness and Cognition, 57*, 41–53. https://doi.org/10.1016/j.concog.2017.11.003

Sedlmeier, P., Loße, C., & Quasten, L. C. (2018). Psychological effects of meditation for healthy practitioners: an update. *Mindfulness, 9*(2), 371–387.

Seitz, R. J., Nickel, J., & Azari, N. P. (2006). Functional modularity of the medial prefrontal cortex: Involvement in human empathy. *Neuropsychology, 20*(6), 743–751. https://doi.org/10.1037/0894-4105.20.6.743

Sharma, K., Chandra, S., & Dubey, A. K. (2018a). Exploration of lower frequency EEG dynamics and cortical alpha asymmetry in long-term Rajyoga meditators. *International Journal of Yoga, 11*(1), 30–36. https://doi.org/10.4103/ijoy.IJOY_11_17

Sharma, K., Trivedi, R., Chandra, S., Dubey, A. K., Kaur, P., Kumar, P., Singh, K., Chandra, S., & Khushu, S. (2018b). Enhanced white matter integrity in corpus callosum of long-term Brahmakumaris Rajyoga meditators. *Brain Connectivity, 8*(1), 49–55. https://doi.org/10.1089/brain.2017.0524

Smith, A. M., & Messier, C. (2014). Voluntary out-of-body experience: An fMRI study. *Frontiers in Human Neuroscience, 8*, 70. https://doi.org/10.3389/fnhum.2014.00070

Sukhsohale, N. D., & Phatak, M. S. (2012). Effect of short-term and long-term Brahmakumaris Raja Yoga meditation on physiological variables. *Indian Journal of Physiology and Pharmacology, 56*(4), 388–392.

Telles, S., & Desiraju, T. (1993). Autonomic changes in Brahmakumaris Rajayoga meditation. *International Journal of Psychophysiology, 15*(2), 147–152. https://doi.org/10.1016/0167-8760(93)90072-w

Travis, F., & Shear, J. (2010). Focused attention, open monitoring and automatic self-transcending: Categories to organize meditations from Vedic, Buddhist and Chinese traditions. *Consciousness and Cognition, 19*(4), 1110–1118. https://doi.org/10.1016/j.concog.2010.01.007

van Oort, J., Tendolkar, I., Hermans, E. J., Mulders, P. C., Beckmann, C. F., Schene, A. H., Fernandez, G., & van Eijndhoven, P. F. (2017). How the brain connects in response to acute stress: A review at the human brain systems level. *Neuroscience & Biobehavioral Reviews, 83*, 281–297. https://doi.org/10.1016/j.neubiorev.2017.10.015

Van Veen, V., & Carter, C. S. (2002). The anterior cingulate as a conflict monitor: FMRI and ERP studies. *Physiology & Behavior, 77*(4–5), 477–482. https://doi.org/10.1016/s0031-9384(02)00930-7

Effect of Raja Yoga Meditation on psychological and functional outcomes in spinal cord injury patients

Abstract

Background: The people injured with Spinal Cord are suffering at many aspects physically, mentally, emotionally, socially & financially and their care givers too. Raja-yoga(RYM) meditation is a powerful tool for holistic healing. This therapy is unique because it heals a person from within. Raja-yoga transforms the biochemistry of the brain in turn having a harmonizing effect on the whole organism.

Objective: To explore new dimensions for healing through RYM in spinal cord injury (SCI) patients alongwith their caregivers in order to increase quality of life with inner strength. The primary objective of this study was to find out effect of RYM on spinal cord injury patients.

Materials and Methods: This is pre-post observational study with two groups (1) Patients with Conventional rehabilitation with RYM (2) Patients with only conventional rehabilitation in SCI patients. Caregivers also assessed pre-post intervention to find effect of RYM. A total of 100 SCI patients and 100 caregivers were recruited based on eligibility criteria and ready to give consent for the study. The age of SCI patients ranged from 16 years to 60 years. 50 subjects were assigned in each group. The duration of study was 4 weeks. The sessions were conducted for 45 min each at premises of ISIC for 6 days per week. Meditation practice was done for 20 minutes through a guided commentary and motivation was given through BrahmaKumaris spiritual knowledge for 25 minutes. Pre and Post assessment was done using standard tools namely Perceived stress Scale(PSS), Hospital Anxiety and Depression Score(HADS), Scale (HADS), Spinal Cord Independence Measure (SCIM), WHO Quality of Life BREF (WHOQOL-BREF), Numeric Pain Rating (NPR).

Results: Out of all parameters studied, PSS ($p<0.001$), HADS ($p=0.001$), QOL-BREF ($p<0.001$), showed statistically significant changes for patients measured before and after the intervention in both the arms. SCIM ($p=0.513$) and NPR ($p=0.055$), significant changes were observed within the arm measured pre - post assessment, however they did not show the significant difference between intervention and control arm. Caregivers parameter studied PSS ($p<0.001$), HADS ($p=0.004$) and observed significant changes in both the arms.

Conclusion: Significant differences were observed in psychological scales before and after Raja yoga meditation. It suggests the use of RYM might help spinal cord injury patients for better and early recovery.

Indian
Spinal Injuries
Centre

01/09/2012

TO WHOM IT MAY CONCERN

This is to certify that Prajapita Brahmakumari's Ishwariya Vishwavidhyalya, Vasant Kunj have done their socially beneficial services from October, 2011 till date at Complimentary & Alternative Medicine Department (Meditation Hall provided by the hospital) at Indian Spinal Injuries Centre. This project have been conducted under SpARC Wing. Their services have been physically, mentally, spiritually, and socially benefited by number of patients coming to the hospital that covers OPD & IPD patients as well as staff members of the hospital.

We appreciate Brahma Kumari's for their excellent services. We wish them all success in future.

CHITRA KATARIA
HOD Rehabilitation ISIC
Principal
ISIC Institute of Rehabilitation Sciences

Dr. PARAM HANS MISHRA
MBBS, PGDHHM, PGDIM,
MHA (AIIMS), DNB (H & A H)
Medical Superintendent, ISIC

An ISO 9001, ISO 14001 and OHSAS 18001 Certified Organization
Sector- C, Vasant Kunj, New Delhi-110070 Phone : +91-11-4225 5225 (30 Lines) Fax: +91-11-2689 8810
E-mail: info@isiconline.org Web : www.isiconline.org

IJOY International Journal of Yoga

ORIGINAL ARTICLE

Year : 2021 | Volume : 14 | Issue : 1 | Page : 36-42

Effect of Raja yoga Meditation on psychological and functional outcomes in spinal cord injury patients

Ekta Chalageri[1], Gayatri Vishwakarma[2], Randhir Lal Ranjan[2], Ramajayam Govindaraj[3], Harvinder Singh Chhabra[2]

1 Spiritual Applications Research Centre of Rajyoga Education and Research Foundation of Brahma Kumaris, New Delhi, India.

2 Indian Spinal Injuries Centre, New Delhi, India.

3 Centre for Consciousness Studies, National Institute of Mental Health and Neurosciences, Bengaluru, Karnataka, India.

Date of Submission 27-Jun-2020 | Date of Decision 26-Aug-2020 | Date of Acceptance 20-Oct-2020 | Date of Web Publication 05-Feb-2021

Abstract

Background: Spinal cord injury (SCI) is a debilitating disorder with dysfunction in daily activities and psychological consequences like anxiety as well as depression impacting the quality of life substantially. Existing treatments focus mainly on rehabilitation, symptom reduction, and secondary complications. However, psychological, social, and existential issues are least addressed in the prevailing models.

Aims: To study the role of meditation in addressing psychological impairment and any resultant improvement in functional outcomes in SCI patients.

Methods: Nonrandomized controlled study was conducted in a tertiary care center for SCI patients. Hospital inpatients were recruited into either experimental intervention group (add on easy raja yoga with conventional rehabilitation-ER n = 50) or control intervention group (conventional rehabilitation alone-CR n = 50). Patients in the ER group received easy raja yoga for 1 month, along with conventional rehabilitation and the CR group patients received only conventional rehabilitation. All the subjects were assessed for psychological (perceived stress scale [PSS], Hospital Anxiety and Depression Scale [HADS]) and functional impairment (spinal cord independence measure (SCIM), numeric pain rating (NPR) and WHO quality of life-BRIEF (WHOQOLBREF)] at baseline and after 1 month.

Results: After 1 month of add-on easy raja yoga, there was significant decrease in the scores of HADS ($F[1,88] = 272.92$, $P < 0.001$), PSS ($F[1,88] = 274.41$, $P < 0.001$) and NPR ($F[1,88] = 60.60$, $P < 0.001$) and significant increase in the scores of WHOQOLBREF ($F[1,88] = 349.94$, $P < 0.001$) and SCIM ($F[1,88] = 29.09$, $P < 0.001$) in the ER group compared to CR group in analysis of covariance.

Conclusion: One-month add-on easy raja yoga improves psychological and functional outcomes (HADS, PSS, NPR, WHOQOLBREF and SCIM) in patients with SCI. Future studies with robust designs are needed to validate the results.

Keywords: Psychological and functional impairment, raja yoga, spinal cord injury

Introduction

Spinal cord injury (SCI) is a debilitating disorder with impairment in motor, sensory, and autonomic functions and it is very commonly caused by trauma. Every year millions of people sustain SCI globally.[1] People with SCI are predominantly in the age group of 20–40 years.

-relatively the most productive time of life. People with SCI are two to five times more likely to die prematurely than people without SCI.[1] Adding to the acute impairments, secondary health problems such as pressure sore, sepsis, respiratory muscle impairment, etc., increases the cost of management enormously. Due to direct and indirect cost of management, including long.

-term rehabilitation, psychological and social problems are also very common and make the condition more complex.

Difficulty in carrying out activities of daily living independently due to the neuromuscular compromise and the ensuing psychological and social distress affects the quality of life considerably. A recent study has shown that 17%–25% of the people with SCI are prone to develop psychological disorders[2] and >36% of them were prescribed psychotropic medications,[2] A metanalysis of 19 studies had shown a depression prevalence of 22.2% following SCI.[3] Chronic pain, fatigue, depressed mood, anxiety, and reduced self-efficacy following SCI are also reported in the literature.[4]

After acute management of SCI, rehabilitative and preventive management is the mainstay of care for people with SCI for successful reintegration of psychological and social life. Optimal management of physical and psychological impairment following SCI should go parallelly, as physical and psychological factors influence each other. For example, inadequate management of chronic pain could lead to depression, which in turn could worsen chronic pain.[5] Hence the need for a multidisciplinary management team including surgeons, physicians, physiotherapist, nurses, occupational therapist, dietician, psychologists, etc., is of paramount importance. In fact, the long-term outcome of quality of life is inversely proportional to the quality of care.[2]

Prevailing rehabilitation models focus on symptom reduction, optimizing functional outcomes, and prevention of secondary health problems like pressure sore, spasticity of muscles, etc., and their functional consequences. But as the problems related to SCI are complex involving psychological, social, and existential factors, it is imperative to explore applications of complementary therapies along with conventional treatment to strengthen the patient as an individual in a holistic way.

In recent times, besides conventional care, mind-body practices like yogasana, pranayama and meditation are found to be helpful in managing the physical, psychological, and social distress in people with SCI.[6],[7] Among people with SCI, complementary and integrative health interventions usage is reported to be 14% to 73%, and 3% of SCI patients use them in the first few weeks of inpatient rehabilitation.[8] Patients receiving complementary therapies had shown greater reductions in pain severity and improvement in the quality of life and measures related to activities of daily living.[8]

Mind-body practices used in therapeutic setup range widely from physical movement-based therapies like yogasana, tai chi, Qi Gong to mental focusing or observation related practices like mindfulness, sahaj yoga, raja yoga, etc.[9] For patients with SCI who are mostly paraplegic or tetraplegic, though movement-based practices like yogasana and pranayama would help due to improved body and breath awareness, meditation-based practices would play an apt role to improve the psychological functioning and related outcomes. Indeed, improvement in psychological functioning would reflexively improve physical functioning also, as physical and psychological factors influence each other.

In this study, we have evaluated the effect of Brahmakumaris Raja yoga (also called as easy raja yoga) on patients with SCI. Easy raja yoga is meditation technique with a framework of four different limbs comprising of (i) wisdom (gyan), (ii) remembrance (yog), (iii) practice of virtues (dharana) and (iv) service i.e., to have good wishes for self and others (seva). The terms yoga and dharana used here is meant differently from that used commonly in ashtnanga yoga. For complete details of the easy raja yoga module, refer the appendix. Easy raja yoga has been used in various conditions like coronary heart disease, tension headache, for depression and anxiety in patients undergoing coronary artery bypass surgery, substance abuse, and diabetes mellitus.[10],[11],[12]

In this study, we aimed at evaluating the effect of Easy raja yoga on psychological and functional outcomes of patients with SCI. Our primary hypothesis was that 1-month practice of easy raja yoga would reduce anxiety and depression in patients with SCI measured by Hospital Anxiety and Depression Scale (HADS) and stress measured by the perceived stress scale (PSS). Further, we also hypothesized that 1-month practice of easy raja yoga would improve functional independence measure assessed by spinal cord independence measure (SCIM) and quality of life assessed by WHO quality of life-brief (WHOQoLBREF) and would reduce pain measured by numeric pain rating (NPR) Scale.

Methods

Non-randomized controlled trial was conducted at a tertiary care SCI centre in north India. The study was approved by the institutional ethics committee (REF ISIC/IIRS/RP/2015/111). Acute and Chronic SCI patients (n = 100, 50 in each arm) admitted in the hospital and undergoing treatment and rehabilitation were recruited based on eligibility and their willingness to participate in the trial with written informed consent. Based on patients' choice, subjects were recruited by the consultant in the treating team to either experimental intervention group (add on easy raja yoga with conventional rehabilitation-ER) or control intervention group (conventional rehabilitation alone-CR). All the subjects continued with their conventional treatment as prescribed by the treating team. Patients' unwillingness to participate in the study had no impact on regular treatment.

SCI patients in the age group of 16–60 years of either sex, either tetraplegic or paraplegic, with ability to understand the instructions were recruited. Patients who cannot sit for at least 30–45 min; expected to discharge within 1 month; with polytrauma; critically ill requiring life support measures like ventilator were excluded.

Patients in the ER group were taught a structured, easy raja yoga module by a qualified easy raja yoga teacher for 1 month along with conventional rehabilitation, and the CR group patients were given only conventional rehabilitation delivered by a multidisciplinary team including physician/surgeon, nurse, psychologist, physiotherapist, occupational therapist, peer counselor and dietician. All subjects were assessed at the beginning and end of 1 month with the following measures. Baseline and post data were collected by a trained physiotherapist who was not involved in recruitment or statistical analysis of the data.

Hospital anxiety and depression scale

Zigmond and Snaith originally developed this scale in 1983 to determine the levels of anxiety and depression among hospitalized patients.[13] It is a fourteen-item scale with seven items for anxiety and other seven items for depression. The total HADS score may be regarded as a global measure of psychological distress. It's a self-rated scale. Higher score represents higher anxiety and depression.

Perceived stress scale

Sheldon Cohen developed the PSS in 1983.[14] It evaluates the intensity of stress perceived by the individual in real-life situations in the last 1 month. Scores are made on a Likert scale ranging from 0 to 4. Higher score represents higher perceived stress. It is a valid and reliable tool used across disorders and in healthy population.

Spinal cord independence measure

This is a disability scale which describes the ability of person with SCI to accomplish their daily routine activities and functional assessments of this population.[15] This tool is more sensitive to capture the change following any intervention and hence commonly used in clinical trials. It has four sub-scales measuring (i) self-care, (ii) respiration and sphincter management, (iii) mobility in room and toilet and (iv) mobility indoors and outdoors. SCIM-III is the latest version and comprises 19 items score ranges from 0 to 100. Change in score of SCIM III over a period of time reflects functional change overall in a person with SCI.

WHO quality of life-BREF

The WHOQOL-BREF is the short version of WHOQOL-100 developed by the WHOQOL group.[16] It has 26 items measuring four domains comprising of physical health, psychological health, social and environmental health. It is a self-administered scale with scores ranging from 4 to 20 (after transformation for comparability with WHOQOL-100 scores). This scale is used across disorders and in a healthy population to assess the quality of life.

Numeric pain rating

It is a uni-dimensional measure of pain intensity in adults. The NPRS is a visual analog scale in which a respondent selects a number from segmented numeric scale with scores from zero to ten that show the intensity of his/her pain.

Socio-demographic data and the data of different variables measured were coded and entered in an excel sheet. Continuous data such as PSS, HADS, QOL, SCIM, and NPR were tested for normality using the Shapiro–Wilk test. For baseline comparison between groups, t-test for two independent sample mean was used for continuous variables and Chi-square test was used for categorical variables. Analysis of covariance (ANCOVA) was performed with baseline assessment as covariate and intervention group as between factor for comparing the postassessment. The coded data were analyzed by a statistician blind to the intervention using the software? Jamovi 1.2, Amsterdam, Netherlands.[17]

Results

Out of 150 patients approached, 100 agreed to participate in the study, with 50 in ER group and 50 in the CR group allotted as per patients' choice. Among the ER group four patients dropped as they got discharged early and from the CR group five patients dropped (unable to trace contact). There were 46 patients in ER group and 45 patients in the CR group available for analysis. An overview of the study flow is given in [Figure 1].

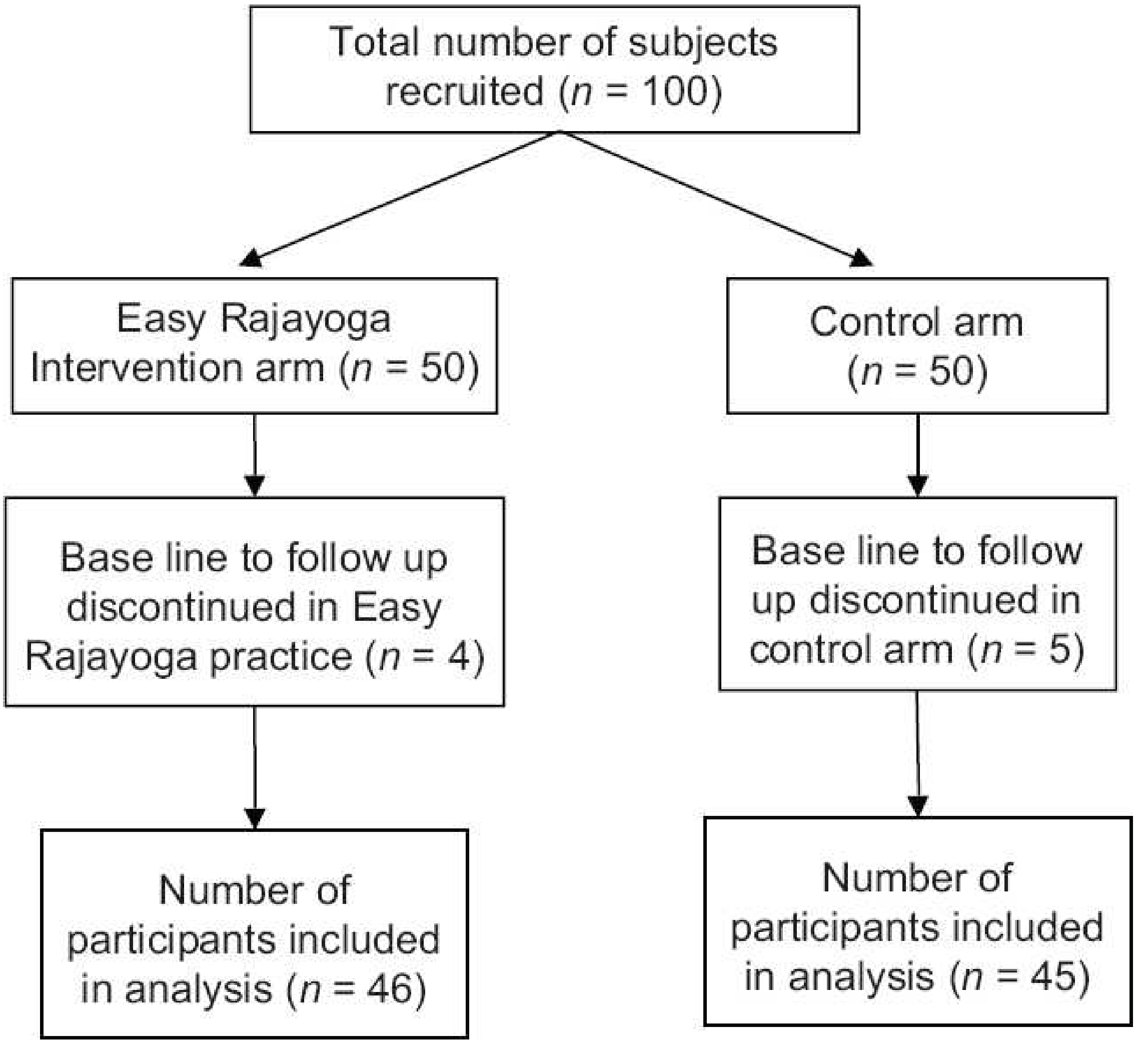


Figure 1: Outline of study flow

Baseline data were compared for both the groups and details are given in [Table 1].

Variables	Intervention (n=46)	Control (n=45)	t/χ^2
Age (years)	31.19 (10.36)	34.48 (12.48)	−1.37
Sex ratio (male:female)	36:10	41:4	2.88
Married:single	26:20	28:17	0.30
Years of education	13.20 (3.13)	13.31 (3.66)	−0.16
PSS	29.98 (6.220)	26.51 (6.622)	2.57*
HADS	28.41 (7.308)	24.02 (8.341)	2.67**
QOL	48.91 (12.207)	55.89 (13.074)	−2.63*
NPR	4.78 (3.076)	4.40 (3.165)	0.58
SCIM	31.76 (15.571)	38.84 (17.272)	−2.05*

*P<0.05; **P<0.01; ***P<0.001. Values within bracket are standard deviation and outside bracket are mean. PSS=Perceived stress scale, HADS=Hospital anxiety and depression scale, SCIM=Spinal cord independence measure, NPR=Numeric pain rating, WHOQOLBREF=WHO quality of life

Table 1: Group-wise baseline data

Data were tested for normality and found to be normally distributed. As there was significant difference at baseline for all the variables except NPR, data were analyzed with ANCOVA with baseline assessment as covariate and intervention group as between factor for comparing the post assessment [Table 2]. Following 1-month easy raja yoga practice, there was significant decrease in the scores of HADS (F(1,88) = 272.92, P < 0.001), PSS (F[(,88) = 274.41, P < 0.001) and NPR (F(1,88) = 60.60, P < 0.001) and significant increase in the scores of WHOQOLBREF (F(1,88) = 349.94, P < 0.001) and SCIM (F(1,88) = 29.09, P < 0.001) in the ER group compared to CR group.

Variable	Group	Mean (SD)		F (df)	Partial η^2
		Pre	Post		
PSS	Intervention	29.98 (6.220)	12.22 (4.412)	274.41*** (1,88)	0.757
	Control	26.51 (6.622)	25.40 (6.580)		
HADS	Intervention	28.41 (7.308)	8.72 (3.828)	272.92*** (1,88)	0.756
	Control	24.02 (8.341)	22.29 (7.754)		
QOL	Intervention	48.91 (12.207)	87.87 (7.265)	349.94*** (1,88)	0.799
	Control	55.89 (13.074)	59.22 (12.954)		
NPR	Intervention	4.78 (3.076)	1.20 (1.572)	60.60*** (1.88)	0.408
	Control	4.40 (3.165)	3.56 (2.590)		
SCIM	Intervention	31.76 (15.571)	46.74 (17.085)	29.09*** (1,88)	0.248
	Control	38.84 (17.272)	44.20 (17.981)		

*P<0.05, **P<0.01, ***P<0.001. PSS=Perceived stress scale, HADS=Hospital anxiety and depression scale, SCIM=Spinal cord independence measure, NPR=Numeric pain rating, WHOQOLBREF=WHO quality of life

Table 2: Pre-post comparison (analysis of covariance)

We also performed post hoc subgroup analysis for the level of injury (paraplegia and tetraplegia) and type of injury (acute SCI and chronic SCI). Subgroup analysis was performed with difference scores (pre minus post) to test for the group difference between ER group and CR group. As the data were found to be normal with Shapiro-Wilk test, independent t-test was performed. Both paraplegia and tetraplegia patients who were in the ER group improved significantly (P < 0.001) [Table 3] than the CR group subjects in PSS, HADS, SCIM, NPR and WHOQOLBREF, though the change in paraplegia patients was more than tetraplegia patients. Similarly, both acute and chronic SCI patients who were in the ER group improved significantly

(P < 0.001) [Table 4] than the CR group in PSS, HADS, SCIM, NPR, and WHOQOLBREF, though acute SCI patients responded with greater change in scores than chronic SCI patients.

Variables	Paraplegia			Tetraplegia		
	Intervention (n=22)	Control (n=29)	t	Intervention (n=24)	Control (n=16)	t
PSS						
Pre	30.1 (6.0)	25.8 (6.2)	−13.54***	29.8 (6.5)	27.9 (7.3)	−9.43***
Post	12.4 (4.5)	24.6 (7.0)		12.1 (4.4)	26.9 (5.7)	
HADS						
Pre	27.9 (7.8)	23.7 (8.2)	−12.71***	28.9 (7.2)	24.6 (8.8)	−8.10***
Post	7.9 (3.8)	21.6 (7.4)		9.5 (3.8)	23.5 (8.6)	
SCIM						
Pre	43.7 (13.2)	47.9(14.4)	4.59***	20.8 (7.5)	22.3 (5.9)	4.82***
Post	62.1 (8.9)	54.7 (13.1)		32.6 (7.9)	25.3 (5.8)	
NPR						
Pre	4.9 (3.1)	4.2 (3.0)	−4.80***	4.7 (3.1)	4.8 (3.5)	−3.76**
Post	0.95 (1.5)	3.4 (2.3)		1.4 (1.6)	3.9 (3.1)	
QOL						
Pre	50.4 (11.1)	58.3 (13.8)	15.81***	47.6 (13.2)	51.4 (10.6)	10.21***
Post	89.4 (7.8)	62.1 (13.2)		86.5 (6.6)	54.1 (11.0)	

*P<0.05, **P<0.01, ***P<0.001. Values within bracket are standard deviation and outside bracket are mean. PSS=Perceived stress scale, HADS=Hospital anxiety and depression scale, SCIM=Spinal cord independence measure, NPR=Numeric pain rating, WHOQOLBREF=WHO quality of life

Table 3: Comparison between intervention and control group for paraplegia and tetraplegia (t values are from independent t-test for difference (pre-post) scores.

Variables	Acute			Chronic		
	Intervention (n=23)	Control (n=21)	t	Intervention (n=23)	Control (n=24)	t
PSS						
Pre	30.6 (5.9)	28.8 (5.9)	−11.56***	29.4 (6.5)	24.50(6.6)	−10.67***
Post	12.4 (4.0)	26.9 (5.5)		12.0 (4.8)	24.0 (7.2)	
HADS						
Pre	29.4 (6.4)	27.8 (6.5)	−12.99***	27.5 (8.1)	20.7 (8.5)	−9.47***
Post	8.7 (3.6)	24.6 (5.4)		8.7 (4.1)	20.3 (8.9)	
SCIM						
Pre	33.6 (16.9)	33.9(13.9)	4.28***	29.9 (14.1)	43.1(18.9)	3.89**
Post	50.3 (16.0)	41.1(14.9)		43.2 (17.7)	46.9(20.2)	
NPR						
Pre	4.7 (3.1)	3.8 (2.9)	−4.44***	4.8 (3.1)	4.9 (3.3)	−3.80***
Post	0.8 (1.3)	2.9 (2.3)		1.6 (1.7)	4.1 (2.7)	
QOL						
Pre	47.0 (10.6)	51.9(10.3)	15.94***	50.8 (13.6)	59.4 (14.4)	10.63***
Post	87.4 (6.5)	57.6 (9.8)		88.3 (8.1)	60.3 (15.3)	

*P<0.05, **P<0.01, ***P<0.001. Values within bracket are standard deviation and outside bracket are mean. PSS=Perceived stress scale, HADS=Hospital anxiety and depression scale, SCIM=Spinal cord independence measure, NPR=Numeric pain rating, WHOQOLBREF=WHO quality of life

Table 4: Comparison between intervention and control group for acute and chronic patients (t values are from independent t-test for difference (pre-post) scores.

Discussion

Study results show that 1-month practice of easy raja yoga helps patients with SCI in reducing depression, anxiety, stress, pain, and enhancing functional independence and quality of life. The results are concurrent with previous studies with mind-body interventions like yogasana, pranayama, and meditation.[7],[8] The results also confirm our primary and secondary hypotheses.

Reduction in anxiety, depression, and stress-related symptoms with mind-body intervention has been reported in SCI patients in few recent studies.[7],[8] It is worth exploring further the possible mechanisms to guide clinicians for these techniques to be applied in bedside practice along with conventional treatment strategies. It would help in avoiding/reducing the prescription of psychotropics for anxiety and depression, which are obviously secondary to the mental trauma following SCI. It would also reduce the burden of psychological distress cascading into social burden in the form of caregivers' stress. Moreover, improving psychological functions would also reduce the mental stress and hence the pain and related consequences like muscle spasticity due to downregulation of hypothalamo-pituitary-adrenal axis stress pathway. One of the key components in easy raja yoga is practicing soul consciousness with self-respect (swaman). This could have mediated increase in self-esteem and hence reduction of depressive symptoms. Many studies in the past had reported the predictive role of self-esteem in depression.[18],[19]

Reduction of pain in chronic pain disorders is one of the robust evidence available for the effect of mind-body interventions, especially in low back pain.[20],[21] Though the mechanisms behind this effect are not clear, this is one of the consistent findings. Previous studies too have documented reduced pain in patients with SCI.[6],[22] In this study, reduction in pain score following easy raja yoga could be due to the practice of sakshi bhav (equanimity), which is integral to easy raja yoga. Sakshi bhav is a mental state where one consciously witnesses the pleasant and unpleasant happenings (either in the body, mind or social relations) as it unfolds.[23] Sakshi bhav though similar to mindfulness, is different in many aspects, especially the context with which it is practiced in raja yoga. The understandings required for the practice of sakshi bhav in raja yoga are as follows:

1. Peace and positivity are our original nature; pain, suffering, and all negative emotions are acquired due to ignorance of our original nature of positivity. Hence anchoring ourselves to our original nature enables to stop reacting to the pain and suffering in the body, mind, or social relations.

2. Everything in this universe, both matter and nonmaterial beings (like soul), pass through the stages of sato, rajo and tamo. Pain and suffering are the indications of tamo stage prevailing all around. Understanding this Universal flow equips one to realize the need for creating the positive feeling in the self (i.e., recreating a sato stage) instead of getting struck with the question of why me? It empowers one to perform the subtle but powerful actions of right thinking and creating pleasant feelings instead of entangling in the vicious cycle of pain and suffering. It gives a sense of hope by consciously keeping away from the trauma created by the past.

3. The supreme/Universal being (conceptualized as a Divine point of light) is a wonderful source of positive energy, as He is away from the effect of past, present, and future. Focusing on this Divine energy, which is actually called yoga in eastern scriptures, would encourage one to inculcate the virtue of equanimity or sakshi bhav with ease.

Improvement in quality of life and functional independence could be due to the profound psychological and spiritual impact of easy raja yoga on thoughts, emotions, and behavior of the patients. Similar to other established psychosocial interventions such as cognitive behavioral therapy, coping effectiveness training, and pain management program,[24] easy raja yoga could also be one of the psychosocial intervention programs for SCI patients, especially in the eastern population. As psychological stress could influence cognition, affect and behavior, including physical functioning of an individual,[25],[26] so could positive and elevated spiritual thoughts impact the triad of cognition, affect, and conation. Recent studies have shown improvement of real-world functioning socially and occupationally with mind-body interventions possibly mediated by the experience of well-being due to positive thoughts and feelings.[27],[28] Some studies have found improvement in musculoskeletal functions like improved posture and gait balance, reduced spasticity following mind-body practices in disorders like Parkinson, and multiple sclerosis supporting this notion.[29],[30],[31],[32] Apart from the indirect effect of psychological factors affecting physical process in mind-body practices, studies have also shown meditation and lifestyle modification directly affect the body causing structural changes like increased cortical thickness and reduced telomere shortening.[33],[34],[35] Though the study results are encouraging, there are several limitations of this study. Being a nonrandomized controlled trial, results need to be tested further in a planned randomized controlled trial to avoid bias in the selection and recruitments of the subjects, which impacts the results considerably. All rating scales used in this study were self-rated except SCIM.

Self-rated scales have the merit of capturing outcome responses as close to subjects' experience as possible but at the cost of social desirability bias leading to type 1 error very commonly. Though most of the SCI patients develop depression and anxiety, systematic evaluation of depression to qualify syndromal depression was not done. Only s?hort-term effect is demonstrated in this study. Whether the effects would persist for longer duration needs to be tested in future long term follow-up studies. Investigating inflammatory and cognitive biomarkers would add more validity to the results to support the psychological findings. Easy raja yoga intervention was delivered at the hospital setup. Whether it could be translated in a community set up after the patients get discharged needs to be explored further. Future trials could focus more on the aforementioned limitations and explore the possible biological mechanisms for the available evidence of efficacy.

Conclusion

One-month add on easy raja yoga improves psychological and functional outcomes in patients with SCI along with improvement in the quality of life and subjective measure of pain. Further studies with the robust design are required to validate the efficacy of easy raja yoga on psychological and functional outcomes. Possible biological mechanisms also need to be studied systematically for its applications in clinical set up.

Ethical clearance: The study was approved by the institutional ethics committee (REF ISIC/IIRS/RP/2015/111).

Financial support and sponsorship: Nil.

Conflicts of interest: There are no conflicts of interest.

References

1. Spinal Cord Injury. Available from: https://www.who.int/news-room/fact-sheets/detail/spinal-cord-injury [Last accessed on 2020 Sep 04].
2. Craig A, Nicholson Perry K, Guest R, Tran Y, Dezarnaulds A, Hales A, et al. Prospective study of the occurrence of psychological disorders and comorbidities after spinal cord injury. Arch Phys Med Rehabil 2015;96:1426-34.
3. Williams R, Murray A. Prevalence of depression after spinal cord injury: A meta-analysis. Arch Phys Med Rehabil 2015;96:133-40.
4. Craig A, Tran Y, Wijesuriya N, Middleton J. Fatigue and tiredness in people with spinal cord injury. J Psychosom Res 2012;73:205-10.
5. Kennedy P, Hasson L. The relationship between pain and mood following spinal cord injury. J Spinal Cord Med 2017;40:275-9.
6. Curtis K, Hitzig SL, Leong N, Wicks C, Ditor DS, Katz J. Evaluation of a modified yoga program for persons with spinal cord injury. Ther Recreation J 2015;49:97.
7. Madhusmita M, Ebnezar J, Srinivasan TM, Mohanty PP, Deepeshwar S, Pradhan B. Efficacy of yoga as an add-on to physiotherapy in the management of patients with paraplegia: Randomised controlled trial. J Clin Diagn Res 2019;13:KC01-6.
8. Taylor SM, Cheung EO, Sun R, Grote V, Marchlewski A, Addington EL. Applications of complementary therapies during rehabilitation for individuals with traumatic Spinal Cord Injury: Findings from the SCIRehab Project. J Spinal Cord Med 2019;42:571-8.
9. Wahbeh H, Elsas SM, Oken BS. Mind-body interventions: Applications in neurology. Neurology 2008;70:2321-8.
10. Gupta SK, Sawhney RC, Rai L, Chavan VD, Dani S, Arora RC, et al. Regression of coronary atherosclerosis through healthy lifestyle in coronary artery disease patients—Mount Abu Open Heart Trial. Indian Heart J 2011;63:461-9.
11. Kiran U, Ladha S, Makhija N, Kapoor PM, Choudhury M, Das S, et al. The role of Rajyoga meditation for modulation of anxiety and serum cortisol in patients undergoing coronary artery bypass surgery: A prospective randomized control study. Ann Card Anaesth 2017;20:158-62.
12. Does Raja Yoga meditation Bring out Physiological and Psychological General Well Being Among Practitioners of It? Available from: http://internalmedicine.imedpub.com/does-raja-yoga-meditation-bring-out-physiological-andpsychologi-

cal-general-well-being-among-practitioners-of-it.php?aid=6409. [Last accessed on 2020 Sep 04]
13. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand 1983;67:361-70.
14. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav 1983;24:385-96.
15. Catz A, Itzkovich M, Agranov E, Ring H, Tamir A. SCIM—spinal cord independence measure: A new disability scale for patients with spinal cord lesions. Spinal Cord 1997;35:850-6.
16. Group W. Development of the World Health Organization WHOQOL-BREF quality of life assessment. The WHOQOL Group. Psychol Med 1998;28:551-8.
17. Love J, Dropmann D, Selker RJ. Jamovi. Amsterdam, Netherlands: Jamovi Project; 2018.
18. Sowislo JF, Orth U. Does low self-esteem predict depression and anxiety? A meta-analysis of longitudinal studies. Psychol Bull 2013;139:213-40.
19. Brown GW, Andrews B, Harris T, Adler Z, Bridge L. Social support, self-esteem and depression. Psychol Med 1986;16:813-31.
20. Astin JA. Mind-body therapies for the management of pain. Clin J Pain 2004;20:27-32.
21. Cramer H, Lauche R, Haller H, Dobos G. A systematic review and meta-analysis of yoga for low back pain. Clin J Pain 2013;29:450-60.
22. Curtis K, Hitzig SL, Bechsgaard G, Stoliker C, Alton C, Saunders N, et al. Evaluation of a specialized yoga program for persons with a spinal cord injury: A pilot randomized controlled trial. J Pain Res 2017;10:999-1017.
23. Prajapita Brahmakumaris Ishwariya Vishwa Vidyalaya. Avyakt Murli 2009-2010. Mount Abu: Gyanamrit Bhavan; 2010.
24. Li Y, Bressington D, Chien WT. Systematic review of psychosocial interventions for people with spinal cord injury during inpatient rehabilitation: Implications for evidence-based practice. Worldviews Evid Based Nurs 2017;14:499-506.
25. Lin N, Ensel WM. Life stress and health: Stressors and resources. Am Sociol Rev 1989;54:382-99.
26. DeLongis A, Folkman S, Lazarus RS. The impact of daily stress on health and mood: Psychological and social resources as mediators. J Pers Soc Psychol 1988;54:486-95.
27. Duraiswamy G, Thirthalli J, Nagendra HR, Gangadhar BN. Yoga therapy as an add-on treatment in the management of patients with schizophrenia A randomized controlled trial. Acta Psychiatr Scand 2007;116:226-32.
28. Varambally S, Gangadhar BN, Thirthalli J, Jagannathan A, Kumar S, Venkatasubramanian G, et al. Therapeutic efficacy of add-on yogasana intervention in stabilized outpatient schizophrenia: Randomized controlled comparison with exercise and waitlist. Indian J Psychiatry 2012;54:227-32.
29. Oken BS, Kishiyama S, Zajdel D, Bourdette D, Carlsen J, Haas M, et al. Randomized controlled trial of yoga and exercise in multiple sclerosis. Neurology 2004;62:2058-64.
30. Velikonja O, Curic K, Ozura A, Jazbec SS. Influence of sports climbing and yoga on spasticity, cognitive function, mood and fatigue in patients with multiple sclerosis. Clin Neurol Neurosurg 2010;112:597-601.
31. Ahmadi A, Nikbakh M, Arastoo A, Habibi AH. The effects of a yoga intervention on balance, speed and endurance of walking, fatigue and quality of life in people with multiple sclerosis. J Hum Kinet 2010;23:71-8.
32. Roland KP. Applications of yoga in Parkinson's disease: A systematic literature review. Res Rev Parkinsonism 2014;4:1-8.
33. Afonso RF, Balardin JB, Lazar S, Sato JR, Igarashi N, Santaella DF, et al. Greater cortical thickness in elderly female yoga practitioners A cross-sectional study. Front Aging Neurosci 2017;9:201.
34. Lazar SW, Kerr CE, Wasserman RH, Gray JR, Greve DN, Treadway MT, et al. Meditation experience is associated with increased cortical thickness. Neuroreport 2005;16:1893-7.
35. Schutte NS, Malouff JM, Keng SL. Meditation and telomere length: A meta-analysis. Psychol Health 2020;35:901-15.

Correspondence Address:
Ramajayam Govindaraj
Centre for Consciousness Studies, Department of Neurophysiology, National Institute of Mental Health and Neurosciences, Hosur Road, Bengaluru - 560 029, Karnataka
India

Source of Support: None, Conflict of Interest: None

SCIENTIFIC REPORTS
natureresearch

Check for updates

OPEN

Rajyoga meditation induces grey matter volume changes in regions that process reward and happiness

M. G. Ramesh Babu[1], Rajagopal Kadavigere[2], Prakashini Koteshwara[2], Brijesh Sathian[3] & Kiranmai S. Rai[1]✉

Studies provide evidence that practicing meditation enhances neural plasticity in reward processing areas of brain. No studies till date, provide evidence of such changes in Rajyoga meditation (RM) practitioners. The present study aimed to identify grey matter volume (GMV) changes in reward processing areas of brain and its association with happiness scores in RM practitioners compared to non-meditators. Structural MRI of selected participants matched for age, gender and handedness (n = 40/group) were analyzed using voxel-based morphometric method and Oxford Happiness Questionnaire (OHQ) scores were correlated. Significant increase in OHQ happiness scores were observed in RM practitioners compared to non-meditators. Whereas, a trend towards significance was observed in more experienced RM practitioners, on correlating OHQ scores with hours of meditation experience. Additionally, in RM practitioners, higher GMV were observed in reward processing centers—right superior frontal gyrus, left inferior orbitofrontal cortex (OFC) and bilateral precuneus. Multiple regression analysis showed significant association between OHQ scores of RM practitioners and reward processing regions right superior frontal gyrus, left middle OFC, right insula and left anterior cingulate cortex. Further, with increasing hours of RM practice, a significant positive association was observed in bilateral ventral pallidum. These findings indicate that RM practice enhances GMV in reward processing regions associated with happiness.

An important aspect of human life is the subjective experiences of happiness[1,2]. Happiness necessarily does not merely depend on wealth and material possessions[3,4], but a kind of subjective feeling of positive emotions linked to pleasure and pleasant feelings. It is challenging to define happiness because of its subjective nature. It can be conceptualized by two general approaches, hedonic and eudaimonic. Hedonic approach importantly focusses on affective components such as positive emotions and pleasure, whereas the eudaimonic approach mainly focuses on personal well-being that includes concepts of personal growth, purpose in life and sense of autonomy. Individual happiness depends on the coherence functions of both approaches[5,6]. Happiness plays a crucial role in positive psychology and the fundamental goal of many individuals[7], which can be achieved by practicing meditation regularly. Meditation awakens the individual's inner consciousness and allows them to remain in conscious attention and positive state of mind despite fluctuating experiences of the external environment at any given moment. This helps to achieve happiness.

Studies on happiness by psychologists have helped to identify various features of happiness, whereas investigations by neuroscientists have identified the functional neuroanatomy of reward and pleasure together, providing a comprehensive insight into happiness[8]. Happiness is most relevant to reward and pleasure that are multifaceted psychological concepts. The process within the phenomenon of reward consists of motivation (wanting), learning and affect (happiness—pleasure liking)[5]. Physiological, pharmacological, and behavioral studies confirm that dopamine secreting regions in the nucleus accumbens (NAcc) located in the ventral striatum (VS) and ventral tegmental area (VTA) of the brain play a central role in reward[9]. The NAcc is known as "pleasure center" in the brain and is known to generate positive hedonic states regardless of any source of pleasure-inducing stimuli

[1]Department of Physiology, Melaka Manipal Medical College, Manipal Academy of Higher Education [MAHE], Manipal, Karnataka 576104, India. [2]Department of Radiodiagnosis and Imaging, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, Karnataka 576104, India. [3]Deputy Chair for Research, Geriatrics and Long Term Care Department, Rumailah Hospital, PO Box-3050, Doha, Qatar. ✉email: kiranmai.rai@manipal.edu

such as monetary reward, social reward, food, water, sex, drugs, etc. It involves the regulation of subjective and behavioral aspects of pleasure and reward. Further, activation of NAcc helps one to be in joyful states, achieved by repeated contemplative practices[10]. The dopamine secreting neurons in these regions play an essential role in positive emotions by mediating pleasure and positive reinforcement[11,12]. Whereas in a study by Pecina et al. 2006, opioid secreting neurons have been reported to be responsible for regulating pleasure in animals[13]. Though NAcc plays an important role in reward processing, it is also involved in modulating behavior to aversive and painful stimuli[14].

Recent studies on reward centers emphasize that there are more extensive brain areas involved in the reward process apart from VTA and NAcc. Research studies on both animals and humans show that VTA is activated when reward is obtained. This center further innervates the NAcc, and the orbitofrontal cortex (OFC). Activation in medial OFC is associated with subjective reports of pleasure for musical, olfactory, and gustatory stimuli, at the time of a reward[15]. By using state of the art of neuro-imaging technologies like positron emission tomography and functional magnetic resonance imaging (MRI), various other regions, including cortical and subcortical regions, were identified to be involved in reward processing in the human brain. The cortical regions include OFC, cingulate cortex, medial prefrontal cortex (mPFC), and insula. The subcortical regions consist of the NAcc, ventral pallidum (VP), substantia nigra (SN), and VTA. These areas are also called "hedonic hotspots" which form reward-related circuitry in the brain[5,8]. These identifications reveal that the cortico-basal ganglia network is an integral part in reward circuit which is a central component for developing and monitoring motivated behavior. Besides, the limbic structure such as the hippocampus and amygdala send inputs to the VS and takes part in reward processing. VP plays a vital role in integrating the GABA, glutamate, opioid, and dopamine signals from NAcc, striatum, amygdala, and prefrontal cortex[9]. VP involves in learning, motivation, and reward through mesocorticolimbic circuits[16]. A study on SOHAM meditation suggests that higher grey matter density in VP is associated with reward processing and positive motivation[17]. Apart from these cortical and sub-cortical regions that involve in reward process, the precuneus also engages in different other processing such as reward-based decision-making task. It is a key structure in the default mode network that exhibits task-dependent connectivity within this network and right frontoparietal network[18,19]. Several studies reported the importance of precuneus, which has a role in the subjective experience of happiness, including emotional and cognitive components and subjective well-being[1,2,20,21].

The term Raja yoga has been described in many scripts and texts including the Bhagavat Gita, and books rewritten by Yoga Sutra of Patanjali, Raja Yoga by Swami Vivekananda etc. In this manuscript Rajyoga meditation (RM) refers to Brahmakumaris school of thought which describes the basis for this type of meditation. RM is different from other types of meditation as it is an open-eye meditation technique. Most of the mediation techniques are closed-eye meditation practice focusing on their thoughts or count breathing, or chanting mantra, or remaining silent, etc. In RM practice, a person is instructed to realize himself/herself as self/soul (an eternal form of point of light) situated between the eyebrows while gazing on a meaningful external symbol (a point of light that is considered as symbolic representation of Supreme Soul/God)[22]. Also they are instructed to think positively about the innate qualities such as peace, love, bliss, etc. which are latent within the self[23,24]. There are very few studies published on RM, particularly in the field of neurocognitive research. A study by Sharma, K 2018, using electroencephalography (EEG), observed alpha and theta wave pattern in frontal and parietal areas of the brain that involves in the processes of regulation of selective and sustained attention for emotional and cognitive processing in long-term RM practitioners during meditation[23]. In another EEG study, enhanced lower alpha power in EEG recording was observed in the long-term as well as a short-term meditation practice. It suggests that the RM practitioners can move into a stable state of meditation within a few minutes irrespective of their meditation training. However, long-term practitioners can attain this state quicker than short-term meditators under varying external conditions. Hence RM practice, being an open-eye meditation technique, has potential applications in daily life[25]. A combined EEG and functional MRI study by Panda 2016, has provided the first evidence on the mental state during rest and meditative state of RM practitioners by analyzing on spatial extents and temporal dynamics of the default mode network[26]. These studies in RM practitioners suggest that the open-eye meditation technique plays a potential role in daily life and influences the brain regions that are mentioned in various other types of meditation techniques.

There are no studies have reported the impact of RM practice on inducing changes in reward processing areas of brain that are associated with subjective states of happiness. Therefore, we hypothesize that RM practice will induce grey matter volume (GMV) changes in brain regions that process reward and happiness and more years of RM experience will induce more GMV changes in brain regions that process reward. Thus, the aim of the present study was to identify RM induced neural changes in the brain regions that are involved in reward processing and its association with individual happiness scores measured by using Oxford happiness questionnaire (OHQ). To test our hypothesis, ROI masks created were used for the brain regions involved in reward process and happiness by applying threshold free cluster enhancement (TFCE) approach.

Results

Analysis of OHQ. RM practitioners showed a significantly higher OHQ score (mean ± SD: 131.88 ± 16.74), (t = 3.33, df = 78, p = 0.001) than non-meditators (NM) (mean ± SD, 118 ± 18.17). Further on analysis, a trend towards significant positive association was observed (Spearman's correlation coefficient = 0.276, p = 0.084) when OHQ scores were correlated with normalized hours of meditation experience (Fig. 1).

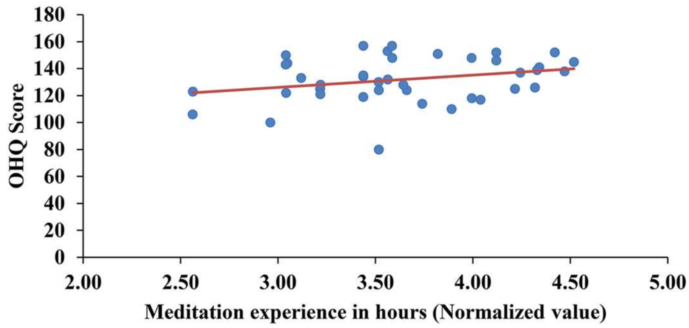


Figure 1. Correlation of OHQ scores with normalized hours of meditation experience showing a trend towards significance ($p = 0.084$).

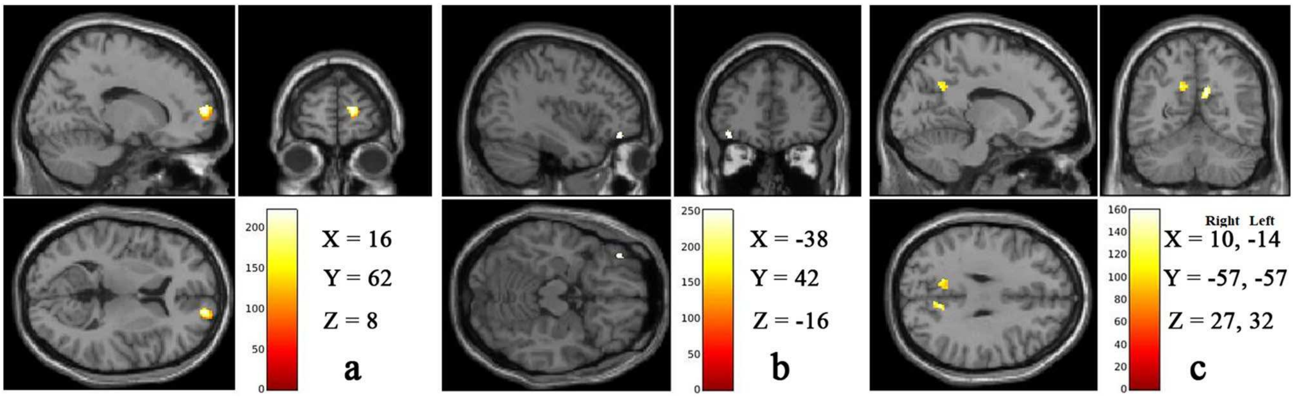


Figure 2. Representative structrual MRI images, showing significant difference ($p < 0.05$ FWE TFCE corrected) in (**a**) right superior frontal gyrus, (**b**) inferior orbitofrontal gyrus and (**c**) bilateral precuneus in RM practitioners than NM. Color bar represents TFCE-value. These representative structural MRI images were compiled and MNI coordinates were inserted into this compiled image using Adobe Photoshop version CS3 (https://www.adobe.com/in/).

Brain regions	Side	MNI coordinates			k	*p*-value*
		X	Y	Z		
Superior frontal gyrus	Right	16	62	8	280	0.005
Inferior orbito frontal cortex	Left	− 38	42	− 16	45	0.037
Precuneus	Right	10	− 57	27	264	0.011
	Left	− 14	− 57	32	112	0.019

Table 1. GMV increase in brain regions that process reward and happiness of RM practitioners. *$p < 0.05$ FWE TFCE corrected, k = cluster size (number of voxels).

Comparison of GMV of reward centers of brain between RM practitioners and NM. In RM practitioners, a significant increase in GMV in the right superior frontal gyrus (SFG), left inferior OFC, and bilateral precuneus were observed as shown in Fig. 2. The details of peak voxel coordinates in MNI space, numbers of voxels in a cluster and p values are given in Table 1.

Association of GMV of brain regions that process reward and happiness with their OHQ scores in RM practitioners. The result of multiple regression analysis showed a correlation of OHQ scores with brain regions related to reward processing in RM practitioners and not in NM. A significant positive correlation was found in the right SFG, left middle OFC, right insula and left ACC (Fig. 3) in RM practitioners. No significant negative correlations in brain regions that process reward and happiness were observed in RM practitioners. Table 2 shows details of cluster size of the identified brain regions, x, y, z coordinates in MNI space and *p*-values.

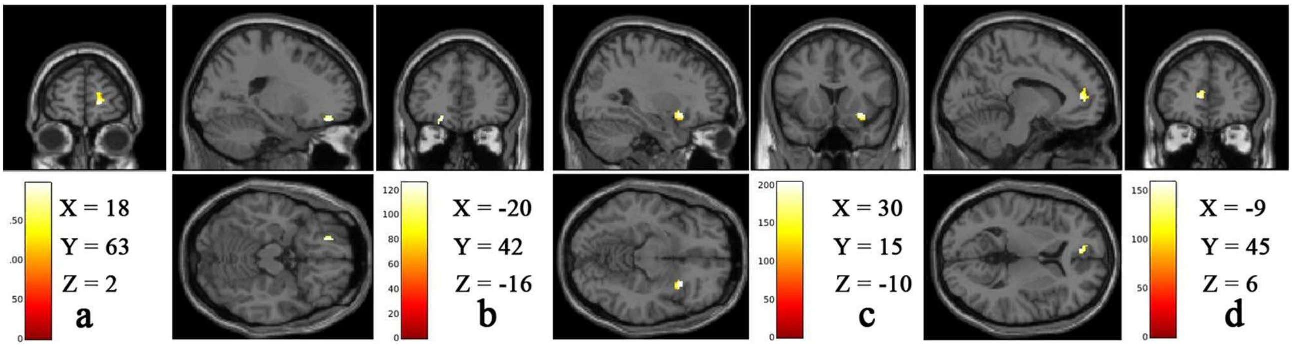


Figure 3. Representative structual MRI image, showing significant ($p<0.05$, FWE TFCE corrected) positive correlation with GMV of (**a**) right superior frontal gyrus, (**b**) left middle orbitofrontal gyrus, (**c**) right insula and (**d**) left anterior cingulate cortex in RM practitioners. Color bar represents TFCE value. These representative structural MRI images were compiled and MNI coordinates were inserted into this compiled image using Adobe Photoshop version CS3 (https://www.adobe.com/in/).

Brain regions	Side	MNI coordinates			k	*p*-value*
		X	Y	Z		
Superior frontal gyrus	Right	18	63	2	357	0/008
Middle orbitofrontal cortex	Left	− 20	42	− 16	58	0.002
Insula	Right	30	15	− 10	155	0.001
Anterior cingulate cortex	Left	− 9	45	6	195	0.027

Table 2. Positive association of OHQ scores with reward processing areas of the brain in RM practitioners. *FWE TFCE corrected *p* value, k = cluster size (number of voxels).

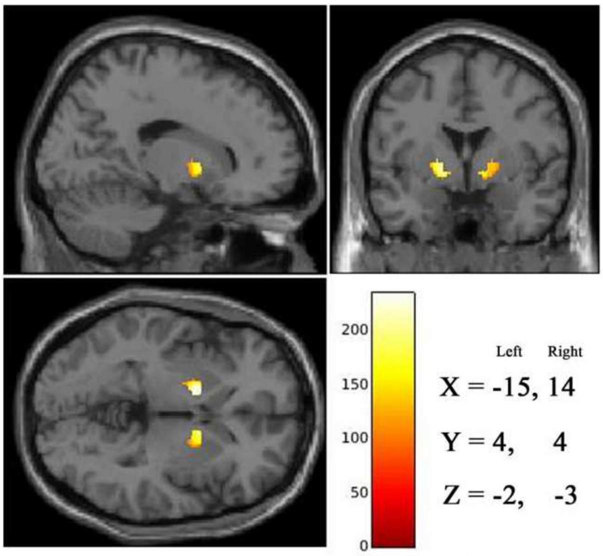


Figure 4. Representative structural MRI image, showing significant ($p<0.05$ FWE TFCE corrected) positive association of GMV of bilateral ventral pallidum in RM practitioners with hours of meditation practice. Color bar represents TFCE value. These representative structural MRI images were compiled and MNI coordinates were inserted into this compiled image using Adobe Photoshop version CS3 (https://www.adobe.com/in/).

Brain regions	Side	MNI Coordinates			k	*p*-value*
		X	Y	Z		
Ventral Pallidum	Left	− 15	4	−2	220	0.009
	Right	14	4	− 3	203	0.016

Table 3. Correlation of meditation experience associated with GMV change in ventral pallidum in RM practitioners. *FWE TFCE corrected *p*-value, k = cluster size (number of voxels).

GMV of brain regions that process reward and happiness associated with hours of meditation experience. A significant positive association was found in bilateral VP of brain regions related to reward processing in RM practitioners on performing multiple regression analysis to correlate meditation experience, as shown in Fig. 4. There were no significant negative correlations observed in RM practitioners. Table 3 shows details of cluster size of the identified brain regions, x, y, z coordinates in MNI space and *p*-values.

Discussion

In the present study, RM practitioners had significantly higher OHQ scores than NM. Additionally, a trend towards significance in OHQ scores was observed in RM practitioners with more hours of RM experience. An earlier study on mindfulness meditation reported that happiness, self-compassion and higher levels of dispositional mindfulness are positively associated with frequency of meditation practice[27]. In contrary to this report, the present study shows that the association between happiness scores and RM experience was not significantly correlated, although there was a trend towards significance. This suggests that RM practice can improve happiness levels, irrespective of hours of RM experience. The higher happiness scores observed in experienced RM practitioners maybe because of emphasizing on a fundamental spiritual understanding of self and rediscovering the latent positive qualities within an individual[22,28].

Further, group comparison between RM and NM showed that RM practitioners had higher GMV in the right precuneus. Studies show that this region along with the posterior cingulate cortex, is of primary importance since it receives the highest blood flow and cortical glucose metabolism at rest, as it is a part of the default mode network. Neuroimaging studies in humans reveal its essential role in subjective consciousness[29] and subjective experience[30] for integrating internal and external information[31]. Thus, the precuneus region appears to be involved in gathering information from different modes at a conscious level and is responsible for the subjective experience of happiness. A study on healthy volunteers using subjective happiness measure, purpose in life, positive and negative emotional intensity scales by Sato W 2015, reported a positive association between GMV of precuneus with subjective measures of happiness in healthy volunteers. This study suggests that the precuneus plays a vital role in mediating subjective experience of happiness by combining emotional and cognitive components of happiness[2]. Neuroimaging studies using VBM analytical technique on meditators have also shown findings of higher GMV in the precuneus region. In a pilot study by Kurth F 2014, observed higher GMV in the right precuneus after mindfulness meditation intervention and suggested that this region is essential for meditation practice[32]. This region has extensive communication with resting-state and external task regions. It processes self-relevant information which helps to engage in meditation[33,34]. Thus, in the present study, observation of increased GMV in precuneus in RM practitioners when compared with NM indicates that these changes in the precuneus may be due to higher subjective experiences of happiness in RM practitioners (indicated by their higher OHQ scores).

Moreover, the present study also shows significantly higher GMV in right SFG (part of mPFC) and left ACC that is significantly positively associated with OHQ scores in RM practitioners than those in NM. Both SFG and ACC are part of reward centers[35,36]. Studies on long-term Sahaja yoga meditation and others suggest that mPFC is responsible for maintaining meditation, attention, emotional regulation, behavior and cognitive control[37–39]. The interoceptive functioning of this region contributes to value-based decision-making. Such higher interoceptive abilities are associated with mindfulness meditation experience[40]. Positive thinking and happiness support brain growth, as well as the generation and reinforcement of new synapses, particularly in PFC, which serves as the integration center of all brain-mind functions[41]. The dorsolateral and medial PFC areas are involved in the choice of reward that varies over time and also important in normative decision-making related to monetary reward[42].

Further, a study also shows that insight meditation experience is associated with cognitive control and self-regulation by dorsolateral PFC and dorsal ACC[43]. Greater activation in rostral ACC and dorsal mPFC in mindfulness meditators provides evidence that meditators can keep away from distractions and can control their emotions. The activity in the ACC decreases in long-term adept and Buddhist meditators, which suggests that, as these meditators become more efficient on focused attention, emotional regulation becomes unnecessary[44,45]. Integrative body-mind training, 30 min/day for five days, improves the cerebral blood flow to the ventral ACC, mPFC and insula which are the critical brain regions for self-regulation[46]. Research on transcendental meditation suggests that mPFC and ACC are essential in the mechanism of regulating mental state[47]. ACC is the complex structure that has an extensive connection with other reward regions such as VS and VP[9]. A positive hedonic environment attenuates the ACC activity and is responsible for behavioral adaptation[48]. Studies on ACC and amygdala in mindfulness meditators suggest that ACC helps to maintain the attention to a stimulus and the amygdala is responsible for generating emotions. Through these brain regions, meditation regulates negative thoughts and decreases emotional reactivity that helps to overcome psychiatric disorders such as depression and borderline personality disorders[49,50]. The higher GMV in right SFG and left ACC in the present study indicates that practicing RM may help to gain voluntary control over attention, behavior and emotional regulation.

Additionally, in the present study, a significant increase in GMV in left inferior OFC, right insular cortex and a smaller left middle OFC that was positively associated with happiness scores were observed in RM practitioners. Anatomically, insular region has bidirectional connections with the structures that are related to reward and decision making which includes the OFC, ACC, NAcc, and the amygdala[51]. Insular cortex plays a key role in integrating information related to emotions and introspection. These information are then forwarded to the OFC and ACC, which influence decision making[52]. Functional MRI study in several Buddhist traditions including Shamatha/breath-focus, Vipasana/insight, compassion, Tong-Len and other Tibetan style meditations, suggests that the individuals with more meditation experience may have an enhanced awareness of present moment experience[53]. Insula, along with ACC and striatum, are involved in the maintenance of meditative states with less effort and attentional control[54]. OFC regulates the process of reward and punishment[55]. Increased activation of this region has been observed during reward or loss incurred[56]. A study by Estela C et al. 2009, reported a graded increase in the activation of this region in relation to reward[52]. Greater grey matter concentration in the medial OFC is dependent on mindfulness meditation training might reflect an improved ability to modify emotional responses[57]. Thus, these supporting findings indicate that long-term RM practice may enhance awareness of present moment experience, attentional control and helps the practitioner to maintain the meditative states with less effort.

Finally, the interesting finding in the present study is the significant correlation of GMV in bilateral VP with hours of RM experience. VP is part of the basal ganglia and is well known to play an important role in the planning and regulation of motor activity. Modern-day high-resolution human brain imaging technology validates and clarifies the role of the VP in human emotional response and psychiatric disorders[58]. Accumulating evidence from recent studies reveals that apart from its role in motor activity, the VP also plays an essential role in hedonic response to a pleasant stimulus. Also, VP produces this response in the background activity of ACC[5,59]. The dopaminergic fibers regulate the activity of glutamatergic neurons from the frontal cortex to striatum and project back to the frontal cortex via pallidum and thalamus. It is reported that increased dopamine release during meditation, which suppresses the cortico-striatal glutamatergic transmission, is associated with motor control. The increase of dopamine associated with meditation training may contribute to dopaminergic neurogenesis[37]. VP is one of the central components of the reward circuit which sub-serve the functions of positive motivation and reward[9]. The VP receives a reward signal from NAcc and other forebrain limbic structures to execute it[60,61]. Studies on volunteers who had chronic pain and sadness correlate with the deactivation of m-opioid receptors in the VP. This is identified that they had behavioral problems associated with negative affect which suggests that the m-opioid receptors in the VP regulate the positive affect. It regulates the affective/motivational process at the conscious or unconscious level[58,62,63]. A study on SOHAM meditators suggests that higher grey matter density in VP is associated with reward and positive motivation[17].

Additionally, an earlier study shows that reward-centers down-regulate hedonic effects themselves as a result of repeated exposure of worldly rewards corresponding to the conditioned suppression of dopamine[64]. Everyday thought patterns that are repetitive, predictable and rewarded behaviors initially support their development but later may lose their ability to process the rewarded behavior which has become repetitive. This may be due to a continuous suppression of dopamine-related activity in NAcc[10] which is the key region in reward processing. This may explain the reason for not findings a significant increase in GMV or any correlation in VS and NAcc, in the present study. Moreover, the interesting finding in the present study is the significant positive association of GMV in bilateral VP with RM experience, which may indicate that RM practice may contribute to the automatic mind states of developing positive motivation and experience of reward.

The potential limitation in the present study is the education levels which were not matched between groups. Education plays an important role in brain modulation based on the individual's education levels and may introduce a confounding effect if not matched[65–67]. The hippocampus and amygdala regions play an important role in the reward processing[9] are directly or indirectly influenced by levels of education of the participants. In this study, no significant changes were observed in the hippocampus and amygdala either in *t*-test or in correlation analysis even after adding education levels as a covariate. In the future, repeating a similar type of study with larger sample size and matching years or levels of education may help to overcome this confounding effect.

Conclusion

This study provides the first evidence for the underlying neural substrate of higher GMV changes in reward processing areas of RM practitioners including right SFG, left ACC, left OFC, right insula and bilateral VP as well as precuneus an important structure that mediates happiness. This was observed to be associated with higher happiness scores in RM practitioners compared to the happiness levels in NM. Besides, years of RM experience was observed to enhance GMV in these reward processing regions to greater extents. However, the happiness scores were not positively associated with hours of meditation experience, indicating that RM practice provides happiness, irrespective of the time span of RM experience, and RM practice may contribute to the automatic mind states of developing positive motivation and experience of reward.

Methods

Participants. The total number of RM practitioners and non-meditators (NM) in both the groups were eighty (n = 40/group). They were matched for age, gender and handedness. Subjective happiness levels were measured using OHQ and MRI obtained was used to study structural changes in the brain regions that process reward and happiness. The social-demographic details of all participants are given in Table 4. The participants who had the following exclusion criteria for the study, such as metabolic disorders, addiction to drugs or alco-

	Meditators (n-40)	Non-meditators (n = 40)	P value
Age (mean ± SD) (Range: minimum–maximum)	41.28 ± 8.05 (26.4–52.85)	40.06 ± 7.21 (26.32–55.16)	0.48 (t-test)
Gender (n)			
Male	20	20	1.0 (X^2 test)
Female	20	20	
Handedness (n)			
Right	39	39	1.0 (Fisher's exact test)
Left	1	1	
Educational levels			
School	20	21	0.001 (Fisher's exact test)
Degree	3	14	
Postgraduate	13	5	
PhD/PDF	4	0	
Meditation Experience (in hours)	8022.24 ± 8767.24	NA	NA

Table 4. Socio-demographic details of participants. *NA* not applicable.

hol, mental disorders, physical illness, and claustrophobia, were not selected. Participants who were practicing only RM and regularly attending spiritual and meditation classes were recruited from Brahma Kumaris Rajyoga Meditation Centre, Manipal, Udupi, and Mangalore cities of Karnataka, India. The hours of meditation experience were calculated by their years of meditation experience, hour/s spent in meditation per day and hours spent in meditation retreat. NM participants were volunteers for this study and were selected from Manipal, Udupi regions of Karnataka, India. After obtaining approval from the institutional ethical committee (IEC 566/2013) Kasturba Hospital, MAHE, Manipal for human studies, this study was conducted. Standard ethical guidelines laid down by Declaration of Helsinki-World Health Organization was followed for all methods in this study. All the participants were informed about the study well in advance and MRI safety precautions were explained to all. Before the study, a signed-in informed consent form was obtained from each participant.

Psychological test tool. OHQ, developed by Peter Hills in 2002[68], a self-reported cognitive scale that measures subjective happiness level was used for this study. Psychologists and sociologists widely use it as a tool for assessing happiness status[69–73]. OHQ is a unidimensional scale with 29-items, designed to measure happiness status, which is a reliable and valid questionnaire with reliability alpha coefficient of 0.91. It employs a 6-point Likert-type format of the response, from 'strongly disagree' to 'strongly agree, to measure self-reported happiness score. Higher the score more will be the happiness level. The filled-in OHQs by all participants were collected and the total score for the 29 items were calculated. In this study, the overall score of the OHQ was considered.

MRI acquisition. Structural MRI data were acquired for all participants with Philips Acheiva Medical Imaging 1.5 T scanner with 8 SENSE head-coil. High-resolution three-dimensional sets of data of the whole brain were collected using T1 weighted, TFE—turbo field echo sequence. It consists of sagittal partitions with slice thickness 1 mm, TE/TR (echo/repetition time) 3.703 ms /7 ms, flip angle 8°, matrix 256 × 256, 1 × 1 voxel dimension, and field of view 256 mm which yielded 175 slices encompassing the whole brain.

Image analysis. Voxel based morphometric analysis is a method for investigating neuroanatomical alterations in the brain in an unbiased and objective way using T1-weighted structural MRI scans. VBM analysis involves the measurement of voxels in the brain MRI, and regional GMV can be obtained[74]. Statistical comparison of GMV between two or more different experimental groups can be analysed and the statistical significant differences in the volume of brain regions can be established. In recent years, this technique has become very popular and it is also used to detect stimuli-induced morphological changes in the brain where functional MRI is not suitable for study[75]. In the present study to detect GMV changes in brain, VBM method was applied by using the CAT12 toolbox version 12.6 (https://www.neuro.uni-jena.de/cat/) installed in the SPM12 software toolbox (ftp://ftp.fil.ion.ucl.ac.uk/spm), and the common platform for this software was MATLAB software version R2019a.

Initially, all the DICOM images were converted into single file NIFTY format by using MRI Convert version 2.1.0 (https://lcni.uoregon.edu/downloads/mriconvert). Then all the converted images were manually reoriented and fixed with the anterior commissure as origin which matches the canonical image template provided in SPM12. All the preprocessing steps for VBM analysis were carried out using the CAT12 tool as mentioned in the VBM manual (https://www.neuro.uni-jena.de/cat12/CAT12-Manual.pdf). For initial segmentation, a sensitive segmentation method than the normal VBM method known as DARTEL (Diffeomorphic anatomic registration through exponentiated Lie algebra algorithm) segmentation method was applied to segment the MRI images. By this method, we obtained affine transformed images of grey and white matter. TIV estimate option in CAT12 tool generates total intracranial volume (TIV) for each subject and was used for homogeneity check and as nuisance covariate. After the segmentation process, all images were inspected manually by displaying one slice for all images. Moreover, quality of data such as resolution, noise and bias were also obtained. Using this information, the weighted average quality of all images were B or higher, which represents very good quality.

Therefore, none of the images were excluded from the analysis. A study-specific template was created representing the sample of study using affine registered grey and white matter images. Further, this template was used to generate normalized, modulated, non-linear DARTEL warped segmented images of grey and white matter in Montreal Neurological Institute (MNI) Space. A FWHM (full width at half maximum) isotropic Gaussian kernel with 8 mm size was used for VBM statistical analysis.

Creating Region of Interest (ROI) Masks. A 3D ROI sphere mask was created for the regions that represent the reward processing regions using WFU-Pickatlas (Wake Forest University) atlas tool (https://fmri.wfubmc.edu/software/pickatlas) to test the study hypothesis. Bilateral union masks for cortical and sub-cortical centers using "x, y, z" coordinates in MNI space mentioned in the studies related to reward and meditation are as follows: for cortical centers 8 mm masks created for OFC (± 27, 42, – 14)[15,76,77], ACC (± 6, 51, 10)[78], insula (± 30, 10 -15)[38], and precuneus (± 6, 54, 22)[77], regions. For sub-cortical structures, 4 mm masks were created for NAcc (± 10, 9, – 4)[15], VP (± 14, – 10, – 8)[59], basolateral amygdala (± 32, 0, -26)[79], and hippocampus (± 18, – 37, – 11)[80] For mid-brain regions that involve in reward processing, 2 mm masks were created including SN (± 12, – 12, – 12), and VTA (0, – 15, – 12) regions[15,81]. Totally 11 bilateral union masks for reward centers were created. Since this tool creates masks with voxel dimensions of 2 mm in x, y, z directions by default, using a co-register (reslice) option in SPM12, all the masks were co-registered with a VBM output image to get the same voxel dimensions for all ROI masks created.

Statistical analysis. SPSS version 22, was used to perform *t*-test and find out the difference in mean OHQ score between groups. A correlation analysis was performed to correlate hours of meditation experience with OHQ score in RM. Since hours of meditation experience were not normally distributed (mean ± SD: 8022.24 ± 8767.69), a normalized value for hours of meditation experience (mean ± SD: 3.64 ± 0.52) and Spearman correlation coefficient was considered in the correlation analysis. Correlation results were reported significant if the *p*-value < 0.05.

For VBM analysis, to compare between 2 groups, the basic statistical model was applied to conduct a *t*-test to find out voxel-wise gray matter (GM), and white matter (WM) volume changes between NM and RM using the CAT12 toolbox. ANCOVA was performed with a flexible factorial design to compare group differences and adjusted for TIV, age, and education levels which were entered as covariates to remove confounding effect due to variable head/brain size, aging process and influence of education. An absolute threshold masking 0.1 was applied to all the smoothed images to avoid edge effect around the borders of GM and WM. The t-contrasts [-1 1] for NM > RM and [-1 1] for RM > NM were used to measure group differences. A multiple regression analysis was performed to correlate the reward center of the brain with hours of meditation experience and OHQ by entering these variables as independent variables. Since there was collinearity ($cos\ \theta = 0.7$) between these two variables which was identified from the SPM design orthogonality output map. Hence, multiple regression analysis was performed separately for these two independent variables to avoid multi collinearity issues. For both multiple regression analyses TIV, age, and education level were entered as nuisance covariates. The *t*-contrasts [1] for positive correlation and [– 1] for negative correlation were used. All other parameters were kept the same as for the *t*-test. TFCE, a non-parametric methods, with 5000 permutations[82] was applied by using the TFCE tool version 185 (https://dbm.neuro.uni-jena.de/tfce/). This approach combines focal effects with large voxel height and size of the cluster in VBM data. It is more reliable and effective for group-level analysis with or without the requirement of high and uniform spatial smoothness[83]. The 3D ROI sphere masks were used for small volume correction in the TFCE approach. The resultant voxels were considered significant, if it is above the threshold value $p < 0.05$, after correcting for family wise error (FWE) using multiple comparison with TFCE in the ROIs. The final output, SPM statistical map image, was overlaid on the single subject representative image from SPM canonical template.

Received: 30 May 2020; Accepted: 11 September 2020
Published online: 30 September 2020

References

1. Lyubomirsky, S. Why are some people happier than others? The role of cognitive and motivational processes in well-being. *Am. Psychol.* **56**, 239–249 (2001).
2. Sato, W. *et al.* The structural neural substrate of subjective happiness. *Sci. Rep.* **5**, 16891 (2015).
3. Biswas-Diener, R. & Diener, E. Making the best of a bad situation: Satisfaction in the slums of Calcutta. *Soc. Indic. Res.* **55**, 329–352 (2001).
4. Diener, E. & Biswas-Diener, R. Will money increase subjective well-being? A literature review and guide to needed research. *Soc. Indic. Res.* **57**, 119–169 (2002).
5. Kringelbach, M. L. & Berridge, K. C. The functional neuroanatomy of pleasure and happiness. *Discov. Med.* **9**, 579–587 (2010).
6. Campos, D. *et al.* Meditation and happiness: Mindfulness and self-compassion may mediate the meditation-happiness relationship. *Pers. Individ. Dif.* **93**, 80–85 (2016).
7. Cohn, M. A., Fredrickson, B. L., Brown, S. L., Mikels, J. A. & Conway, A. M. Happiness unpacked: Positive emotions increase life satisfaction by building resilience. *Emotion* **9**, 361–368 (2009).
8. Funahashi, S. Brain mechanisms of happiness. *Psychologia* **54**, 222–233 (2011).
9. Haber, S. N. & Knutson, B. The reward circuit: Linking primate anatomy and human imaging. *Neuropsychopharmacology* **35**, 4–26 (2010).
10. Sharp, P. E. Meditation-induced bliss viewed as release from conditioned neural (thought) patterns that block reward signals in the brain pleasure center. *Relig. Brain Behav.* **4**, 202–229 (2014).
11. Schultz, W., Tremblay, L. & Hollerman, J. R. Reward processing in primate orbitofrontal cortex and basal ganglia. *Cereb. Cortex* **10**, 272–283 (2000).

12. Rangel, A., Camerer, C. & Montague, P. R. A framework for studying the neurobiology of value-based decision making. *Nat. Rev. Neurosci.* **9**, 545–556 (2008).
13. Peciña, S., Smith, K. S. & Berridge, K. C. Hedonic hot spots in the brain. *Neuroscientist* **12**, 500–511 (2006).
14. Levita, L. *et al.* The bivalent side of the nucleus accumbens. *Neuroimage* **44**, 1178–1187 (2009).
15. Hagerty, M. R. *et al.* Case study of ecstatic meditation: FMRI and EEG evidence of self-stimulating a reward system. *Neural Plast.* **2013**, 1–12 (2013).
16. Tindell, A. J., Berridge, K. C. & Aldridge, J. W. Ventral pallidal representation of pavlovian cues and reward: population and rate codes. *J. Neurosci.* **24**, 1058–1069 (2004).
17. Kumar, U., Guleria, A., Kishan, S. S. K. & Khetrapal, C. L. Effect of SOHAM meditation on human brain: a voxel-based morphometry study. *J. Neuroimaging* **24**, 187–190 (2014).
18. Utevsky, A. V., Smith, D. V. & Huettel, S. A. Precuneus is a functional core of the default-mode network. *J. Neurosci.* **34**, 932–940 (2014).
19. Kirk, U., Brown, K. W. & Downar, J. Adaptive neural reward processing during anticipation and receipt of monetary rewards in mindfulness meditators. *Soc. Cogn. Affect. Neurosci.* **10**, 752–759 (2015).
20. Lyubomirsky, S. & Lepper, H. S. A measure of subjective happiness: preliminary reliability and construct validation. *Soc. Indic. Res.* **46**, 137–155 (1999).
21. Shi, L. *et al.* Brain networks of happiness: dynamic functional connectivity among the default, cognitive and salience networks relates to subjective well-being. *Soc. Cogn. Affect. Neurosci.* **13**, 851–862 (2018).
22. Ramsay, T., Manderson, L. & Smith, W. Changing a mountain into A mustard seed: spiritual practices and responses to disaster among New York Brahma Kumaris. *J. Contemp. Relig.* **25**, 89–105 (2010).
23. Sharma, K., Chandra, S. & Dubey, A. K. Exploration of lower frequency EEG dynamics and cortical alpha asymmetry in long-term rajyoga meditators. *Int. J. Yoga* **11**, 30–36 (2018).
24. Telles, S. & Desiraju, T. Automatic changes in Brahmakumaris Raja yoga meditation. *Int. J. Psychophysiol.* **15**, 147–152 (1993).
25. Nair, A. K., Sasidharan, A., John, J. P., Mehrotra, S. & Kutty, B. M. Just a minute meditation: rapid voluntary conscious state shifts in long term meditators. *Conscious. Cogn.* **53**, 176–184 (2017).
26. Panda, R. *et al.* Temporal dynamics of the default mode network characterize meditation-induced alterations in consciousness. *Front. Hum. Neurosci.* **10**, 372 (2016).
27. Campos, D. *et al.* Exploring the role of meditation and dispositional mindfulness on social cognition domains: a controlled study. *Front. Psychol.* **10**, 809 (2019).
28. Telles, S., Hanumanthaiah, B., Nagarathna, R. & Nagendra, H. R. Improvement in static motor performance following yogic training of school children. *Percept Mot Ski.* **76**, 1264–1266 (1993).
29. Vogt, B. A. & Laureys, S. Posterior cingulate, precuneal and retrosplenial cortices: cytology and components of the neural network correlates of consciousness. *Prog. Brain Res.* **150**, 205–217 (2005).
30. Lou, H. C., Nowak, M. & Kjaer, T. W. The mental self. *Prog. Brain Res.* **150**, 197–204 (2005).
31. Cavanna, A. E. & Trimble, M. R. The precuneus: a review of its functional anatomy and behavioural correlates. *Brain* **129**, 564–583 (2006).
32. Kurth, F., Luders, E., Wu, B. & Black, D. S. Brain gray matter changes associated with mindfulness meditation in older adults: an exploratory pilot study using voxel-based morphometry. *Neuro* **1**, 23–26 (2014).
33. Kurth, F., MacKenzie-Graham, A., Toga, A. W. & Luders, E. Shifting brain asymmetry: The link between meditation and structural lateralization. *Soc. Cogn. Affect. Neurosci.* **10**, 55–61 (2015).
34. Boccia, M., Piccardi, L. & Guariglia, P. The meditative mind: A comprehensive meta-Analysis of mri studies. *Biomed Res. Int.* **2015**, 1–11 (2015).
35. Dong, G., Lin, X., Hu, Y. & Lu, Q. Brain activity in advantageous and disadvantageous situations: Implications for reward/punishment sensitivity in different situations. *PLoS ONE* **8**, e80232 (2013).
36. Bush, G. *et al.* Dorsal anterior cingulate cortex: A role in reward-based decision making. *Proc. Natl. Acad. Sci. USA* **99**, 523–528 (2002).
37. Kang, D. H. *et al.* The effect of meditation on brain structure: Cortical thickness mapping and diffusion tensor imaging. *Soc. Cogn. Affect. Neurosci.* **8**, 27–33 (2013).
38. Hernández, S. E., Suero, J., Barros, A., González-Mora, J. L. & Rubia, K. Increased grey matter associated with long-term Sahaja yoga meditation: A voxel-based morphometry study. *PLoS ONE* **11**, e0150757 (2016).
39. Lutz, A., Slagter, H. A., Dunne, J. D. & Davidson, R. J. Attention regulation and monitoring in meditation. *Trends Cogn. Sci.* **12**, 163–169 (2008).
40. Kirk, U. & Montague, P. R. Mindfulness meditation modulates reward prediction errors in a passive conditioning task. *Front. Psychol.* **6**, 1–8 (2015).
41. Susan, R. Happy brain, happy life. *Positive Psychology* (2011). https://www.psychologytoday.com/us/blog/prime-your-gray-cells/201108/happy-brain-happy-life. Accessed 27 Sept 2019.
42. Cho, S. S. *et al.* Morphometric correlation of impulsivity in medial prefrontal cortex. *Brain Topogr.* **26**, 479–487 (2013).
43. Fox, K. C. R. *et al.* Meditation experience predicts introspective accuracy. *PLoS ONE* **7**, e45370 (2012).
44. Holzel, B. K. *et al.* Differential engagement of anterior cingulate and adjacent medial frontal cortex in adept meditators and non-meditators. *Neurosci. Lett.* **421**, 16–21 (2007).
45. Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B. & Davidson, R. J. Neural correlates of attentional expertise in long-term meditation practitioners. *Proc. Natl. Acad. Sci. USA* **104**, 11483–11488 (2007).
46. Yuan, K. *et al.* Reduced Fractional Anisotropy of Corpus Callosum Modulates Inter-Hemispheric Resting State Functional Connectivity in Migraine Patients without Aura. *PLoS ONE* **7**, 30–32 (2012).
47. Yamamoto, S., Kitamura, Y., Yamada, N., Nakashima, Y. & Kuroda, S. Medial prefrontal cortex and anterior cingulate cortex in the generation of alpha activity induced by transcendental meditation: a magnetoencephalographic study. *Acta Med. Okayama* **60**, 51–58 (2006).
48. Horga, G. *et al.* Adaptation to conflict via context-driven anticipatory signals in the dorsomedial prefrontal cortex. *J. Neurosci.* **31**, 16208–16216 (2011).
49. Silbersweig, D. *et al.* Failure of frontolimbic inhibitory function in the context of negative emotion in borderline personality disorder. *Am. J. Psychiatry* **164**, 1832–1841 (2007).
50. Abercrombie, H. C. *et al.* Metabolic rate in the right amygdala predicts negative affect in depressed patients. *NeuroReport* **9**, 3301–3307 (1998).
51. Reynolds, S. M. & Zahm, D. S. Specificity in the projections of prefrontal and insular cortex to ventral striatopallidum and the extended amygdala. *J. Neurosci.* **25**, 11757–11767 (2005).
52. Camara, E., Rodriguez-Fornells, A. & Münte, T. F. Functional connectivity of reward processing in the brain. *Front. Hum. Neurosci.* **2**, 19 (2009).
53. Hasenkamp, W. & Barsalou, L. W. Effects of meditation experience on functional connectivity of distributed brain networks. *Front. Hum. Neurosci.* **6**, 1–14 (2012).
54. Tang, Y. Y., Rothbart, M. K. & Posner, M. I. Neural correlates of establishing, maintaining, and switching brain states. *Trends Cogn. Sci.* **16**, 330–337 (2012).

55. Rolls, E. T. The orbitofrontal cortex and reward. *Cereb. Cortex* **10**, 284–294 (2000).
56. O'Doherty, J., Kringelbach, M. L., Rolls, E. T., Hornak, J. & Andrews, C. Abstract reward and punishment representations in the human orbitofrontal cortex. *Nat. Neurosci.* **4**, 95–102 (2001).
57. Holzel, B. K. *et al.* Investigation of mindfulness meditation practitioners with voxel-based morphometry. *Soc. Cogn. Affect. Neurosci.* **3**, 55–61 (2008).
58. Napier, T. C. & Mickiewicz, A. L. The role of the ventral pallidum in psychiatric disorders. *Neuropsychopharmacology* **35**, 337 (2010).
59. Van Steenbergen, H., Band, G. P. H., Hommel, B., Rombouts, S. A. R. B. & Nieuwenhuis, S. Hedonic hotspots regulate cingulate-driven adaptation to cognitive demands. *Cereb. Cortex* **25**, 1746–1756 (2015).
60. Churchill, L., Dilts, R. P. & Kalivas, P. W. Changes in γ-aminobutyric acid, μ-opioid and neurotensin receptors in the accumbens-pallidal projection after discrete quinolinic acid lesions in the nucleus accumbens. *Brain Res.* **511**, 41–54 (1990).
61. Boyke, J., Driemeyer, J., Gaser, C., Büchel, C. & May, A. Training-induced brain structure changes in the elderly. *J. Neurosci.* **28**, 7031–7035 (2008).
62. Zubieta, J. K. *et al.* μ-opioid receptor-mediated antinociceptive responses differ in men and women. *J. Neurosci.* **22**, 5100–5107 (2002).
63. Zubieta, J. K. *et al.* Regulation of human affective responses by anterior cingulate and limbic μ-opioid neurotransmission. *Arch. Gen. Psychiatry* **60**, 1145–1153 (2003).
64. Schultz, W. Predictive reward signal of dopamine neurons. *J. Neurophysiol.* **80**, 1–27 (1998).
65. Tang, X., Varma, V. R., Miller, M. I. & Carlson, M. C. Education is associated with sub-regions of the hippocampus and the amygdala vulnerable to neuropathologies of Alzheimer's disease. *Brain Struct. Funct.* **222**, 1469–1479 (2017).
66. Kang, D. W., Lim, H. K., Joo, S. H., Lee, N. R. & Lee, C. U. The association between hippocampal subfield volumes and education in cognitively normal older adults and amnestic mild cognitive impairment patients. *Neuropsychiatr. Dis. Treat.* **14**, 143–152 (2018).
67. Piras, F., Cherubini, A., Caltagirone, C. & Spalletta, G. Education mediates microstructural changes in bilateral hippocampus. *Hum. Brain Mapp.* **32**, 282–289 (2011).
68. Hills, P. & Argyle, M. The Oxford happiness questionnaire: a compact scale for the measurement of psychological well-being. *Pers. Individ. Dif.* **33**, 1073–1082 (2002).
69. Kamthan, S. *et al.* Happiness among second year MBBS students and its correlates using Oxford Happiness Questionnaire. *J. Oral Biol. Craniofacial Res.* **9**, 190–192 (2019).
70. Malmir, M., Khanahmadi, M. & Farhud, D. Dogmatism and happiness. *Iran. J. Public Health* **46**, 326 (2017).
71. Moghadam, M., Rezaei, F., Ghaderi, E. & Rostamian, N. Relationship between attachment styles and happiness in medical students. *J. Fam. Med. Prim. Care* **5**, 593 (2016).
72. Ramesh, M. G., Sathian, B., Sinu, E. & Rai, K. S. Efficacy of Rajayoga meditation on positive thinking: an index for self-satisfaction and happiness in life. *J. Clin. Diagn. Res.* **7**, 2265–2267 (2013).
73. Medvedev, O. N. & Landhuis, C. E. Exploring constructs of well-being, happiness and quality of life. *PeerJ* **6**, e4903 (2018).
74. Ashburner, J. & Friston, K. J. Voxel-based morphometry - The methods. *Neuroimage* **11**, 805–821 (2000).
75. Naegel, S. *et al.* Short latency gray matter changes in voxel-based morphometry following high frequent visual stimulation. *Neural Plast.* https://doi.org/10.1155/2017/1397801 (2017).
76. Kitayama, S. *et al.* Reduced orbitofrontal cortical volume is associated with interdependent self-construal. *Proc. Natl. Acad. Sci. USA* **114**, 7969–7974 (2017).
77. Kirk, U., Skov, M., Christensen, M. S. & Nygaard, N. Brain correlates of aesthetic expertise: a parametric fMRI study. *Brain Cogn.* **69**, 306–315 (2009).
78. Hernández, S. E., Barros-Loscertales, A., Xiao, Y., González-Mora, J. L. & Rubia, K. Gray matter and functional connectivity in anterior cingulate cortex are associated with the state of mental silence during Sahaja Yoga meditation. *Neuroscience* **371**, 395–406 (2018).
79. Hölzel, B. K. *et al.* Stress reduction correlates with structural changes in the amygdala. *Soc. Cogn. Affect. Neurosci.* **5**, 11–17 (2010).
80. Luders, E., Kurth, F., Toga, A. W., Narr, K. L. & Gaser, C. Meditation effects within the hippocampal complex revealed by voxel-based morphometry and cytoarchitectonic probabilistic mapping. *Front. Psychol.* **4**, 398 (2013).
81. Tomasi, D. & Volkow, N. D. Functional connectivity of substantia nigra and ventral tegmental area: maturation during adolescence and effects of ADHD. *Cereb. Cortex* **24**, 935–944 (2014).
82. Smith, S. M. & Nichols, T. E. Threshold-free cluster enhancement: Addressing problems of smoothing, threshold dependence and localisation in cluster inference. *Neuroimage* **44**, 83–98 (2009).
83. Li, H., Nickerson, L. D., Nichols, T. E. & Gao, J.-H. Comparison of a non-stationary voxelation-corrected cluster-size test with TFCE for group-Level MRI inference. *Hum. Brain Mapp.* **38**, 1269–1280 (2017).

Acknowledgements
We sincerely thank Rajyogini BK. Sowrabha, and BK. Sujatha, from the Rajyoga Meditation Centre, Manipal, for facilitating the meditators to participate in this study. Our sincere thanks to all the participants for volunteering in this study. We are grateful to the staff, especially the radiographers from Department of Radiodiagnosis and Imaging, at the Kasturba Hospital, Manipal, for their support. Our sincere thanks to the faculties of Centre for Imaging, Philips, Manipal for their technical support.

Author contributions
Authors R.B.M.G., R.K., and K.S.R. contributed to the conceptualization of this manuscript. Data analysis and interpretation were carried out by authors R.B.M.G., R.K., B.S. and K.S.R. All authors have contributed for reviewing and editing this manuscript.

Funding
We gratefully acknowledge the support and infrastructure provided by MAHE, Manipal for this study. We are also thankful to the Headquarters of Brahmakumaris Rajyoga Meditation Centre and Rajyoga Education & Research Foundation (RERF), Mount Abu, Rajasthan for permission to recruit local RM practitioners and provide partial financial support for this study.

Competing interests
The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to K.S.R.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

frontiers in Human Neuroscience

ORIGINAL RESEARCH
published: 22 July 2016
doi: 10.3389/fnhum.2016.00372

Temporal Dynamics of the Default Mode Network Characterize Meditation-Induced Alterations in Consciousness

Rajanikant Panda[1,2†], *Rose D. Bharath*[1,2*†], *Neeraj Upadhyay*[3], *Sandhya Mangalore*[2], *Srivas Chennu*[4,5] *and Shobini L. Rao*[1]

[1] Cognitive Neuroscience Center, National Institute for Mental Health and Neurosciences, Bangalore, India, [2] Department of Neuroimaging and Interventional Radiology, National Institute for Mental Health and Neurosciences, Bangalore, India, [3] Department of Neurology and Psychiatry, Sapienza University of Rome, Rome, Italy, [4] School of Computing, University of Kent, Chatham Maritime, UK, [5] Department of Clinical Neurosciences, University of Cambridge, Cambridge, UK

OPEN ACCESS

Edited by:
Claudia Voelcker-Rehage, Chemnitz University of Technology, Germany

Reviewed by:
Tao Liu, Zhejiang University, China
Márk Molnár, Hungarian Academy of Sciences, Hungary

***Correspondence:**
Rose D. Bharath
cns.researchers@gmail.com
drrosedawn@yahoo.com

[†]*These authors have contributed equally to this work.*

Received: *08 May 2016*
Accepted: *11 July 2016*
Published: *22 July 2016*

Citation:
Panda R, Bharath RD, Upadhyay N, Mangalore S, Chennu S and Rao SL (2016) Temporal Dynamics of the Default Mode Network Characterize Meditation-Induced Alterations in Consciousness. Front. Hum. Neurosci. 10:372. doi: 10.3389/fnhum.2016.00372

Current research suggests that human consciousness is associated with complex, synchronous interactions between multiple cortical networks. In particular, the default mode network (DMN) of the resting brain is thought to be altered by changes in consciousness, including the meditative state. However, it remains unclear how meditation alters the fast and ever-changing dynamics of brain activity within this network. Here we addressed this question using simultaneous electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) to compare the spatial extents and temporal dynamics of the DMN during rest and meditation. Using fMRI, we identified key reductions in the posterior cingulate hub of the DMN, along with increases in right frontal and left temporal areas, in experienced meditators during rest and during meditation, in comparison to healthy controls (HCs). We employed the simultaneously recorded EEG data to identify the topographical microstate corresponding to activation of the DMN. Analysis of the temporal dynamics of this microstate revealed that the average duration and frequency of occurrence of DMN microstate was higher in meditators compared to HCs. Both these temporal parameters increased during meditation, reflecting the state effect of meditation. In particular, we found that the alteration in the duration of the DMN microstate when meditators entered the meditative state correlated negatively with their years of meditation experience. This reflected a trait effect of meditation, highlighting its role in producing durable changes in temporal dynamics of the DMN. Taken together, these findings shed new light on short and long-term consequences of meditation practice on this key brain network.

Keywords: default mode network, microstate, DMN-microstate, simultaneous EEG-fMRI, meditation

INTRODUCTION

The grand challenge of characterizing the dynamic neural substrate underlying human consciousness has captured the interest of many researchers cutting across disciplinary boundaries and covering altered states ranging from sleep, meditation, hypnosis, anesthesia, coma, disorders of consciousness, delirium tremens, psychoses, etc. Normal consciousness is thought to require both wakefulness and arousal, and several neuro scientifc studies conceptualize wakefulness as a continuum with different levels of awareness (Grill-Spektor et al., 2000; Bar et al., 2001; Kouider et al., 2010). Resting state functional magnetic resonance imaging (rsfMRI) has been used to study the neural correlates of conscious awareness in normal and altered states of consciousness. In particular, this research enterprise has highlighted and progressively refined our understanding of the so-called default mode network (DMN) of the brain, consisting of precuneus/posterior cingulate cortex (PCC), medial frontal cortex (mPFC), the temporoparietal junction (TPJ) and hipocampal formation including parahipocampal cortex, as a key neural correlate of consciousness (Buckner et al., 2008). In particular, researchers have studied changes in the DMN as a function of meditative and introspective cognitive states like day dreaming, mind wandering, and autobiographical memory retrieval (Baerentsen et al., 2010; Baron Short et al., 2010; Hasenkamp et al., 2012; Garrison et al., 2013). These investigations into the neurophenomenology of meditation have found PCC deactivation to be associated with "undistracted awareness" and "effortless doing", with PCC activation being linked to "distracted awareness" and "controlling" in experienced meditators (Garrison et al., 2013). This evidence is in line with the contrasting approaches in two major types of meditation, which either emphasize focused attention or open monitoring. Focused attention meditation aims to reduce mind wandering by concentrating on tasks like breath, sounds or mental imagery, while open monitoring meditation practice encourages mind wandering, and makes one aware of this process (Xu et al., 2014). Extensive study of the DMN in health and disease have also found correlations between DMN connectivity and sleep (Fukunaga et al., 2006; Horovitz et al., 2008; Picchioni et al., 2008), anesthesia (Vincent et al., 2007), disorders of consciousness (Fernández-Espejo et al., 2012; Guldenmund et al., 2012).

While rsfMRI has enabled us to have a fine-grained spatial understanding of the DMN in these states of consciousness, conventional analytical approaches are not best suited to measure the temporal dynamics of its activity, especially during meditation-induced alterations in the state of consciousness. To better understand the temporal dynamics of the DMN, researchers have developed a range of techniques, including time resolved resting fMRI analysis where DMN connectivity is assessed multiple times using sliding temporal windows (Chang and Glover, 2010; Hutchison et al., 2013; Leonardi et al., 2013; Allen et al., 2014; Zalesky et al., 2014). Alternative techniques to obtain temporal detail with fMRI include identification of temporal functional modes using temporal independent component analysis (ICA; Smith et al., 2012), modified seed to voxel based connectivity to define coactivation patterns (Liu and Duyn, 2013) and the recent innovation driven coactivation pattern (Karahanoglu and Van De Ville, 2015). While these methods have attempted to capture the temporal dynamics of the DMN, the time scales of the observed fluctuations in its activity vary from tens of seconds to few minutes in fMRI based studies (Chang and Glover, 2010; Handwerker et al., 2012; Hutchison et al., 2013). In contrast, modeling of electromagnetic brain dynamics using electroencephalography (EEG) and MEG suggest that these neuronal fluctuations called microstates have durations of 100–200 ms (Brandeis and Lehmann, 1989; Pascual-Marqui et al., 1995; Michel et al., 2004; Lehmann et al., 2010; Baker et al., 2014). The concept of microstates was first proposed and demonstrated by Lehmann et al. (1987) when they described brain states that remain stable for 80–120 ms before rapidly evolving into another quasi-stable microstate. The most common parameters used to quantify microstate dynamics are duration or lifespan, which is the average length of time each microstate remains stable whenever it appears. Another useful parameter is frequency of occurrence, which is the average number of times per second that the microstate becomes dominant (Lehmann et al., 1987). Most microstate studies reports four classic microstates which can explain more than 70% of the variation in the scalp topographies manifesting in EEG time series (Tei et al., 2009; Khanna et al., 2015), which have been found to be correlated with rsfMRI networks associated with phonological processing, visual processing, the salience network, and attentional switching (Mantini et al., 2007; Britz et al., 2010). Other studies have reported a higher number of microstates (10–13) with different analysis methods (Musso et al., 2010; Yuan et al., 2012), some of which correlate with the DMN. Here, we refer to the "DMN microstate" as the EEG microstate which correlated maximally with the DMN identified with fMRI. Such microstate analyses have been applied to the study of meditation, where increased duration of microstates has been reported in EEG-based studies in Chan-meditators and Ch'anMo'chao, or Vipassana meditators (Faber et al., 2005; Lo and Zhu, 2009; Tei et al., 2009). Microstate parameters have also been shown to be modulated by psychiatric disorders (Dierks et al., 1997; Lehmann et al., 2005; Kikuchi et al., 2011; Nishida et al., 2013) and even by personality type (Schlegel et al., 2012).

In this study, we analyzed the DMN microstate to understand the mechanisms of meditation-induced alterations in consciousness. By contrasting healthy controls (HCs) at rest against expert meditators at rest and during meditation, we explored both state and trait changes in DMN-microstate dynamics produced by meditation with a hypothesis that these could cause differential alterations in its duration and frequency. The state changes felt during meditation are usually described as a deep sense of calm peacefulness, cessation or slowing of mind's internal dialog and conscious awareness merging completely with the object of meditation (Brown, 1977; Wallace, 1999). Alongside, long-term expertise in meditation also produces durable changes in neural dynamics, with improvements in mental and physical health presumably due to its trait effects (Chiesa and Serretti, 2010, 2011; Hofmann et al., 2010). Here, we describe changes in the spatial configuration of the DMN as a function of meditation, and show that state and trait influences on the temporal dynamics of the DMN microstate can indeed be dissociated.

MATERIALS AND METHODS

Participants

This was a prospective study conducted at a tertiary neurological institute, the National Institute of Mental Health and

Neurosciences (NIMHANS) in Bangalore, India. The study was performed after obtaining informed written consent from the participants. They were recruited as healthy participants in the multi-institutional study on cognitive networks. Ethical approval was obtained from the institutional ethics committee for studies involving humans, convened by NIMHANS (No.NIMHANS/69th IES/2010). The meditator cohort included 20 Raja Yoga expert meditators (male; age: 35 ± 7.9 years, years of education: 15.4 ± 1.6 years, right handed) from the Brahma Kumaris Spiritual Organization, all of them with more than 10 years of Raja yoga meditation practice. Raja yoga meditation involves internally visualizing a glowing star as rays emerging between the eye brows and thus could be considered a type of focused attention type of meditation practice. All participants reported that they spent 1.68 ± 0.59 h in meditation per day in the last 10–22 years (15.2 ± 3.54). They also reported having a cumulative experience of 11332.5 ± 6009.86 h of meditation practice (cumulative experience calculated by combining the numbers of hours per day with years of meditation practice) in their life. Twenty HCs were also recruited for the study. The control participants were matched with the meditator cohort by age, gender, education and ethnicity (male; age: 29 ± 6.8 years, years of education: 16.1 ± 1.1 years, right handed) and both the groups were comparable. None of controls had experience in any type of regular meditative practices. Both meditators and control participants were multilingual (languages known 3.38 ± 0.58), with kannada as first language. None of the participants had any history of neurological or psychiatric illnesses, or prior trauma, and were not on any chronic medications that could affect the experiment.

Experiment Design

The study design was explained to the subjects and instructions were given before performing the EEG-fMRI data collection in the MRI scanner. The participants (both controls and meditators) were instructed to lie awake, with their eyes closed in a relaxed state within the MRI gantry. They were advised to refrain from any cognitive, language or motor tasks during the acquisition. Ear plugs were given to reduce scanner induced noise. Initially a 4.24 min structural MRI was recorded. This allowed them to get familiarized with the MRI environment before starting the rest and meditation session. A single resting EEG-fMRI was obtained in HCs (9.24 min). However in meditators two serial (9.24 min each) resting EEG-fMRI were recorded, one during resting wakefulness, followed immediately by one during meditation. During a *post hoc* interview, all meditators reported that they could satisfactorily achieve the meditative state inside the scanner. This was also subsequently confirmed with analysis of the EEG wave form, where we visually inspected the EEG time series in the time and spectral domains to identify an increase in alpha oscillations during meditation, consistent with previous studies which have reported this increase (Takahashi et al., 2005; Lagopoulos et al., 2009).

Data Acquisition

EEG Data Acquisitions

EEG data were recorded using a 32-channel MR-compatible EEG system (Brain Products GmbH, Gilching, Germany). The EEG cap (BrainCap MR, Brain Products) consisted of 31 scalp electrodes placed according to the international 10–20 system electrode placement and one additional electrode dedicated to the ECG which was placed on the back of the subject. Data were recorded relative to an FCz reference and a ground electrode (GND) according to 10–20 electrode system. Data was sampled at 5000 Hz to enable removal of MRI gradient artifact. The impedance between electrode and scalp was kept below 5 kΩ. EEG was recorded using the Brain Recorder software (Version 1.03, Brain Products). To prevent the movement of the subjects' head, we placed sufficient padding between the head and the head coil of the MRI scanner. Total time for each rest EEG recoding was same as rsfMRI recording (9.24 min), and time locked to each other.

fMRI Data Acquisition

rsfMRI was acquired using a 3T scanner (Skyra, Siemens, Erlangen, Germany). One hundred and eighty-five volumes of gradient-echo, Echo-Planar Images (EPI) were obtained using the following EPI parameters: 36 slices, 4 mm slice thickness in interleaved manner with an field of view (FOV) of 192 × 192 mm, matrix 64 × 64, repetition time (TR) 3000 ms, echo time (TE) 35 ms, re-focusing pulse 90°, matrix- 256 × 256 × 114, voxel size-3 × 3 × 4 mm. We also acquired a three dimensional magnetization prepared rapid acquisition gradient echo (3D MPRAGE) sequence for anatomical information (with the voxel size 1 × 1 × 1 mm, 192 × 192 × 256 matrix) for better registration and overlay of brain activity.

Data Analysis

EEG Artifact Removal and Preprocessing

Raw EEG data was processed offline using BrainVision Analyzer software version 2 (Brain Products GmbH, Gilching, Germany). The gradient artifacts were corrected according to Allen et al. (2000). A moving average width of 20 MR volumes (TRs) was used for gradient correction. Corrected EEG data were filtered using a high-pass filter at 0.03 Hz and a low-pass filter at 75 Hz. The data was then down-sampled to 250 Hz. Ballistocardiogram (BCG) artifacts were removed from the EEG using an averaged subtraction method using heartbeat events (R peaks; Allen et al., 1998, 2000; Goldman et al., 2000), implemented in BrainVision Analyzer 2. Once gradient and BCG artifacts were removed, the data were downsampled to 250 Hz. They were visually inspected for artifacts resulting from muscular sources or head movement artifact and any epoch containing any channel varying more than 150 μV was rejected. Finally, the signal was filtered with a band-pass of 0.01–45 Hz. To confirm that the meditators were in the meditative state during the second session, EEG spectral analysis was carried out for the entire 9.24 min for resting state and for the entire 9.24 min for meditative state. A fast fourier transform (FFT) was used to calculate spectral power density (μV^2).

EEG Feature Extraction

The EEG microstates were derived from the resting EEG data using sLORETA software. To compute microstates the local maxima of the global field power (GFP; Lehmann and Skrandies, 1980) were identified. Since scalp topography remains stable around peaks of GFP as a result of temporal smoothing in sLORETA, they are representative of the transient microstates (Pascual-Marqui et al., 1995; Koenig et al., 2002). The algorithm implemented for estimating microstates is based on a modified version of the classical k-means clustering method in which cluster orientations are estimated. An optimal number of 13 clusters for this method was determined by means of a cross-validation criterion (Pascual-Marqui et al., 1995). The entire EEG data at each time point was decomposed into a temporal sequence of one of these 13 EEG microstates. We used this EEG microstate decomposition to guide the analysis of the rsfMRI data at the single subject level.

rsfMRI Preprocessing

The rsfMRI analysis was performed using FSL software (FMRIB's Software Library[1]), in particular with the fMRI Expert Analysis Tool (FEAT) and multivariate exploratory linear decomposition into independent components (MELODIC) modules. The first five functional images (EPI volumes) were discarded from each of the subjects' rsfMRI data to allow for signal equilibration, giving a total of 180 volumes used in analysis. We conducted motion correction using MCFLIRT (Jenkinson et al., 2002), and non-brain tissue (Scalp, CSF, etc.) removal using the Brain Extraction Toolbox (Smith, 2002). The average head motion of the subjects was also not found to significantly differ between the groups. Spatial smoothing was performed using a Gaussian kernel of 5 mm full width at half maximum (FWHM), followed by a mean based intensity normalization of all volumes by the same factor, and then a high temporal band-pass filtering with sigma 180 s. These temporal filtering parameters were based on previously validated methodology employed by Beckmann and Smith (Smith et al., 2004; Beckmann and Smith, 2005; Beckmann et al., 2005). We co-registered the EPI volumes with the individual subject's high-resolution anatomical volume in MNI152 standard space template and re-sampled the filtered data into standard space, keeping the re-sampled resolution at the fMRI resolution (3 mm) using FNIRT, the FMRIB non-linear image registration tool (Klein et al., 2009). Two participants from each group were excluded due to uncorrectable cardio-ballistic and motion artifacts during data preprocessing.

Identification of DMN-Microstate

The spectral Z-stats maps of the EEG microstates were created by convolving all the 13 microstates with the gamma hemodynamic response function using customized three column format in FEAT Version 5.98, part of FSL (FMRIB's Software Library[2]). The GLM was modeled as an event related design, where EEG microstates were considered as explanatory variables (regressors) for rsfMRI analysis. This procedure, enabled us to combine EEG and fMRI time series despite their very different sampling rates. To do so, the onset time and the duration of each EEG microstate were provided as inputs to the GLM and convolved with a gamma hemodynamic response function (Musso et al., 2010). This rsfMRI, thus informed by the EEG microstates, was analyzed at the individual level to derive subject-wise Z-stats maps for each microstate. We examined the spatial correlation (R) between the spectral Z-stats map and the DMN component estimated by ICA of blood-oxygen-level dependent (BOLD) activity (see below). Using the FSL utility "fslcc", the Z-stats maps which correlated with BOLD ICA map of the DMN with a correlation of at least 0.3 were selected for further analysis (Kiviniemi et al., 2011). When more than one microstate Z-map correlated with the DMN the one with highest correlation was selected. This subject-wise spectral Z-stats map of the DMN microstate was included in further group analysis. Group level analysis was done using the higher level FEAT tool, where three group mean effects (controls at rest, meditators at rest and meditation state) were extracted by specifying the contrast (1 0 0; 0 1 0; 0 0 1) respectively.

Independent Components (ICs)

Functional connectivity was ascertained using ICA which decomposes the rsfMRI data into statistically independent spatial maps (and associated time series). This is a data driven approach by which we can extract the functional networks in a voxel-wise manner based on their spatial and temporal signal fluctuations. ICA of rsfMRI was carried out with the probabilistic independent components analysis (PICA) using FSL's MELODIC method. This single-subject ICA was carried out with FEAT MELODIC data exploration, in which the rsfMRI data was extracted into the independent components (ICs) during the preprocessing step. All extracted IC were visually inspected. Non-motion related noise sources such as eye related artifacts, field in homogeneity, high frequency noise, slice dropout and gradient instability were removed on the basis of existing literature (Smith et al., 2004; Beckmann and Smith, 2005; Beckmann et al., 2005). ICs that showed clearly identifiable patterns in both spatial and frequency domains, and activations in frequency plots below 0.1 Hz were removed to reduce respiration and heart rate related artifacts. The selected noise components were removed using the command "fsl_regfilt" defined in FSL MELODIC. Multivariate group PICA was then carried out using FSL MELODIC (Beckmann and Smith, 2005; Beckmann et al., 2005), to derive maximally spatially ICs across all datasets (18 control and 18 meditator × 2 sessions), which were temporally concatenated. The data set was decomposed into 15 sets of independent vectors which describe signal variation across the

[1]www.fmrib.ox.ac.uk/fsl

[2]http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/

temporal (timecourses) and spatial (maps) domain by optimizing for non-Gaussian spatial source distributions using the Fast ICA algorithm. The resulting maps were threshold using an alternative hypothesis test with a significance level of $p > 0.5$ (i.e., an equal weight is placed on false positives and false negatives) by fitting a Gaussian/Gamma mixture model to the histogram of intensity values (Smith et al., 2004; Beckmann and Smith, 2005). Finally, the components representing the DMN were visually identified from the set of group IC maps by comparing their constituent cortical sources with the regions of the DMN reported in the literature (Beckmann and Smith, 2005; Beckmann et al., 2005; Damoiseaux et al., 2006).

DMN-Microstate Statistical Analysis

The mean duration and number of occurrences per second of the DMN microstates were calculated for each subject. The duration of the DMN-microstate was defined as a continuous time epoch (milliseconds) during which all EEG GFP maps were assigned to the the DMN-microstate class by the k-means clustering algorithm. The frequency of occurrence of the DMN-microstate is defined the number of such occurrences per second. Group differences were calculated for both the DMN-microstate duration and frequency of occurrence for all subjects. Independent samples t-tests were carried out to compare the difference between meditators and controls at rest, and a paired sample t-test was carried out between the meditator at rest and during meditation. At a 95% confidence interval (CI), a p-value of < 0.05 was considered significant. Furthermore, the number of years of meditation practice were correlated with the duration and occurrence of DMN microstates with a pearson correlation. Multiple comparisons were compensated for by FDR correction.

DMN Dual Regression Analysis

Groupwise comparison of rsfMRI ICs was performed using dual regression, which allows for voxel-wise comparisons[3]. The set of spatial maps from the group-mean analysis (GroupICs) was used to generate subject-specific-spatial maps and associated time series (Beckmann et al., 2009; Filippini et al., 2009). DMN component maps from all subjects were arranged into a single 4D file and voxel-wise differences were estimated. Statistical differences were assessed using randomized, on-parametric permutation, incorporating the threshold-free cluster enhancement (TFCE) technique (Smith et al., 2009). Separate null distributions of t-values were derived for the contrasts reflecting the inter-group effects by performing 5000 random permutations and testing the difference between groups or against zero for each iteration (Nichols and Holmes, 2002). To estimate group mean effects, HC > meditator, meditator > HCs, meditator > meditation and mediation > meditator contrasts were used and the resultant statistical maps were threshold at $p < 0.05$ (family-wise error (FWE) corrected). Following this, inter-group effects were threshold by at $p < 0.05$ (false discovery rate (FDR) corrected; Filippini et al., 2009). When the voxel wise differences between the groups were higher, the term "increased connectivity" was used and vice versa.

[3]http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/DualRegression

RESULTS

Despite being in an MRI scanner with gradient acoustic noise, with a fixed head and body position, all meditators reported that they were able to stay awake in relaxed state and also enter into a meditative state as instructed. Visual inspection of the EEG for sleep spindles and K-complexes confirmed that none of the subjects fell asleep during rsfMRI data acquisition. In all the results presented below, three conditions are compared, controls at rest, meditators at rest, and the same meditators during meditation.

Group Level EEG Frequency Differences During Meditation

Significant changes were noted in spectral power of EEG frequency bands between the meditation and rest states in meditators. Meditators had increased power particularly in the alpha, theta and beta frequencies in the meditation state compared to rest state, which is depicted in the **Figure 1**. This also ascertained that the meditators did not go into meditative state during resting state and performed meditation in meditative state as instructed.

Spatial Analysis of DMN-Microstate and DMN During Meditation

Figure 2 depicts the average DMN-microstate, the corresponding Z-stats map and rsfMRI-derived DMN ICA component in HCs, meditators at rest (meditator) and during meditation.

Dual regression analysis (**Figure 3**) of the rsfMRI DMN revealed that meditators were different from HCs ($p < 0.05$) already at rest, as they had decreased posterior cingulate (number of voxels: 223, T-max: 0.987, coordinates: −4, −40, 26) connectivity, increased right middle frontal gyrus (MFG; number of voxels: 263, T-max: 0.956, coordinates: 42, 8, 46) and left middle temporal gyrus (MTG; number of voxels: 53, T-max: 0.963, coordinates: −52, −48, 6) connectivity. This

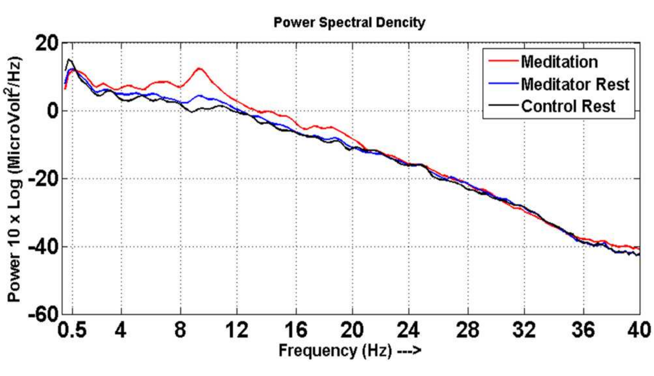


FIGURE 1 | Power spectra. Power spectral density distribution for meditators at meditative state (red line) and at rest (blue line), control at rest (black line).

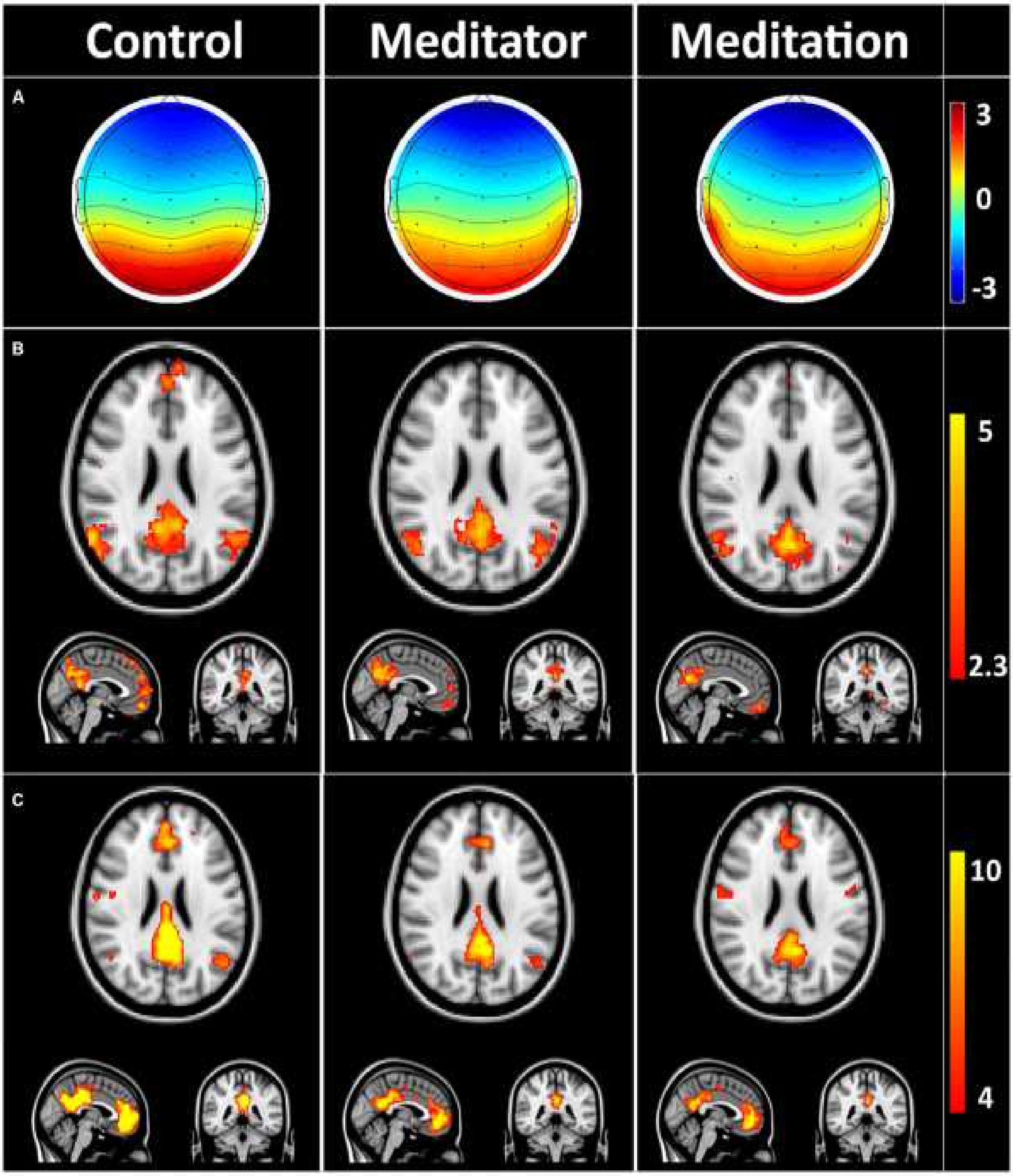


FIGURE 2 | Default mode network (DMN) microstates during rest and meditation. (A) Group averaged electroencephalography (EEG) microstate in controls at rest (control), meditator at rest state (meditator) and meditator during meditation (meditation). **(B)** Group averaged Z-stats maps corresponding to the DMN microstates. **(C)** Corresponding DMN components derived from resting state functional magnetic resonance imaging (rsfMRI) using independent components analysis (ICA). The striking spatial similarity between the EEG-derived DMN Z-stats map **(B)** and rsfMRI-derived DMN **(C)** is evident. Meditators showed evidence of decreased connectivity in precuneus/posterior cingulate cortex (PCC) and medial prefrontal cortex (mPFC) at rest, which decreased further during meditation **(C)**.

relatively lower cingulate connectivity was further significantly reduced relative to rest, when the meditators entered into the meditative state (number of voxels: 107, T-max: 0.998, coordinates: −2, −40, 26). Alongside this reduction, we also observed increased left MTG (number of voxels: 122, T-max: 0.992, coordinates: −58, −46, 8) and right MFG (number of voxels: 424, T-max: 0.998, coordinates: 40, 8, 46) connectivity during meditation.

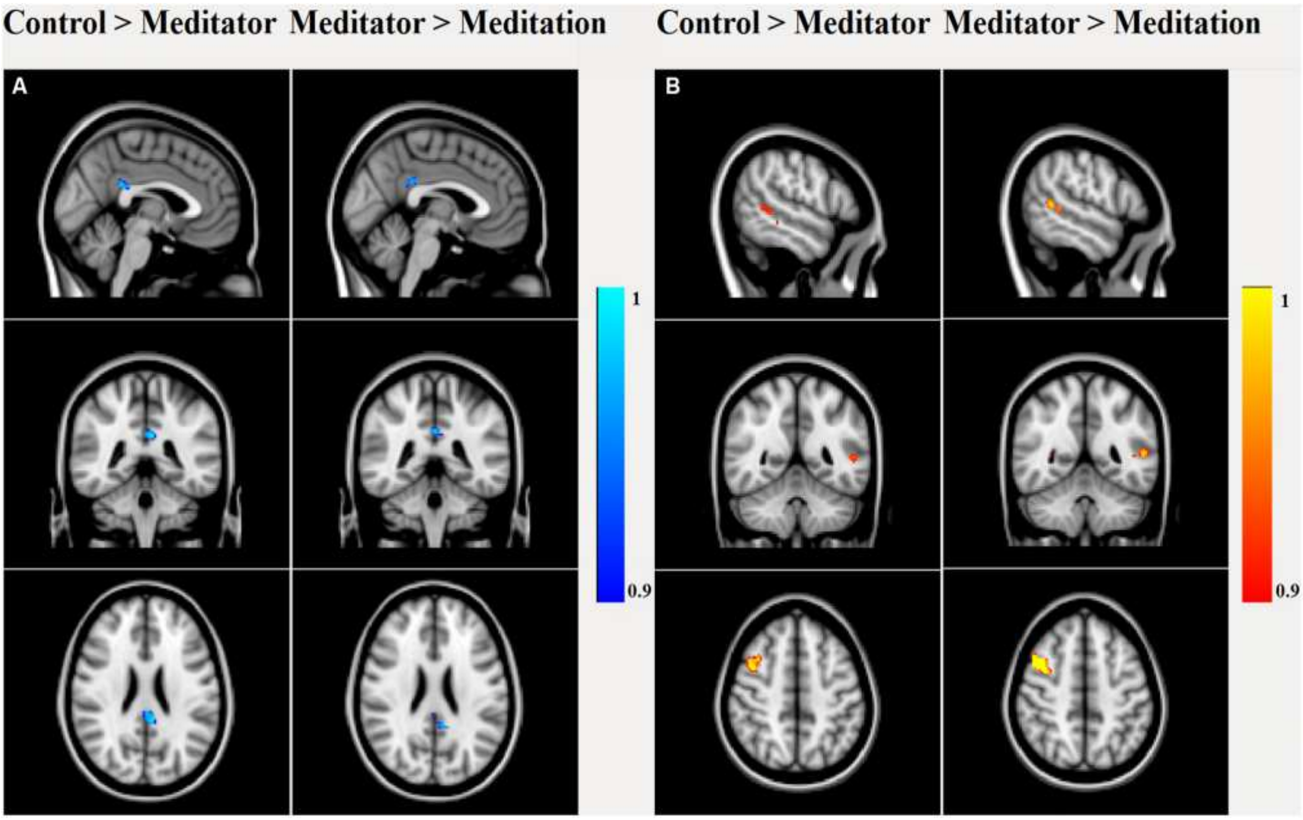


FIGURE 3 | Dual regression analysis of group main and between-group effects in the rsfMRI DMN component. Between-group effects showed significant ($p < 0.05$ false discovery rate (FDR) corrected) decreased PCC connectivity in meditators compared to controls, which further decreased during meditation. **(A)** Meditators had higher connectivity in right middle frontal gyrus (MFG) and left middle temporal gyrus (MTG) than controls, which again increased during meditation **(B)**.

Temporal Analysis of the DMN-Microstate

The meditators at rest had increased duration and higher frequency of occurrence of the DMN-microstate compared to controls (**Figure 4**).The mean duration of the DMN-microstate was 93.05 ± 15.18 ms in HCs and 118.88 ± 12.78 ms in meditators at rest (Unpaired t-test, $t = -3.55$; df = 34; p = 3.6E-06); the mean frequency of its occurrence was 3.15 ± 0.66/s in controls and 3.84 ± 0.48/s in meditators (Unpaired t-test, $t = -3.56$; df = 34; $p = 0.001$). During meditation the duration and frequency of occurrence increased significantly further. Specifically, during meditation, the mean duration of DMN-microstate was 134.27 ± 11.21 ms (Paired t-test, $t = -5.06$; df = 17; p = 9.5E-05) and the mean frequency of occurrence was 4.03 ± 0.46/s (Paired t-test, $t = -5.06$; df = 17; p = 1.3E-06; **Figure 4**).

Correlation of DMN-Microstate Dynamics With Years of Experience in Meditation

The observed differences in the temporal properties of the DMN-microstate suggested a combination of state and trait-based influences. To further explicate the influence of long-term meditation experience in engendering trait differences between meditators and controls, we correlated the duration and frequency of occurrence of the DMN-microstate in individual meditators with their meditation experience in years. The results are summarized in **Figure 5**. There was a very strong, significant positive correlation in the duration of DMN-microstate in meditators at rest ($r = 0.96$, p = 7.3E-11) and in the meditative state ($r = 0.51$, $p = 0.03$) with years of meditation practice (**Figure 5A**). Interestingly, in each meditator, the net increase in the duration of the DMN-microstate during meditation relative to rest actually correlated negatively with the years of meditation practice (**Figure 5C**, $r = -0.549$, $p = 0.023$). This implied that the more experienced meditators had a DMN-microstate duration akin to being in a meditative state even at rest, highlighting how the state effect of meditation on DMN dynamics gradually transitions into a trait effect that potentially permanently alters it over many years of practice. However, this effect could potentially be explained away by the age of the meditators rather than their years of experience, as participants with longer years of experience were older than those with lesser experience. To address this potential confound, we regressed out this effect by including age of the meditator as a covariate in the correlation analysis. Having accounted for the influence of age, we still found a significant negative correlation between the state-induced change in DMN-microstate duration and years of mediation experience ($r = -0.549$, $p = 0.03$). This confirmed that there was indeed a trait-level modulation of the DMN's dynamics produced

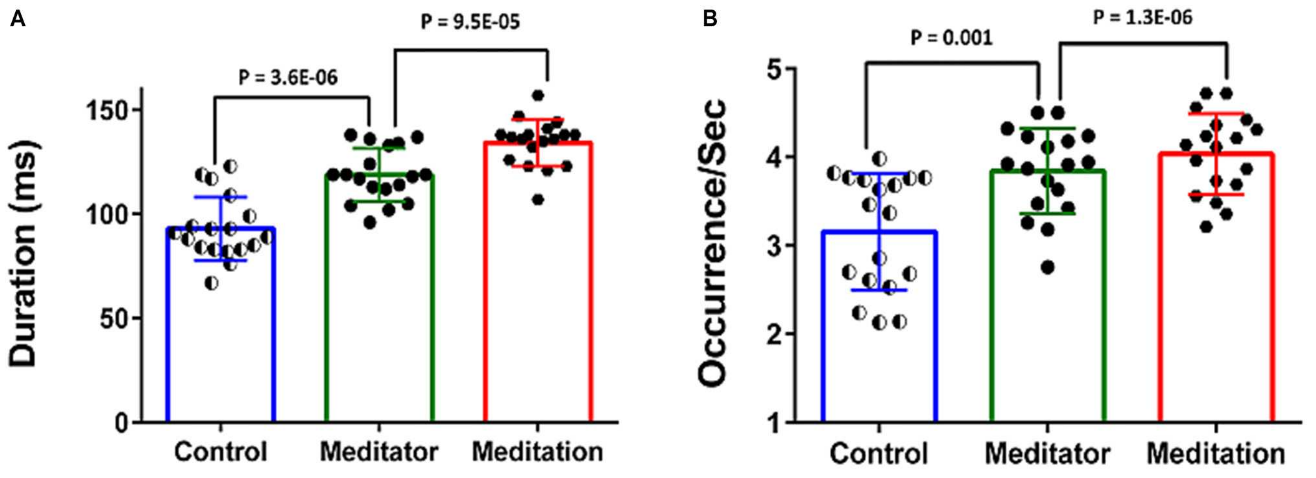


FIGURE 4 | Temporal dynamics of the DMN-microstate. Bar charts plot the duration **(A)** and occurence/s **(B)** of the DMN-microstate in healthy controls (HCs), meditators at rest and during meditation. Both measures were significantly higher in meditators than in controls, and increased further during meditation.

by meditation experience, that could not be explained away by aging.

Further, we found that this pattern of effects were specific to the duration of the DMN-microstate. Specifically, the effect of meditation experience on the frequency of occurrence of the DMN-microstate was not statistically significant, either at rest ($r = 0.43$, $p = 0.06$) or in the meditative state ($r = 0.46$, $p = 0.053$), though there was a trend towards increasing DMN-microstate occurrence with increasing years of meditation practice (**Figure 5B**). Further, the meditation state induced increase in the frequency of occurrence did not correlate with years of practice ($r = -0.004$, $p = 0.98$). As the frequency of occurrence of the DMN-microstate was unaffected by the years of experience, it was distinct from duration and is probably indicative of the state effect of meditation, as seen in **Figure 4B**.

DISCUSSION

We have investigated dynamic alterations of the DMN using simultaneous EEG-fMRI, with the aim of characterizing the spatial and temporal changes caused by meditation induced alterations of consciousness. Using spatial ICA analysis of our fMRI data, we found that the posterior cingulate hub of the DMN was less strongly connected in meditators, which became further reduced during meditation. In contrast, the right middle frontal and left middle temporal gyri were more active in meditators and during meditation. By linking the fMRI with EEG, we were able to identify the DMN microstate in all participants, by matching its spatial configuration to their respective DMN ICA components. The temporal properties of this DMN-microstate highlighted its significantly higher duration and frequency of occurrence, in meditators at rest and during meditation. Further, the relationship between these temporal properties and years of meditation experience enabled us to explore state and trait influences on DMN dynamics. This analysis suggested that in less experienced meditators, entering into a meditative state was associated with significant increases both in the duration and frequency of the DMN-microstate. As experience with meditation increased, there was a progressively higher duration of the DMN-microstate at rest and entering a state of meditation only brought about an increase in its frequency of occurrence. Taken together, these findings elucidate salient spatiotemporal mechanisms of meditation, and particularly highlight its role in altering the temporal dynamics of brain activity over short and long time scales.

Within the large body of fMRI literature on resting state networks, the DMN has been a particular focus of attention (Raichle et al., 2001; Buckner et al., 2008) as a key brain network that underlies awareness of the self within the environment. Our finding of decreased PCC connectivity and increased temporal and frontal connectivity within the DMN during meditation has been reported previously in seed to voxel connectivity studies (Farb et al., 2007; Brewer et al., 2011). Alongside, the significance of the temporo-frontal regions during meditation has been consistently highlighted in previous task based fMRI studies (Brefczynski-Lewis et al., 2007; Lagopoulos et al., 2009). Indeed, our findings mirror those from recent studies on fMRI of meditation (Baijal and Srinivasan, 2010; Cahn et al., 2010; Hasenkamp and Barsalou, 2012; Hasenkamp et al., 2012). In particular, Hasenkamp and Barsalou (2012) studied the effects of meditation experience on DMN functional connectivity, and demonstrated increased connectivity in frontal areas during meditation in meditators with more experience, which they interpreted as evidence of greater attentional control gained with such experience. In our meditator cohort, these attentional control networks could also be similarly more active in the expert meditators. This increased attentional control, along with decreased PCC connectivity, is hypothesized to undergo neuroplastic changes that enable them to gain better control of mind-wandering. Based on evidence of task positive networks being recruited at rest, it has been argued that continuous and regular meditation

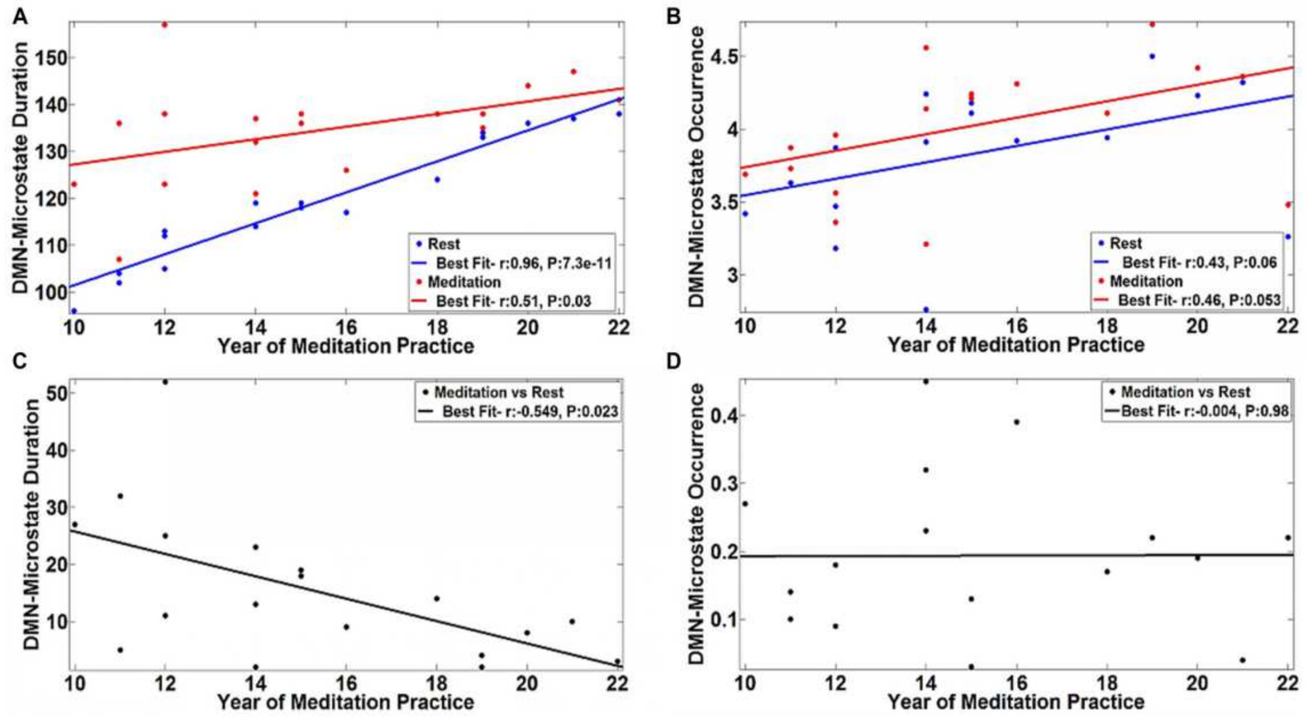


FIGURE 5 | Correlation of DMN-microstate dynamics with meditation experience. The duration **(A)** and frequency of occurrence **(B)** of the DMN-microstate were positively correlated with years of experience. The blue and red lines in dicate the linear fits of these DMN-microstate properties measured during meditation and rest, respectively. Duration was less altered as a function of state in more experienced meditators. Corroborating this trait effect, the difference in DMN-microstate duration between meditation and rest was negatively correlated with years of experience **(C)**. No such trait effect was observed in the frequency of occurrence of the DMN-microstate **(D)**.

practice transforms the rest state of experienced meditators (Brewer et al., 2011). However in the current study the right frontal and left temporal areas described are part of the DMN and do not represent task positive networks. However, it is possible that this neuroplasticity is mediated by task positive networks, and future research could elucidate how meditation modulates the relationship between these different brain networks.

Within this research context, our finding have generated new evidence delineating temporal changes in DMN activity that accompanies these spatial changes. Our finding of increasing frequency of occurrence of the DMN-microstate during meditiation implies that there is a decreased occurrence of other microstates, thus resulting in an overall decrease in variability in the temporal dynamics of brain activity. According to large scale dynamical models of consciousness (Deco et al., 2013), resting brain can be divided into three states, namely the spontaneous state, multistable attractor states and unstable spontaneous state, differing in their coupling strengths. The state with least coupling strength is the spontaneous state and that with highest coupling strength is the unstable spontaneous state often associated with a task. Human consciousness is postulated to be positioned at the verge of instability defined to lie between the multistable attractor state and the unstable spontaneous state. Within this framework, decreased variability within such a dynamical system is compatible with our finding of increased frequency of the DMN microstate during meditation. It is worth noting that the focus of the analysis here has been on the DMN-microstate, as that was the only microstate that was consistently present in all subjects. This is similar to findings reported by Musso et al. (2010), whose group analysis only revealed a fronto-occipital network that overlapped with visual networks and the DMN. This is despite the fact that all the subjects in their study had microstates which correlated with several other resting state networks. With the continual advancement in methodological tools for simultaneous EEG-fMRI analysis, we might be able parse spatiotemporal brain dynamics with the requisite detail and consistency for mapping all the resting state networks.

Our finding of experienced meditators having a higher duration of DMN microstate that did not change much in the meditative state is consistent with the philosophical perspective (Lutz et al., 2008), behavioral (Carter et al., 2005; Srinivasan and Baijal, 2007) and brain structural changes (Lazar et al., 2005) related to the trait effects of meditative practice. Because of the synergistic interaction between state and trait effects it has been largely difficult to design studies to separate these effects (Cahn and Polich, 2006) and hence relatively few studies that have exclusively looked at the state effect of meditation. In future research, the study of neurophenomenology of meditation, which correlates moment-to-moment first person reports of internal experience to guide neuroimaging analysis might be able to separate state effect from trait effects of meditation (Jack and Shallice, 2001; Jack and Roepstorff, 2002; Lutz et al., 2002).

CONCLUSION

Our investigation of the spatial configuration of the DMN in meditators and during meditation revealed a decrease in posterior cingulate connectivity, and a complementary increase in middle frontal and temporal connectivity. Using temporal microstate analysis applied to simultaneous EEG-fMRI data, we found that the duration and frequency of occurrence of the DMN-microstates are useful metrics of meditation-induced altered consciousness, and increase systematically across controls, meditators during rest and during meditation. We report complementary roles of these metrics, where duration primarily reflected the trait effect and occurrence represented the state effect of meditation. Our results shed new light on the neurobiology of meditation, and its effect on the spatiotemporal properties of the DMN in particular.

AUTHOR CONTRIBUTIONS

RP and RDB have contributed equally for this article. Contributions to the conception or design of the work by RP, RDB, SLR. Data acquisition done by RP and NU and analysis was carried out by RP, RDB, NU, SM. RDB, SC interpreted the results of the study. Manuscript drafted by RP followed by RDB, SC, NU revised the manuscript critically for important intellectual content. Final approval and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved by all authors.

FUNDING

We acknowledge the support of the Department of Science and Technology, Govt. of India, India for providing the 3T MRI scanner exclusively for research in the field of neurosciences.

ACKNOWLEDGMENTS

We thank Dr. S. R. Chandra for ascertaining the quality of EEG (Department of Neurology, National Institute of Mental Health and Neurosciences (NIMHANS), India). We thank BK. Ambika, BK. Sneha, BK. Sushilchandra and BK. Srikant from Spiritual Application Research Center (SpARC), Prajapita Brahamakumari Iswariya Viswa Vidyalaya for facilitating the participation of expert meditators. We are grateful to the staff especially the radiographers, for their support. Finally, we thank all the participants for their time.

REFERENCES

Allen, E. A., Damaraju, E., Plis, S. M., Erhardt, E. B., Eichele, T., and Calhoun, V. D. (2014). Tracking whole-brain connectivity dynamics in the resting state. *Cereb. Cortex* 24, 663–676. doi: 10.1093/cercor/bhs352

Allen, P. J., Josephs, O., and Turner, R. (2000). A method for removing imaging artifact from continuous EEG recorded during functional MRI. *Neuroimage* 12, 230–239. doi: 10.1006/nimg.2000.0599

Allen, P. J., Polizzi, G., Krakow, K., Fish, D. R., and Lemieux, L. (1998). Identification of EEG events in the MR scanner: the problem of pulse artifact and a method for its subtraction. *Neuroimage* 8, 229–239. doi: 10.1006/nimg.1998.0361

Baerentsen, K. B., Stødkilde-Jørgensen, H., Sommerlund, B., Hartmann, T., Damsgaard-Madsen, J., Fosnaes, M., et al. (2010). An investigation of brain processes supporting meditation. *Cogn. Process.* 11, 57–84. doi: 10.1007/s10339-009-0342-3

Baijal, S., and Srinivasan, N. (2010). Theta activity and meditative states: spectral changes during concentrative meditation. *Cogn. Process.* 11, 31–38. doi: 10.1007/s10339-009-0272-0

Baker, A. P., Brookes, M. J., Rezek, I. A., Smith, S. M., Behrens, T., Smith, P. J. P., et al. (2014). Fast transient networks in spontaneous human brain activity. *Elife* 3:e01867. doi: 10.7554/elife.01867

Bar, M., Tootell, R. B. H., Schacter, D. L., Greve, D. N., Fischl, B., Mendola, J. D., et al. (2001). Cortical mechanisms specific to explicit visual object recognition. *Neuron* 29, 529–535. doi: 10.1016/s0896-6273(01)00224-0

Baron Short, E., Kose, S., Mu, Q., Borckardt, J., Newberg, A., George, M. S., et al. (2010). Regional brain activation during meditation shows time and practice effects: an exploratory FMRI study. *Evid Based Complement. Alternat. Med.* 7, 121–127. doi: 10.1093/ecam/nem163

Beckmann, C. F., DeLuca, M., Devlin, J. T., and Smith, S. M. (2005). Investigations into resting-state connectivity using independent component analysis. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 360, 1001–1013. doi: 10.1098/rstb.2005.1634

Beckmann, C. F., Mackay, C. E., Filippini, N., and Smith, S. M. (2009). Group comparison of resting-state fMRI data using multi-subject ICA and dual regression. *Neuroimage* 47:S148. doi: 10.1016/s1053-8119(09)71511-3

Beckmann, C. F., and Smith, S. M. (2005). Tensorial extensions of independent component analysis for multisubject fMRI analysis. *Neuroimage* 25, 294–311. doi: 10.1016/j.neuroimage.2004.10.043

Brandeis, D., and Lehmann, D. (1989). Segments of event-related potential map series reveal landscape changes with visual attention and subjective contours. *Electroencephalogr. Clin. Neurophysiol.* 73, 507–519. doi: 10.1016/0013-4694(89)90260-5

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., and Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proc. Natl. Acad. Sci. U S A* 104, 11483–11488. doi: 10.1073/pnas.0606552104

Brewer, J. A., Worhunsky, P. D., Gray, J. R., Tang, Y.-Y., Weber, J., and Kober, H. (2011). Meditation experience is associated with differences in default mode network activity and connectivity. *Proc. Natl. Acad. Sci. U S A* 108, 20254–20259. doi: 10.1073/pnas.1112029108

Britz, J., Van De Ville, D., and Michel, C. M. (2010). BOLD correlates of EEG topography reveal rapid resting-state network dynamics. *Neuroimage* 52, 1162–1170. doi: 10.1016/j.neuroimage.2010.02.052

Brown, D. P. (1977). A model for the levels of concentrative meditation. *Int. J. Clin. Exp. Hypn.* 25, 236–273. doi: 10.1080/00207147708415984

Buckner, R. L., Andrews-Hanna, J. R., and Schacter, D. L. (2008). The brain's default network: anatomy, function, and relevance to disease. *Ann. N Y Acad. Sci.* 1124, 1–38. doi: 10.1196/annals.1440.011

Cahn, B. R., Delorme, A., and Polich, J. (2010). Occipital gamma activation during Vipassana meditation. *Cogn. Process.* 11, 39–56. doi: 10.1007/s10339-009-0352-1

Cahn, B. R., and Polich, J. (2006). Meditation states and traits: EEG, ERP and neuroimaging studies. *Psychol. Bull.* 132, 180–211. doi: 10.1037/0033-2909.132.2.180

Carter, O. L., Presti, D. E., Callistemon, C., Ungerer, Y., Liu, G. B., and Pettigrew, J. D. (2005). Meditation alters perceptual rivalry in Tibetan Buddhist monks. *Curr. Biol.* 15, R412–R413. doi: 10.1016/j.cub.2005.05.043

Chang, C., and Glover, G. H. (2010). Time-frequency dynamics of resting-state brain connectivity measured with fMRI. *Neuroimage* 50, 81–98. doi: 10.1016/j.neuroimage.2009.12.011

Chiesa, A., and Serretti, A. (2010). A systematic review of neurobiological and clinical features of mindfulness meditations. *Psychol. Med.* 40, 1239–1252. doi: 10.1017/s0033291709991747

Chiesa, A., and Serretti, A. (2011). Mindfulness based cognitive therapy for psychiatric disorders: a systematic review and meta-analysis. *Psychiatry Res.* 187, 441–453. doi: 10.1016/j.psychres.2010.08.011

Damoiseaux, J. S., Rombouts, S. A. R. B., Barkhof, F., Scheltens, P., Stam, C. J., Smith, S. M., et al. (2006). Consistent resting-state networks across healthy subjects. *Proc. Natl. Acad. Sci. U S A* 103, 13848–13853. doi: 10.1073/pnas.0601417103

Deco, G., Jirsa, V. K., and McIntosh, A. R. (2013). Resting brains never rest: computational insights into potential cognitive architectures. *Trends Neurosci.* 36, 268–274. doi: 10.1016/j.tins.2013.03.001

Dierks, T., Jelic, V., Julin, P., Maurer, K., Wahlund, L. O., Almkvist, O., et al. (1997). EEG-microstates in mild memory impairment and Alzheimer's disease: possible association with disturbed information processing. *J. Neural. Transm. (Vienna)* 104, 483–495. doi: 10.1007/bf01277666

Faber, P. L., Lehmann, D., Barendregt, H., Kaelin, M., and Gianotti, L. R. R. (2005). Increased duration of EEG microstates during meditation. *Brain Topogr.* 18, 131.

Farb, N. A. S., Segal, Z. V., Mayberg, H., Bean, J., Mckeon, D., Fatima, Z., et al. (2007). Attending to the present: mindfulness meditation reveals distinct neural modes of self-reference. *Soc. Cogn. Affect. Neurosci.* 2, 313–322. doi: 10.1093/scan/nsm030

Fernández-Espejo, D., Soddu, A., Cruse, D., Palacios, E. M., Junque, C., Vanhaudenhuyse, A., et al. (2012). A role for the default mode network in the bases of disorders of consciousness. *Ann. Neurol.* 72, 335–343. doi: 10.1002/ana.23635

Filippini, N., MacIntosh, B. J., Hough, M. G., Goodwin, G. M., Frisoni, G. B., Smith, S. M., et al. (2009). Distinct patterns of brain activity in young carriers of the APOE-ϵ4 allele. *Proc. Natl. Acad. Sci. U S A* 106, 7209–7214. doi: 10.1016/s1053-8119(09)71381-3

Fukunaga, M., Horovitz, S. G., van Gelderen, P., de Zwart, J. A., Jansma, J. M., Ikonomidou, V. N., et al. (2006). Large-amplitude, spatially correlated fluctuations in BOLD fMRI signals during extended rest and early sleep stages. *Magn. Reson. Imaging* 24, 979–992. doi: 10.1016/j.mri.2006.04.018

Garrison, K. A., Santoyo, J. F., Davis, J. H., Thornhill, T. A., Kerr, C. E., and Brewer, J. A. (2013). Effortless awareness: using real time neurofeedback to investigate correlates of posterior cingulate cortex activity in meditators' self-report. *Front. Hum. Neurosci.* 7:440. doi: 10.3389/fnhum.2013.00440

Goldman, R. I., Stern, J. M., Engel, J., and Cohen, M. S. (2000). Acquiring simultaneous EEG and functional MRI. *Clin. Neurophysiol.* 111, 1974–1980. doi: 10.1016/s1388-2457(00)00456-9

Grill-Spektor, K., Kushnir, T., Hendler, T., and Malach, R. (2000). The dynamics of object-selective activation correlate with recogntion performance in human. *Nat. Neurosci.* 3, 837–843. doi: 10.1038/77754

Guldenmund, J. P., Vanhaudenhuyse, A., Boly, M., Laureys, S., and Soddu, A. (2012). A default mode of brain function in altered states of consciousness. *Arch. Ital. Biol.* 150, 107–121. doi: 10.4449/aib.v150i2.1373

Handwerker, D. A., Roopchansingh, V., Gonzalez-Castillo, J., and Bandettini, P. A. (2012). Periodic changes in fMRI connectivity. *Neuroimage* 63, 1712–1719. doi: 10.1016/j.neuroimage.2012.06.078

Hasenkamp, W., and Barsalou, L. W. (2012). Effects of meditation experience on functional connectivity of distributed brain networks. *Front. Hum. Neurosci.* 6:38. doi: 10.3389/fnhum.2012.00038

Hasenkamp, W., Wilson-Mendenhall, C. D., Duncan, E., and Barsalou, L. W. (2012). Mind wandering and attention during focused meditation: a fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage* 59, 750–760. doi: 10.1016/j.neuroimage.2011.07.008

Hofmann, S. G., Sawyer, A. T., Witt, A. A., and Oh, D. (2010). The effect of mindfulness-based therapy on anxiety and depression: a meta-analytic review. *J. Consult. Clin. Psychol.* 78, 169–183. doi: 10.1037/a0018555

Horovitz, S. G., Fukunaga, M., de Zwart, J. A., van Gelderen, P., Fulton, S. C., Balkin, T. J., et al. (2008). Low frequency BOLD fluctuations during resting wakefulness and light sleep: a simultaneous EEG-fMRI study. *Hum. Brain Mapp.* 29, 671–682. doi: 10.1002/hbm.20428

Hutchison, R. M., Womelsdorf, T., Allen, E. A., Bandettini, P. A., Calhoun, V. D., Corbetta, M., et al. (2013). Dynamic functional connectivity: promise, issues and interpretations. *Neuroimage* 80, 360–378. doi: 10.1016/j.neuroimage.2013.05.079

Jack, A. I., and Shallice, T. (2001). Introspective physicalism as an approach to the science of consciousness. *Cognition* 79, 161–196. doi: 10.1016/s0010-0277(00)00128-1

Jack, A. I., and Roepstorff, A. (2002). Introspection and cognitive brain mapping: from stimulus-response to script-report. *Trends Cogn. Sci.* 6, 333–339. doi: 10.1016/s1364-6613(02)01941-1

Jenkinson, M., Bannister, P., Brady, M., and Smith, S. (2002). Improved optimization for the robust and accurate linear registration and motion correction of brain images. *Neuroimage* 17, 825–841. doi: 10.1006/nimg.2002.1132

Karahanoglu, F. I., and Van De Ville, D. (2015). Transient brain activity disentangles fMRI resting-state dynamics in terms of spatially and temporally overlapping networks. *Nat. Commun.* 6:7751. doi: 10.1038/ncomms8751

Khanna, A., Pascual-Leone, A., Michel, C. M., and Farzan, F. (2015). Microstates in resting-state EEG: current status and future directions. *Neurosci. Biobehav. Rev.* 49, 105–113. doi: 10.1016/j.neubiorev.2014.12.010

Kikuchi, M., Koenig, T., Munesue, T., Hanaoka, A., Strik, W., Dierks, T., et al. (2011). EEG microstate analysis in drug-naive patients with panic disorder. *PLoS One* 6:e22912. doi: 10.1371/journal.pone.0022912

Kiviniemi, V., Vire, T., Remes, J., Elseoud, A. A., Starck, T., Tervonen, O., et al. (2011). A sliding time-window ICA reveals spatial variability of the default mode network in time. *Brain Connect.* 1, 339–347. doi: 10.1089/brain.2011.0036

Klein, A., Andersson, J., Ardekani, B. A., Ashburner, J., Avants, B., Chiang, M. C., et al. (2009). Evaluation of 14 nonlinear deformation algorithms applied to human brain MRI registration. *Neuroimage* 46, 786–802. doi: 10.1016/j.neuroimage.2008.12.037

Koenig, T., Prichep, L., Lehmann, D., Sosa, P. V., Braeker, E., Kleinlogel, H., et al. (2002). Millisecond by millisecond, year by year: normative EEG microstates and developmental stages. *Neuroimage* 16, 41–48. doi: 10.1006/nimg.2002.1070

Kouider, S., de Gardelle, V., Sackur, J., and Dupoux, E. (2010). How rich is consciousness? The partial awareness hypothesis. *Trends Cogn. Sci.* 14, 301–307. doi: 10.1016/j.tics.2010.04.006

Lagopoulos, J., Xu, J., Rasmussen, I., Vik, A., Malhi, G. S., Eliassen, C. F., et al. (2009). Increased theta and alpha EEG activity during nondirective meditation. *J. Altern. Complement. Med.* 15, 1187–1192. doi: 10.1089/acm.2009.0113

Lazar, S. W., Kerr, C. E., Wasserman, R. H., Gray, J. R., Greve, D. N., Treadway, M. T., et al. (2005). Meditation experience is associated with increased cortical thickness. *Neuroreport* 16, 1893–1897. doi: 10.1097/01.wnr.0000186598.66243.19

Lehmann, D., and Skrandies, W. (1980). Reference-free identification of components of checkerboard-evoked multichannel potential fields. *Electroencephalogr. Clin. Neurophysiol.* 48, 609–621. doi: 10.1016/0013-4694(80)90419-8

Lehmann, D., Faber, P. L., Galderisi, S., Herrmann, W. M., Kinoshita, T., Koukkou, M., et al. (2005). EEG microstate duration and syntax in acute, medication-naïve, first-episode schizophrenia: a multi-center study. *Psychiatry Res.* 138, 141–156. doi: 10.1016/j.pscychresns.2004.05.007

Lehmann, D., Ozaki, H., and Pal, I. (1987). EEG alpha map series: brain micro-states by space-oriented adaptive segmentation. *Electroencephalogr. Clin. Neurophysiol.* 67, 271–288. doi: 10.1016/0013-4694(87)90025-3

Lehmann, D., Pascual-Marqui, R. D., Strik, W. K., and Koenig, T. (2010). Core networks for visual-concrete and abstract thought content: a brain electric microstate analysis. *Neuroimage* 49, 1073–1079. doi: 10.1016/j.neuroimage.2009.07.054

Leonardi, N., Richiardi, J., Gschwind, M., Simioni, S., Annoni, J. M., Schluep, M., et al. (2013). Principal components of functional connectivity: a new approach to study dynamic brain connectivity during rest. *Neuroimage* 83, 937–950. doi: 10.1016/j.neuroimage.2013.07.019

Liu, X., and Duyn, J. H. (2013). Time-varying functional network information extracted from brief instances of spontaneous brain activity. *Proc. Natl. Acad. Sci. U S A* 110, 4392–4397. doi: 10.1073/pnas.1216856110

Lo, P. C., and Zhu, Q. (2009). "Microstate analysis of alpha-event brain topography during chan meditation," in *Proceedings of the 2009 International Conference on Machine Learning and Cybernetics* (Baoding, China), Vol. 2, 717–721.

Lutz, A., Lachaux, J.-P., Martinerie, J., and Varela, F. J. (2002). Guiding the study of brain dynamics by using first-person data: synchrony patterns correlate with ongoing conscious states during a simple visual task. *Proc. Natl. Acad. Sci. U S A* 99, 1586–1591. doi: 10.1073/pnas.032658199

Lutz, A., Slagter, H. A., Dunne, J. D., and Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends Cogn. Sci.* 12, 163–169. doi: 10.1016/j.tics.2008.01.005

Mantini, D., Perrucci, M. G., Del Gratta, C., Romani, G. L., and Corbetta, M. (2007). Electrophysiological signatures of resting state networks in the human brain. *Proc. Natl. Acad. Sci. U S A* 104, 13170–13175. doi: 10.1073/pnas.0700668104

Michel, C. M., Murray, M. M., Lantz, G., Gonzalez, S., Spinelli, L., and Grave de Peralta, R. (2004). EEG source imaging. *Clin. Neurophysiol.* 115, 2195–2222. doi: 10.1016/j.clinph.2004.06.001

Musso, F., Brinkmeyer, J., Mobascher, A., Warbrick, T., and Winterer, G. (2010). Spontaneous brain activity and EEG microstates. A novel EEG/fMRI analysis approach to explore resting-state networks. *Neuroimage* 52, 1149–1161. doi: 10.1016/j.neuroimage.2010.01.093

Nichols, T. E., and Holmes, A. P. (2002). Nonparametric permutation tests for functional neuroimaging: a primer with examples. *Hum. Brain Mapp.* 15, 1–25. doi: 10.1002/hbm.1058

Nishida, K., Morishima, Y., Yoshimura, M., Isotani, T., Irisawa, S., Jann, K., et al. (2013). EEG microstates associated with salience and frontoparietal networks in frontotemporal dementia, schizophrenia and Alzheimer's disease. *Clin. Neurophysiol.* 124, 1106–1114. doi: 10.1016/j.clinph.2013.01.005

Pascual-Marqui, R. D., Michel, C. M., and Lehmann, D. (1995). Segmentation of brain electrical activity into microstates: model estimation and validation. *IEEE Trans. Biomed. Eng.* 42, 658–665. doi: 10.1109/10.391164

Picchioni, D., Fukunaga, M., Carr, W. S., Braun, A. R., Balkin, T. J., Duyn, J. H., et al. (2008). fMRI differences between early and late stage-1 sleep. *Neurosci. Lett.* 441, 81–85. doi: 10.1016/j.neulet.2008.06.010

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., and Shulman, G. L. (2001). A default mode of brain function. *Proc. Natl. Acad. Sci. U S A* 98, 676–682. doi: 10.1073/pnas.98.2.676

Schlegel, F., Lehmann, D., Faber, P. L., Milz, P., and Gianotti, L. R. R. (2012). EEG microstates during resting represent personality differences. *Brain Topogr.* 25, 20–26. doi: 10.1007/s10548-011-0189-7

Smith, S. M. (2002). Fast robust automated brain extraction. *Hum. Brain Mapp.* 17, 143–155. doi: 10.1002/hbm.10062

Smith, S. M., Fox, P. T., Miller, K. L., Glahn, D. C., Fox, P. M., Mackay, C. E., et al. (2009). Correspondence of the brain's functional architecture during activation and rest. *Proc. Natl. Acad. Sci. U S A* 106, 13040–13045. doi: 10.1073/pnas.0905267106

Smith, S. M., Jenkinson, M., Woolrich, M. W., Beckmann, C. F., Behrens, T. E. J., Johansen-Berg, H., et al. (2004). Advances in functional and structural MR image analysis and implementation as FSL. *Neuroimage* 23, S208–S219. doi: 10.1016/j.neuroimage.2004.07.051

Smith, S. M., Miller, K. L., Moeller, S., Xu, J., Auerbach, E. J., Woolrich, M. W., et al. (2012). Temporally-independent functional modes of spontaneous brain activity. *Proc. Natl. Acad. Sci. U S A* 109, 3131–3136. doi: 10.1073/pnas.1121329109

Srinivasan, N., and Baijal, S. (2007). Concentrative meditation enhances preattentive processing: a mismatch negativity study. *Neuroreport* 18, 1709–1712. doi: 10.1097/wnr.0b013e3282f0d2d8

Takahashi, T., Murata, T., Hamada, T., Omori, M., Kosaka, H., Kikuchi, M., et al. (2005). Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. *Int. J. Psychophysiol.* 55, 199–207. doi: 10.1016/j.ijpsycho.2004.07.004

Tei, S., Faber, P. L., Lehmann, D., Tsujiuchi, T., Kumano, H., Pascual-Marqui, R. D., et al. (2009). Meditators and non-meditators: EEG source imaging during resting. *Brain Topogr.* 22, 158–165. doi: 10.1007/s10548-009-0107-4

Vincent, J. L., Patel, G. H., Fox, M. D., Snyder, A. Z., Baker, J. T., Van Essen, D. C., et al. (2007). Intrinsic functional architecture in the anaesthetized monkey brain. *Nature* 447, 83–86. doi: 10.1038/nature05758

Wallace, B. A. (1999). The buddhist tradition of samatha: methods for refining and examining consciousness. *J. Conscious. Stud.* 6, 175–187.

Xu, J., Vik, A., Groote, I. R., Lagopoulos, J., Holen, A., Ellingsen, O., et al. (2014). Nondirective meditation activates default mode network and areas associated with memory retrieval and emotional processing. *Front. Hum. Neurosci.* 8:86. doi: 10.3389/fnhum.2014.00086

Yuan, H., Zotev, V., Phillips, R., Drevets, W. C., and Bodurka, J. (2012). Spatiotemporal dynamics of the brain at rest–exploring EEG microstates as electrophysiological signatures of BOLD resting state networks. *Neuroimage* 60, 2062–2072. doi: 10.1016/j.neuroimage.2012.02.031

Zalesky, A., Fornito, A., Cocchi, L., Gollo, L. L., and Breakspear, M. (2014). Time-resolved resting-state brain networks. *Proc. Natl. Acad. Sci. U S A* 111, 10341–10346. doi: 10.1073/pnas.1400181111

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

IJW Nair, A. K., John, J. P., Mehrotra, S., & Kutty, B. M., (2018) What contributes to wellbeing gains - proficiency or duration of meditation related practices? *International Journal of Wellbeing*, *8*(2), 68-88. doi:10.5502/ijw.v8i2.696

ARTICLE

What contributes to wellbeing gains – proficiency or duration of meditation related practices?

Ajay Kumar Nair · John P. John · Seema Mehrotra · Bindu M. Kutty

Abstract: Several studies have shown physical and mental health benefits associated with different schools of meditation. However, reviews have recommended interpretation of study outcomes in the context of school specific traditional practices. In the literature, practice proficiency is often conflated with hours or years of meditation practice and it is difficult to attribute wellbeing gains directly to the proficiency of practice. We carried out two studies to examine wellbeing, practice proficiency, and duration of practice amongst Brahma Kumaris Rajayoga (BKRY) practitioners from India. In Study 1, we surveyed participants (n = 1009) to record the socio-demographics, spiritual lifestyle components, and wellbeing enhancement attributed to their spiritual practice. We developed new measures for evaluating proficiency of BKRY practice and for assessment of progress in wellbeing attributed to BKRY practice. Both measures had high internal consistency scores (alphas 0.95, 0.93). Block-wise hierarchical linear regression analysis showed that after accounting for demographic variables, BKRY practice proficiency strongly predicted progress in wellbeing, explaining over 51.6% of the total variance. In Study 2, we took three well-matched groups (*n* = 86) that were distinct on the basis of duration of practice (long term, short term and zero term). We examined wellbeing differences in these three groups and the extent of correlation of wellbeing with practice proficiency, progress in wellbeing and duration of practice. We conclude that meditation practice does improve wellbeing and that proficiency of practice is better correlated with most aspects of wellbeing than duration of practice but there are a few aspects of wellbeing that increase with sustained practice over a long time. We recommend that studies involving other schools of spiritual/religious practice incorporate tradition-specific proficiency assessment (instead of using years of practice as a proxy) and also use the Progress in Wellbeing scale for assessing practice-aided improvements in wellbeing.

Keywords: spirituality, wellbeing, meditation, Brahma Kumaris, Rajayoga

1. Introduction

Spiritual, religious and meditative practices are associated with enhanced wellbeing (Koenig, 2012; Sedlmeier et al., 2012; Sharma, 2006) but several methodological concerns have been raised regarding the extant studies (Goyal et al., 2014; Sedlmeier et al., 2012). Suggestions to address these methodological concerns are being formulated (Davidson & Kaszniak, 2015; Lutz, Jha, Dunne, & Saron, 2015) with the note that while there has been progress, research in this domain is still in its early stages (Awasthi, 2013; Davidson & Kaszniak, 2015).

Meditation expertise, proficiency and duration of practice are often used as synonymous terms (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Kaliman et al., 2014) but there is a need for a more nuanced approach. Since different schools of thought differ in terms

Bindu M. Kutty
National Institute of Mental Health and Neuro Sciences
India
bindu.nimhans@gmail.com

of techniques and goals, as well as underlying belief systems (Dahl, Lutz, & Davidson, 2015; Sedlmeier et al., 2012), there is a need to study the unique context of a given practice while interpreting any outcome (Lutz et al., 2015; Thomas & Cohen, 2014). While there have been attempts to connect practice proficiency and better health outcomes (Wiist, Sullivan, St George, & Wayment, 2012), we have not found studies that examined the linkage between practice proficiency and wellbeing.

In this paper, we use the term "school of thought" as an umbrella term for all categories of religious, spiritual and meditative traditions. "Practice proficiency" denotes proficiency of an individual in the context of beliefs, practices and techniques that may be considered an integral part of a particular school of thought. The term "practitioner" refers to an individual who is actively engaged in the beliefs and practices of any one school of thought. We use the term "wellbeing" in a broad sense such that it denotes a good quality of life across several dimensions, including subjective wellbeing (high positive affect, low negative affect, high satisfaction with life), psychological wellbeing (self-acceptance, mastery and competence, positive relations and engagement and growth), meaning in life (framework for looking at life and sense of fulfilment), and quality of life (in the context of spiritual, religious and personal beliefs). "Progress in wellbeing" and "wellbeing gains" refer to a subjective sense of improvement (or deterioration) in wellbeing parameters that a practitioner might experience after initiation of practice and attributes to the practice. "Prior religiosity" refers to regularity of religious practice before becoming a practitioner. "High religiosity" implies daily or regular prayers (others are categorized as "low religiosity"). We use "prior religiosity" as a shorthand for propensity for regular practice, rather than degree of belief in a particular creed. We will use these terms in the context of one school of thought (the Brahma Kumaris) and then consider how this might lead to broader applications.

The Brahma Kumaris (BK) is an international socio-spiritual organization that offers a variety of free self-development courses based on a philosophy of self-mastery termed as Rajayoga (RY) that is distinct from, and unrelated to, Rajayoga as commonly taught in the tradition of the sage Patanjali (Brahma Kumaris, 2018). BKRY teaches four subjects: knowledge (core tenets of the BKRY philosophy that provide a spiritual framework for looking at life), meditation (also referred to as "yoga" within the group; there are many different meditation techniques used in RY including aspects of concentration, mindfulness, compassion, visualization, directed thinking; all these meditation techniques are based on knowledge), inculcation of virtues (visible through behaviour on the basis of knowledge and meditation), and service to humanity (on the basis of the first three subjects) (Brahma Kumaris, 2018; Ramsay, Manderson, & Smith, 2010). BKRY also provides spiritual lifestyle guidelines (diet, celibacy, brief meditative breaks during the day, volunteering for service activities etc.) and spiritual practice recommendations (early morning meditation at 4 a.m. or earlier, daily classes at a meditation centre, meditation before and after class) intended to foster self-development and wellbeing outcomes (Ramsay et al., 2010). The Spiritual Applications Research Centre (SpARC) is a BK-affiliated wing dedicated to facilitate creation of methods for self-development (SpARC, 2018). We wanted to know how BKRY practitioners, given their intense focus on self-development, perceived progress in different aspects of wellbeing (as compared to pre-BKRY days). We also wanted to examine what factors would predict progress in wellbeing. Further, we wanted to compare BKRY practitioners with well-matched non-practitioners, using standard wellbeing measures.

Previous studies on BKRY practitioners have reported an increase in positive thinking and happiness in life (Ramesh, Sathian, Sinu, & Kiranmai, 2013), reduction in middle latency auditory evoked potentials during meditation (Telles & Naveen, 2004) and improvement in respiratory functions, diastolic blood pressure and lipid profile (Mandape, Bharshankar, & Phatak, 2015; Vyas & Dikshit, 2002). An early study on the effect on autonomic changes was inconclusive, mentioning both sympathetic and parasympathetic activations (Telles & Desiraju, 1993), while a more recent study showed a parasympathetic dominance in BKRY practitioners with more than 5 years of experience (Bharshankar, Mandape, Phatak, & Bharshankar, 2015). The Mount Abu Open Heart Trial found regression of coronary atherosclerosis in participants who adhered to a healthy lifestyle – a combination of diet, exercise and stress management through BKRY (Gupta et al., 2011). A neuroimaging study found that BKRY practice (between 10 and 22 years) was correlated with neuroplastic changes in brain networks (Panda, Bharath, Upadhyay, & Mangalore, 2016). A recent EEG study demonstrated state-trait interactions in BKRY practitioners – those with long-term practice (minimum of 10 years) could quickly shift between rest and meditation states as indexed by EEG power changes, whereas novices took more time and the control subjects were unable to achieve any state changes (Nair, Sasidharan, John, Mehrotra, & Kutty, 2017). Interventional studies using BKRY have shown relief in chronic tension headaches and reduction in plasma cortisol levels in those suffering from headaches for over 5 years (Kiran, Behari, Venugopal, Vivekanandhan, & Pandey, 2005), reduced neurotic symptoms and increase in hope and happiness (Misra, Gupta, Alreja, & Prakash, 2013).

We carried out two studies to examine the connection between wellbeing and proficiency. Study 1 surveyed BKRY practitioners to evaluate proficiency and progress in wellbeing attributed to RY practice. We hypothesized that spiritual lifestyle components (regularity of attending spiritual classes and early morning meditation, hours of daily meditation and years of BKRY practice) would predict proficiency, and that proficiency in turn would be a better predictor of progress in wellbeing than years of practice. In Study 2, we examined wellbeing using standard measures in three well-matched groups of those with long-term practice (LTP), short-term practice (STP) and a control group (zero-term practice or ZTP). Our hypothesis was that BKRY practitioners (LTP and STP) would report enhanced wellbeing as compared to ZTP, and that these would be correlated with proficiency of practice. We further hypothesized that LTP would show additional wellbeing enhancements over STP, attributable to their longer-term practice.

2. Study 1: Proficiency and progress in wellbeing in BKRY practitioners

The purpose of Study 1 was to examine: a) BKRY practice proficiency and b) progress in wellbeing in a large sample and to examine possible predictors for each. Both these measures are novel and thus this study was exploratory in nature. These two measures are based on BKRY concepts and were developed with inputs from expert practitioners. In this study, we did not have the opportunity to use other commonly used wellbeing measures.

2.1 Method

2.1.1 Data collection

All survey participants were BKRY practitioners who gave written informed consent and submitted the completed bilingual (English-Hindi or English-Kannada) survey form (called "Rajayoga Practice Checker"). The participants were given the option to withhold their name and contact details if they preferred to stay anonymous.

The survey was administered during different meetings and retreats held in different parts of India – Abu Road (BK headquarters) Bangalore, Coimbatore, Delhi and Chennai. The only criteria for participation were the ability to read and be fluent in English, Hindi or Kannada, and consistent (self-reported) meditation experience of at least 6 months. Data collection during the various meetings and retreats ensured that only serious meditators participated in the study. Two of the small retreats comprised dedicated (full-time) BKRY practitioners, while others consisted of a general membership. The meetings focused on both spiritual research (reviewing spiritual material and preparing testable self-development projects) and self-development, while the retreats focused on experiential aspects.

Prior to the data collection sessions, the need for the survey was highlighted. Participants were given an opportunity for reflection on their own spiritual journey as they took up BKRY practice, and introspection on their strengths and weaknesses in order to rate themselves on the various scales. Detailed explanations with examples were provided to enable the practitioners to carry out the self-rating. Additional clarifications were provided when requested. Honesty and accuracy in filling in the forms were requested and confidentiality was assured, with the commitment that only statistical data would be used for research and development. Since the survey was specifically directed at BKRY practitioners, the questions contained terms that are commonly used within this school of thought. Apart from questions pertaining to socio-demographics and spiritual lifestyle, a key feature of the survey was the self-assessment of 25 core practice components (BKRY practice proficiency scale) covering the four subjects of BKRY. This section was adapted from an unpublished SpARC project that documented the milestones on the journey from novice to mastery. Another important feature was the inclusion of self-assessment of improvement (or deterioration) in several wellbeing parameters (Progress in Wellbeing scale) that the participants attributed to the practice of BKRY.

2.1.2 Novel measures and data analysis

Each school of thought has its own philosophy and set of guidelines for practice that enable optimal progress. The existing literature routinely uses years of practice as a shorthand for degree of practitioner expertise. However, it is possible that a short duration of deliberate practice can lead to proficiency levels that may not be achieved with long durations of casual practice. Thus, there is a need for developing practice proficiency measures for each school of thought that can aid in assessing the progress made by the practitioner. The BKRY practice proficiency scale was developed to fulfil this need. The terminology used in the scale is specific to BKRY and is well understood by the practitioners.

The BKRY practice proficiency scale had 25 items[1] in total, divided into four subscales for measuring each of the four subjects of BKRY. The maximum possible score was 100. The subscale for "Clarity of Knowledge" had seven items that were scored as follows: *Perfect clarity* = 4; *Very clear* = 3; *Some clarity* = 2; *Not sure* = 1; *No idea* = 0. The subscales "Experience of Yoga (Meditation)," "Spiritual Lifestyle" and "Serving the World" had six items each that were scored as follows: *Constant experience* = 4; *Good experience* = 3; *Some experience* = 2; *Trying* = 1; *No experience* = 0. The term "constant experience" in BKRY refers to the state of embodying or being in that state of experience and therefore is the highest extent of experience possible.

The overall scale and each of the subscales had high internal consistency scores. Cronbach's alphas (and McDonald's omegas with confidence intervals) were 0.94 [0.931 (0.919-0.94)] for "Clarity of Knowledge," 0.87 [0.866(0.85-0.881)] for "Experience of Yoga," 0.85 [0.857(0.839-

[1] These items are very specific to the BKRY tradition (for example: concepts such as "tree" and "ladder") and are therefore omitted from the text for clarity and succinctness. The questionnaire can be provided on request.

0.873)] for "Spiritual Lifestyle," 0.88 [0.882(0.867-0.896)] for "Serving the World" and 0.95 [0.948(0.935-0.96)] for the overall proficiency scale.

Several longitudinal studies have reported wellbeing gains in meditators by using a pre-post design across a meditation retreat, typically involving novice practitioners. However, this misses out data from the vast majority of experienced practitioners. Further, intense practice of any school of thought can involve major lifestyle changes, leading to issues in adaptation for both the practitioners and those who come in contact with them. Thus, initially, the practitioners may encounter some deterioration in relationships or personal happiness levels (due to heightened awareness of some personal limitations), while in the long run, most practitioners are likely to experience increased wellbeing across all domains. To test these ideas, we developed the Progress in Wellbeing scale to enable the practitioner to rate the extent of change across multiple dimensions of wellbeing (Table 1 below) after commencement of RY practice and attributable to RY practice. Thus, for carrying out the self-assessment of progress in wellbeing (or lack thereof), the participants had to compare their current state of wellbeing to their baseline state just prior to enrolling in BKRY. We did not provide explicit criteria for rating progress across these dimensions, however, BKRY recommends daily journaling (called a progress "chart" – this is flexible and can take many different formats), and so most participants are quite used to evaluating their progress on a regular basis.

The Progress in Wellbeing scale had eight items for checking the participants' sense of "Overall improvement due to Rajayoga" in various aspects of wellbeing (Table 1). The items were scored as follows: *Excellent progress* = 5; *Very good progress* = 4; *Moderate progress* = 3; *No change* = 2; *Worse in general* = 1; *Worse due to Rajayoga* = 0. The scale had an alpha of 0.93 and omega of 0.933(0.923-0.948).

After computing Proficiency and Progress in Wellbeing scores, hierarchical linear regression was carried out to account for demographic variables (age, gender, education, monthly family income, prior religiosity and commitment level) as a block before examining the effect of practice variables on BKRY proficiency. We included prior religiosity (high or low), as it might have a bearing on practice proficiency, and we included commitment level as a binary variable (full-time commitment to BKRY or not), as it could influence depth and duration of practice. Practitioners with full-time commitment are officially designated as "dedicated" or "surrendered" by the BK organization. We then analyzed the effect of BKRY proficiency on progress in wellbeing after accounting for the demographic variables (as a block).

2.2 Results of Study 1

A total of 1,500 forms were distributed for Study 1. Completed survey forms of 1,009 respondents (67.2%) were analyzed. Both genders were well represented (49.2% female). The average age was 45 years (range 15-83, *SD*=14.9 years). Almost half were married (49.5%). Most were from a Hindu background (97.5%) but there were some respondents from Jain, Muslim, Sikh, Buddhist, Christian or atheistic backgrounds. About half had high religiosity (52.5%, daily or regular prayers) prior to practice of BKRY. The majority were college educated (64.3%) and most had a middle-class family income (76.1%). Income earners formed 41.3% of the group. The non-income earners included dedicated practitioners, householders, students, retired and unemployed categories.

BKRY practice experience ranged from 1 to 57 years (median 12 years). Most respondents meditated for more than 1 hour daily (76.1%) and the median lifetime meditation experience was over 7,000 hours. Most respondents regularly attended BKRY spiritual classes (91%) and practiced early morning meditation (80.4%). More than 90% of the participants felt that they had experienced substantial progress in wellbeing after starting BKRY practice (Table 1).

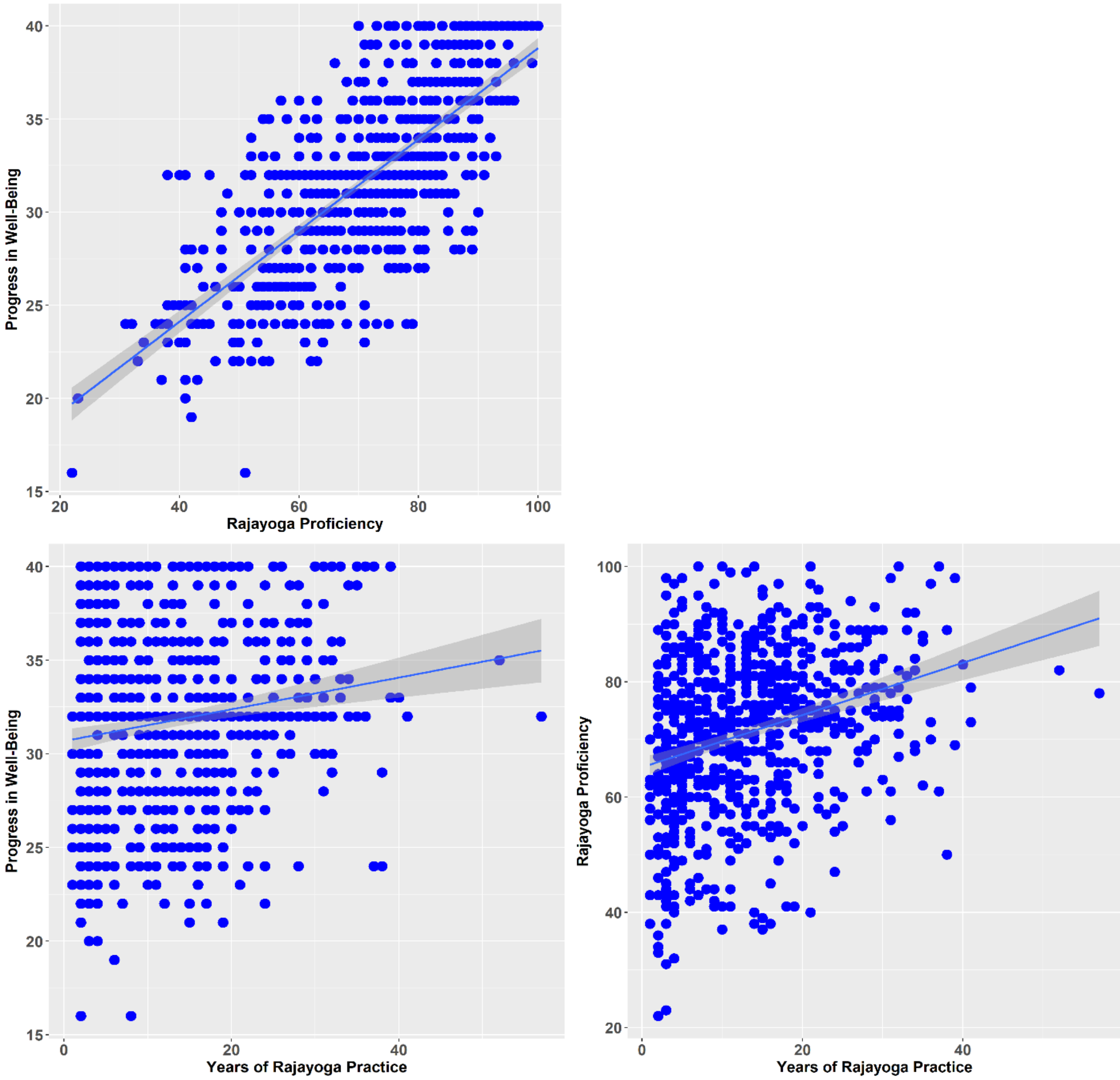
Table 1. Progress in wellbeing attributed to BKRY practice (n = 1009, values in percentage)

	Excellent progress	Very good progress	Moderate	No change	Worse in general	Worse due to Rajayoga	Not filled
Happiness	29.0	51.7	16.3	0.9	0.1	0.4	1.6
Peace	27.4	53.0	16.8	1.1	0.2	0.1	1.4
Harmony	19.6	50.3	24.5	2.2	0.2	0.1	3.1
Values	21.2	48.2	23.5	1.7	0.2	0.0	5.3
Self-Development	23.0	51.0	22.9	0.9	0.3	0.1	1.8
Work Effectiveness	22.3	48.1	24.7	1.7	0.2	0.0	3.1
Spiritual Growth	21.8	50.4	23.7	1.3	0.1	0.0	2.7
Quality of Life	20.4	52.1	23.0	1.2	0.2	0.0	3.1

The RY practice proficiency scores ranged from 22.0 to 100 (M = 71.53, SD = 14.04). Hierarchical linear regression indicated that demographic variables (age, gender, education, monthly family income, prior religiosity and commitment status to BKRY) were significant determinants ($F_{14, 714}$ = 3.53, p < 0.001) and explained 4.6% of the variance (adjusted R-squared). Over and above the demographic variables, years of RY practice, hours of daily meditation, regularity of early morning meditation (4 a.m.) and regularity of spiritual study were significant determinants ($F_{27, 701}$ = 12.95, p < 0.001) of practice proficiency, explaining 30.7% of the total variance.

The Progress in Wellbeing scores ranged from 16 to 40 (M = 31.91, SD = 4.78). As can be seen in Table 1, more than 95% of the participants felt that they had made progress (excellent, very good or moderate) in all the wellbeing dimensions, as compared to the pre-BKRY baseline. Hierarchical linear regression indicated that demographic variables were not significant determinants ($F_{14, 686}$ = 1.30, p = 0.2). Over and above the demographic variables, practice proficiency strongly predicted (Figure 1) progress in wellbeing ($F_{15, 685}$ = 50.9, p < 0.001), explaining 51.68% of the total variance (adjusted R-squared). Figure 1 below shows the correlations between progress in wellbeing, practice proficiency and years of practice. Progress in wellbeing was strongly correlated with proficiency in BKRY practice (r=0.72, 95% CI 0.68 to 0.75) and weekly correlated with years of BKRY practice (r=0.16, 95% CI 0.08 to 0.23). Proficiency was correlated with years of BKRY practice (r=0.29, 95%CI 0.22 to 0.36). Shaded lines show 95% confidence intervals.

Figure 1. Progress in wellbeing as a function of proficiency (top), and years of practice (bottom left) in BKRY. Proficiency as a function of years of practice (bottom right).



2.3 Discussion of Study 1

The results provide evidence to support the hypothesis that the participants experienced improvements in wellbeing due to BKRY practice. While several previous reports have assessed wellbeing in meditators, the present study is the first to specifically query the sense of progress in wellbeing attributed to the practice. Also, as hypothesized, practice proficiency strongly predicted progress in wellbeing.

There have been some attempts to make assessment scales that are specific to other schools of thought. Religious understanding of basic precepts of Buddhism (including the creation of a Buddhist Devoutness Index) was found to predict improvement in health (Wiist et al., 2012). Manocha and colleagues in their study reported that items (such as meditation frequency, group meditation, socialising with other practitioners, and substance usage) in the Meditation Lifestyle Survey (MLS) of long-term Sahaja Yoga practitioners predicted the depth of mental silence experienced (Manocha, Black, & Wilson, 2012). A recent theoretical formulation of a phenomenological matrix of mindfulness-related practices is a welcome development (Lutz et al., 2015), and, as the authors suggested, needs to go through iterations of empirical testing and modification. The present study is the first to link practice proficiency and a corresponding sense of progress in wellbeing attributed to the practice.

The socio-demographics showed that BKs represent all segments of society in terms of age, gender, education, income, profession and marital status. Our study shows that high prior religiosity is not a prerequisite for engaging in or sustaining spiritual practice. Thus, even if the practitioners were not regular in their prayers or other religious/spiritual practices prior to enrolling in BKRY, the majority had a substantial commitment to self-development, as demonstrated by regular attendance of spiritual classes (involving a visit to the local meditation centre and lasting for at least 1 hour), participation in early morning meditation (4 a.m. or earlier) and more than an hour of daily meditation. Taken together, BKs engage in a significant alteration of their personal time and lifestyle choices while progressing on their path of self-development (Ramsay et al., 2010). Since 78.1% of the sample had more than 5 years of BKRY practice, it is likely that the lifestyle changes in these practitioners have been sustained over a long period of time.

We did not assess wellbeing per se using standard measures in Study 1 but other studies have shown that BKRY practitioners have enhanced happiness in life (Ramesh et al., 2013), as compared to non-meditators, and that long-term BKRY practitioners had fewer neurotic symptoms, and higher hope and happiness as compared to short-term practitioners (Misra et al., 2013). These studies are similar to the bulk of the literature that has examined wellbeing in meditators, as they conflate duration of practice with proficiency of practice. To confirm that these two variables are indeed different, we did separate analyses and found that duration of practice predicts proficiency (8.4% of the variance) and progress in wellbeing (2.5% of the variance) but this forms a very small contribution compared to the overall contribution of practice proficiency to progress in wellbeing. Thus our study suggests that instead of using years of practice as a proxy for proficiency or expertise in meditation, there is a need to explicitly assess proficiency using measures that are specific to each school of thought.

How might a practitioner achieve high proficiency within a short duration and another achieve only low proficiency even after long-term practice? A number of factors can contribute to this situation. As discussed earlier, proficiency in BKRY requires significant investment in terms of lifestyle adaptations (Ramsay et al., 2010). The proficiency gains are likely to be dependent on how quickly and how much a practitioner is willing to undergo these changes. For some people, the conceptual framework is compelling enough to make large-scale changes in earnest. Others might be more interested in the stress-relieving aspects of meditation and therefore focus only on that aspect. Overall, our findings are in line with the literature that deliberate and focused practice builds higher competence than routine, unfocused practice (Ericsson, 2006).

Meditation practice, and, to a greater extent, absorption, have an influence on meditation depth (Hölzel & Ott, 2006). In our study, different aspects of meditation depth were part of the assessment of practice proficiency. A study on long-term Sahaja Yoga meditators also showed that experience of mental silence (related to meditation depth) was facilitated by various practices and lifestyle factors (Manocha et al., 2012).

The BKRY practice proficiency scale and its four subscales had high internal consistency scores. The Progress in Wellbeing scale also had a high internal consistency score and can easily be adapted for use with other schools of meditation or spiritual self-development programs. Our study indicates that a full assessment of practice proficiency is indeed a predictor of progress in wellbeing, as suggested by others (Sedlmeier et al., 2012).

While most practitioners reported progress in wellbeing across all the parameters, there were a few respondents who sensed a deterioration in their wellbeing after they started the practice of BKRY due to extraneous factors (< 1%) and specifically due to BKRY practice (<1%), but the latter did not find that it affected their progress in work effectiveness, spiritual growth or overall quality of life. This deterioration in wellbeing could be due to the difficulties in coping with the challenges of self-change or due to difficulties that come when friends and relatives oppose changes in lifestyle. The results show that BKRY practitioners who adapt to the lifestyle changes experience a significant sense of progress in wellbeing. This is in line with other reports that show that meditation practitioners experience enhanced wellbeing on a number of measures (Manocha et al., 2012; Orme-Johnson & Dillbeck, 2014).

3. Study 2: Wellbeing in BKRY practitioners in relation to proficiency and duration

The purpose of Study 2 was to evaluate wellbeing using standard measures in three distinct groups based on duration of practice (LTP, STP and ZTP) but well matched on socio-economic aspects. We then examined (for LTP and STP), correlation between the different wellbeing results and BKRY practice proficiency, as well as duration of practice. While the Progress in Wellbeing scale indicates progress across a number of dimensions (Table 1), it does not necessarily indicate high wellbeing in any of the dimensions, as it is possible that the baseline was quite low. Therefore, we wanted to assess several standard measures of wellbeing and examine how progress in wellbeing correlates with them. Study 2 participants also took part in an EEG study on the ability to rapidly shift between rest and meditation states within a minute (Nair et al., 2017), which constrained the sample size.

3.1 Method

3.1.1 Participants

BKRY practitioners (LTP and STP) were enlisted for the study with help and follow-up support of the regional coordinating offices of BKRY centres in Bangalore. LTP had a minimum of 10 years of meditation experience and STP had at least 6 months and at most 2 years of meditation experience. Control participants (ZTP) were recruited from the local community, and, where possible, were non-meditator colleagues of the practitioner participants. This was done to match the socio-economic and work background as much as possible. Care was taken to ensure that none of the participants had had any lifetime exposure to any other form of meditation. Table 2 below lists the socio-demographics of the participants.

Table 2. Socio-demographics for Study 2 participants

Demographics	LTP (n = 36)	STP (n = 25)	ZTP (n = 25)	Statistics
Age				
Mean	45.06	44.28	45.04	F=0.05, p=0.95
(Min, Max)	(31, 64)	(27, 61)	(27, 59)	
Gender				
Female	14	11	11	χ^2=0.22, p=0.89
Male	22	14	14	
Education				
School Level	8	11	10	χ^2=6.33, p=0.17
Diploma or Degree	15	11	10	
Post Graduate or Above	13	3	5	
Monthly Family Income				
High Income	4	3	4	Low cell counts$
Upper Middle Income	5	3	5	
Lower Middle Income	26	18	16	
Low Income	1	1	0	
Body Mass Index (BMI)				
Mean (Min, max)	24.72 (17, 34)	25.56 (19, 39)	26.12 (20, 34)	F=0.93, p=0.4
Religiosity				
High	19	16	20	χ^2=4.81, p=0.3
Medium	8	4	2	
Low	9	5	3	
Meditation Median (Hrs)	14240	1095	0	**t=12.34, p=0.00**
(Min, max)	(7300, 35040)	(255, 2190)		

Note: $Low cell counts prevent accurate statistics, but these values are comparable and differences are not significant.

3.1.2 Measures

The following wellbeing measures were used:

1) Positive and Negative Affect Schedule (PANAS) – Revised (Rao & Mehrotra, 2006; Feldman Barrett & Russell, 1998; Watson & Clark, 1988). In the revised form (and adapted to the Indian context), this 26-item scale has two 13-item subscales for measuring positive affect and negative affect and has a 5-point Likert-type scale ranging from "Very slightly or not at all" to "Extremely." The state version was used for this study. It is considered to be the affective component of the subjective wellbeing.
2) Psychological Wellbeing (PWB) (Mehrotra, Tripathi & Banu, 2013; Ryff, 1989; Ryff & Keyes, 1995). This is a 20-item revised version of the original scale, adapted to the

Indian context. It assesses the trait notion of eudaimonic wellbeing and has four subscales: Self-Acceptance, Mastery and Competence, Positive Relations and Engagement, and Growth. Each subscale uses the same 6-point Likert-type scale ranging from “Strongly Agree” to “Strongly Disagree.”

3) Satisfaction with Life Scale (SWLS) (Diener. Emmons, Larson, & Griffin, 1985). This is a 5-item scale using a cognitive approach to assess one’s overall level of satisfaction with life. It has a 7-point Likert-type scale ranging from “Strongly Disagree” to “Strongly Agree.” It is considered to be the cognitive component of subjective wellbeing.
4) Life Regard Index (LRI) (Battista & Almond, 1973; Debats, van der Lubbe, & Wezeman, 1993). This 28-item scale evaluates the trait concept of meaningful life and has two 14-item subscales assessing Framework and Fulfilment aspects of a meaningful life. It has a 3-point Likert-type scale with options of “Disagree,” “No Opinion” and “Agree.”
5) WHO Quality of Life – Spiritual Religious or Personal Beliefs (SRPB) (WHOQOL SRPB Group, 2006). This is a 32-item scale with eight subscales with four items each for “Spiritual Connection,” “Meaning and Purpose in Life,” “Experiences of Awe and Wonder,” “Wholeness and Integration,” “Spiritual Strength,” “Inner Peace,” “Hope and Optimism” and “Faith,” each having a 5-point Likert-type scale ranging from “Not at all” to “An extreme amount” or “Extremely” or “Completely” for different subscales. It is used to assess how much one’s belief system might contribute to quality of life. It is a state scale with a timeframe of “last two weeks.”
6) Rajayoga Practice Checker (RPC). This was the same questionnaire used in Study 1. We also made a subset (without the spiritual practice components) for obtaining the socio-demographic details of the ZTP group.

The overall RY proficiency scale (and each of its subscales) and Progress in Wellbeing scale had high internal consistency scores similar to the scores in Study 1. Cronbach’s alphas were 0.90 for “Clarity of Knowledge,” 0.78 for “Experience of Yoga,” 0.85 for “Spiritual Lifestyle,” 0.91 for “Serving the World,” 0.92 for the overall “Rajayoga Proficiency” scale and 0.89 for the “Progress in Wellbeing” scale. Study 2 evaluated wellbeing using a number of measures considering subjective wellbeing, psychological wellbeing, meaning in life, and contribution of belief to quality of life. All the scales used (and their subscales) showed high internal consistency scores, indicating their reliability and suitability for assessment in this population. While Cronbach’s alpha is the most commonly used measure of internal consistency, its use has been criticized with a strong recommendation to instead report McDonald’s omega (Dunn, Baguley, & Brunsden, 2014), along with confidence intervals. Alpha and omega scores were similar in the present study and showed that the scales were reliable and suitable for use. Table 3 below lists the Cronbach’s alphas, McDonald’s omega and confidence intervals for all the wellbeing measures.

Table 3. Reliability scores for the wellbeing measures

Wellbeing Measure	Alpha, Omega (CI)
Positive and Negative Affect Schedule	
Positive Affect	0.87, 0.87(0.81-0.91)
Negative Affect	0.81, 0.82(0.75-0.87)
Psychological Wellbeing	
Overall	0.86, 0.86(0.79-0.90)
Self-Acceptance	0.71, 0.72(0.50-0.81)
Mastery and Competence	0.74, 0.75(0.66-0.81)
Positive Relations	0.68, 0.69(0.57-0.77)
Engagement and Growth	0.66, 0.70(0.49-0.81)
Satisfaction with Life Scale	
Overall	0.76, 0.73(0.59-0.80)
Life Regard Index	
Overall	0.85, 0.84(0.75-0.89)
Framework	0.72, 0.71(0.56-0.80)
Fulfilment	0.75, 0.74(0.62-0.83)
Spiritual, Religious and Personal Beliefs	
Overall	0.96, 0.96(0.95-0.97)
Spiritual Connection	0.87, 0.96(0.95-0.97)
Meaning and Purpose in Life	0.74, 0.75(0.66-0.81)
Experiences of Awe and Wonder	0.77, 0.77(0.66-0.84)
Wholeness and Integration	0.82, 0.82(0.75-0.88)
Spiritual Strength	0.83, 0.83(0.74-0.9)
Inner Peace	0.87, 0.88(0.82-0.92)
Hope and Optimism	0.88, 0.88(0.81-0.93)
Faith	0.86, 0.86(0.79-0.92)

3.2 Results of Study 2

Statistical comparisons (using appropriate methods listed in Table 4 below) revealed that BKRY practitioners (LTP and STP) had significantly enhanced wellbeing as compared to ZTP for almost all the wellbeing measures (Table 4). The exceptions were for subscales on self-acceptance, positive relations, engagement and growth, awe and wonder, and spiritual strength. Further evaluation using the Jonckheere-Terpstra test (which has a directional hypothesis and thus higher power) revealed that all these variables had a significant decreasing trend (i.e., LTP ≥ STP ≥ ZTP), as expected. Most wellbeing variables were correlated with Rajayoga proficiency and with progress in wellbeing (Table 5 below). Three outcome variables were correlated with meditation duration: engagement, wholeness and integration, and spiritual strength.

Table 4a. Wellbeing measures (M and SD) and group differences

Wellbeing measures	LTP (n=36)	STP (n=25)	ZTP (n=25)	Group Results	LTP vs ZTP	STP vs ZTP	LTP vs STP
Positive Affect	47.69 (7.65)	47.08 (8.64)	40.96 (9.83)	**F=5.06, p=0.008**	**p=0.009**	**p=0.037**	p=0.959
Negative Affect	20.56 (6.52)	21.44 (5.32)	28.52 (7.63)	**H=17.66, p=0**	**TRUE, JT=1713**	**TRUE**	FALSE
Overall PWB	101.33 (12.8)	100.24 (13.22)	88.24 (16.4)	**H=10.93, p=0.004**	**TRUE**	**TRUE**	FALSE
Self-Acceptance	22.22 (2.26)	22.28 (3.12)	19.88 (4.12)	**F_t=3.17, p=0.058**	**$JT=992^{*}$**		
Mastery and Competence	26.86 (6.86)	26.92 (5.84)	21.76 (7.83)	**H=8.13 p=0.017**	**TRUE $JT=897^{**}$**	FALSE	FALSE
Positive Relations	23.86 (4.85)	23.44 (5.31)	20.44 (5.98)	H=5.42 p=0.067	**$JT = 953.5^{*}$**		
Engagement and Growth	28.39 (2.16)	27.6 (2.33)	26.14 (4.41)	H=3.99 p=0.136	**$JT = 953^{*}$**		
Life Satisfaction	26.03 (6.54)	27.04 (4.86)	23.28 (5.91)	H=6.16 p=0.046	**$JT = 966^{*}$**		
Overall LRI	76.69 (4.87)	75.4 (6.11)	67.36 (9.21)	**F_t= 7.65, ξ=0.66**	**ξ=0.75**	**ξ=0.63**	ξ=0.10
Framework	39.42 (2.06)	38.84 (2.81)	34.56 (4.49)	**F_t= 7.25, ξ=0.86**	**ξ=0.73**	**ξ=0.72**	ξ=0.07
Fulfilment	37.28 (3.62)	36.56 (4.35)	32.8 (5.05)	**H=13.74 p=0.001**	**TRUE $JT=794^{***}$**	**TRUE**	FALSE
Overall SRPB	134.44 (13.5)	131.48 (15.28)	108.44 (22.6)	**F_t=9.08, ξ=0.7**	**ξ=0.81**	**ξ=0.71**	ξ=0.08
Spiritual Connection	17.14 (1.96)	16.28 (3.18)	12.96 (3.56)	**F_t=9.78, ξ=0.65**	**ξ=0.93**	**ξ=0.70**	ξ=0.07
Meaning and Purpose	16.94 (2.19)	16.68 (2.72)	14.04 (2.56)	**H=17.65, p=0**	**TRUE, $JT = 770^{***}$**	**TRUE**	FALSE
Awe and Wonder	16.17 (2.31)	15.84 (2.59)	13.44 (3.57)	F_t= 2, p=0.156	**$JT = 883^{**}$**		
Wholeness and Integration	16.22 (2.13)	15.96 (2.24)	13.2 (4.05)	**F_t= 4.86, ξ=0.61**	**ξ=0.69**	**ξ=0.58**	ξ=0.11
Spiritual Strength	17.53 (1.86)	16.84 (2.03)	14.24 (4.62)	F_t = 3.16, p=0.059	**$JT = 839^{**}$**		

Table 4b. Wellbeing Measures (M and SD) and group differences

Wellbeing measures	LTP (*n*=36)	STP (*n*=25)	ZTP (*n*=25)	Group Results	LTP vs ZTP	STP vs ZTP	LTP vs STP
Inner Peace	16.39 (2.1)	16.08 (1.89)	12.48 (3.62)	**F_t = 10.89, ξ=0.87**	**ξ=0.76**	**ξ=0.91**	ξ=0.11
Hope and Optimism	16.58 (2.45)	16.88 (2.05)	13.32 (4.07)	**F_t=4.95, ξ=0.61**	**ξ=0.64**	**ξ=0.61**	ξ=0.08
Faith	17.47 (2.08)	16.92 (2.4)	14.76 (3.72)	**F_t=3.7, ξ=0.5**	**ξ=0.55**	**ξ=0.46**	ξ=0.11

F: One-way ANOVA followed by Tukey's HSD post-hoc test. *H:* Kruskal-Wallis rank sum test.
JT: Jonckheere-Terpstra trend test. * p<0.05, decreasing LTP≥STP ≥ZTP
F_t: Robust one-way ANOVA using trimmed data followed by *ξ*: Robust explanatory effect size calculated for robust one-way ANOVA and pairwise post hoc
Note: Values in bold are statistically significant.

Table 5. Correlations between wellbeing measures and proficiency, progress in wellbeing and practice duration

Measure	Practice Proficiency	Progress in Wellbeing	Meditation Duration
Positive and Negative Affect Schedule			
Positive Affect (PA)	***r* = 0.36, *p* = 0.005**	***r* = 0.4, *p* = 0.001**	n.s.
Negative Affect (NA)	**tau = -0.16, *p* = 0.04**	n.s.	n.s.
Psychological Wellbeing Scale (PWB)			
PWB (Overall)	***r* = 0.28, *p* = 0.032**	***r* = 0.31, *p* = 0.015**	n.s.
Self-Acceptance (SA)	**tau = 0.18, *p* = 0.03**	n.s.	n.s.
Mastery (MC)	**tau = 0.18, *p* = 0.026**	**tau = 0.17, *p* = 0.034**	n.s.
Positive Relations (PR)	**tau = 0.2, *p* = 0.015**	**tau = 0.24, *p* = 0.005**	n.s.
Engagement (EG)	n.s.	**tau = 0.19, *p* = 0.026**	**tau = 0.19, *p* = 0.02**
Satisfaction with Life Scale (SWLS)			
Life Satisfaction (LS)	**tau = 0.2, *p* = 0.015**	n.s.	n.s.
Life Regard Index (LRI)			
LRI Total	n.s.	**tau = 0.17, *p* = 0.034**	n.s.
Framework (FR)	n.s.	n.s.	n.s.
Fulfilment (FU)	**tau = 0.2, *p* = 0.017**	**tau = 0.19, *p* = 0.021**	n.s.
Spiritual, Religious and Personal Beliefs (SRPB)			
SRPB (Overall)	***r* = 0.45, *p* = 0**	***r* = 0.41, *p* = 0.001**	n.s.
Connection	**tau = 0.21, *p* = 0.015**	**tau = 0.28, *p* = 0.002**	n.s.
Meaning	n.s.	**tau = 0.18, *p* = 0.03**	n.s.
Awe	**tau = 0.22, *p* = 0.01**	n.s.	n.s.
Wholeness	**tau = 0.39, *p* = 0**	**tau = 0.33, *p* = 0**	**tau = 0.19, *p* = 0.02**
Strength	**tau = 0.32, *p* = 0**	**tau = 0.24, *p* = 0.006**	**tau = 0.22, *p* = 0.01**
Peace	**tau = 0.35, *p* = 0**	**tau = 0.27, *p* = 0.003**	n.s.
Hope	**tau = 0.17, *p* = 0.033**	n.s.	n.s.
Faith	**tau = 0.29, *p* = 0.001**	**tau = 0.31, *p* = 0.001**	n.s.

r: Karl Pearson's product-moment correlation coefficient. tau: Kendall's rank correlation coefficient. n.s.: not significant

3.3 Discussion of Study 2

The results of Study 2 provide evidence to support the hypothesis that the BKRY participants (LTP and STP) had higher wellbeing than controls across a number of measures: subjective wellbeing, psychological wellbeing, meaning in life and contribution of belief into quality of life. We discuss these findings below. As hypothesized, practice proficiency and progress in wellbeing were well correlated with most measures of wellbeing. Surprisingly, and contrary to our hypothesis, LTP did not show more enhanced wellbeing than STP in any measure, and although there were significant trends of higher wellbeing in LTP as compared to STP, there were no overall group differences. Duration of practice was correlated with only three subscales.

3.3.1 Subjective wellbeing

The Subjective Wellbeing (SWB) scores for the ZTP were similar (i.e., no significant differences for Positive Affect (PA), Negative Affect (NA) or Life Satisfaction (LS)) to that found in the literature (Agrawal et al., 2011). Agrawal and colleagues (2011) had evaluated SWB and its socio-demographic correlates in a large sample (n = 1099) from an urban Bangalore population. Since our sample is also from Bangalore, the scores for ZTP in the present study replicate the findings in the literature.

LTP and STP both showed significantly enhanced PA and reduced NA as compared to ZTP, showing that Rajayoga practice is associated with improved affect balance. This is in agreement with recent meta-analyses (Goyal et al., 2014; Sedlmeier et al., 2012) which show decreased NA in meditators, and with a previous study of Rajayoga practitioners that found increased happiness scores in RY meditators as compared to non-meditators (Ramesh et al., 2013). There were no significant differences for PA between LTP and STP, which is in contrast to a previous study which showed that the long-term Rajayoga group scored higher on hope and happiness as compared to the short-term group (Misra et al., 2013). Since Misra and colleagues (2013) had used Lyubomirsky and Lepper's (1999) scale, it is difficult to directly comment on these differences. A recent randomized controlled study on 100 patients (50 were taught Rajayoga and practiced 20 minutes per day for 6 weeks, the other 50 did not practice any meditation; all patients received standard treatment), found that while both groups benefited from the medication, the percentage of relief experienced was much higher in the intervention group, as noted from the Hamilton Anxiety and Depression scales (Kiran, Arora, & Girgila, 2014). This indicates that novices (with less experience than STP) can also benefit from negative affect reduction through Rajayoga practice.

Surprisingly, the groups in the present sample showed no LS related differences (even though the means were higher for the practitioners and the Kruskal-Wallis test did cross the significance threshold), unlike a previous study which showed enhanced "self-satisfaction" among Rajayoga practitioners as compared to controls (Ramesh et al., 2013). The previous study did not examine LS using the "gold standard" (Diener et al., 1985) but instead, they used a subset of questions from the Oxford Happiness Questionnaire (Hills & Argyle, 2002), an instrument that has received criticism for not being directly relevant to assessment of SWB (Kashdan, 2004). Closer examination revealed that LTP and STP show enhanced LS as compared to the population score (Agrawal et al., 2011) reported in the literature ($p < 0.05$ and $p < 0.01$ respectively). Thus, while it is possible that the Rajayoga practitioners have slightly enhanced LS as compared to ZTP, the effect size is still quite small and can be ignored in order to make a conservative estimate. An alternative explanation could be that while LTP and STP do show significant enhancements in other aspects of wellbeing, their goals for self-development and spiritual-transcendence may also be much higher, thereby contributing to an average level of LS similar to ZTP. Since LS is a cognitive-evaluative measure of SWB (unlike PA and NA which contribute to affect balance), the comparison to higher goals might offset the gains in satisfaction achieved due to higher levels of PA and reduced levels of NA. Finally, the Jonckheere-Terpstra test revealed a statistically significant trend of increased LS with duration of practice. (Note that the results show a decreasing trend with decreasing duration of practice – the result is equivalent.)

3.3.2 Psychological wellbeing

There are no studies that have examined psychological wellbeing (PWB) for the adult Indian population for the age range used in the present study. However, there is one report of a large field trial (Mehrotra, Tripathi, & Banu, 2013) for Indian youth (age range 20-35 years, $n = 614$) which can be used as a starting point for examining the results. There were no significant differences (all $p > 0.05$) between the scores obtained by ZTP and the youth population for PWB (overall) or for any of the subscales Self-Acceptance (SA), Mastery and Competence (MC), Positive Relations (PR), and Engagement and Growth (EG). Thus, the results from the current study replicate the findings from the youth study and extend and generalize the results to the adult urban Indian population.

LTP and STP had significantly higher overall PWB scores than ZTP. For MC, only LTP showed significantly enhanced scores as compared to ZTP, which indicates that long-term practice does confer additional wellbeing benefits as compared to short-term practice. Additionally, a statistically significant trend of increasing SA, PR and EG was found with increased years of practice. It is worth noting that PR and EG are considered to be key contributors to flourishing in Seligman's "PERMA" model of wellbeing (Seligman, 2012). Thus, higher proficiency of practice sustained over a long term of practice may well be the key to a life of flourishing.

It is fruitful to discuss the non-significant differences in LS and SA. Global satisfaction with life was not enhanced, possibly due to a sustained gap between enhanced wellbeing and enhanced goals, as it is known that LS measures have an implicit comparison with have-want discrepancy (Wu, 2008). Another factor to be considered is that the study did not assess participants' personal ideals and goals which could possibly influence the LS ratings. SA is defined as having a positive attitude towards the self and a positive view of past life, while acknowledging and accepting one's good and bad qualities (Ryff, 1989). A similar and more recent perspective considers SA to be an overall sense of contentment with oneself and with the way one's life has played out (Mehrotra et al., 2013). While introspection and self-evaluation are important tools for a meditator, self-criticism and judgmental non-acceptance are not healthy – they are strongly linked to various forms of psychopathology such as depression, anxiety, substance abuse, suicide (Kannan & Levitt, 2013). SA on the other hand, is related to self-compassion, which implies being kind to oneself in the face of pain and failure in a mindful way, in a manner distinct from self-pity, self-centeredness and self-complacency (Barnard & Curry, 2011). It is likely that in Rajayoga, a path directed towards self-mastery, critical self-evaluation and self-compassion balance out. Both LS and SA did show a significant trend of enhancement with duration of practice, which indicates that the LS and SA are slightly higher in the practitioners.

An enhancement in sense of mastery (especially self-mastery, since it is a key goal for Rajayoga) in LTP is not surprising. It is noteworthy that the mean values for MC in STP are higher than LTP too, but the SD is smaller and it just missed statistical significance. The trend test was significant, showing that STP also have enhanced sense of mastery as compared to ZTP. Rajayoga mastery requires significant lifestyle changes, which may pose adjustment challenges in PR, as the practitioner tries to bring about these changes while engaging with the circles of family, friends and colleagues. With time, these relationships take a more positive turn, as evidenced by the significant increased trend.

3.3.3 Meaning in life

The Life Regard Index (LRI) evaluates the framework (FR) through which an individual views life goals and aspirations that make life meaningful, and fulfillment (FU) of these goals and aspirations. This scale can be suitably used for practitioners of different schools of thought, as it is not based on any particular belief system (Debats et al., 1993) i.e., it does not base meaning on any specific external belief system or philosophy. In the present study, both LTP and STP had a significantly enhanced sense of meaning in life as compared to ZTP. This is to be expected, as Rajayoga offers a consolidated knowledge framework (as one of the four subjects of Rajayoga) that can be used by the practitioner to look at life and its current challenges and an approach to create a potentially better future. Among the other subjects are meditation (which allows an experiential basis of connecting with God and other living beings), spiritual lifestyle (which brings about discipline and inculcation of desirable qualities), and, finally, service (which promotes contribution to the welfare of others). Through these subjects, Rajayoga provides a structure for developing meaning in life.

3.3.4 Beliefs and quality of life

The Spirituality, Religiousness and Personal Beliefs (SRPB) instrument was developed (WHOQOL SRPB Group, 2006) in conjunction with the Quality of Life assessment tool. It was validated across several religions and cultures (in 18 countries) and recognizes the contribution of the individual's belief system to quality of life. Both LTP and STP had significantly higher scores (than ZTP) for the overall SRPB scale, as well as the subscales measuring spiritual connection, meaning and purpose in life, wholeness and integration, inner peace, hope and optimism, and faith. There was also a significantly increased trend for experiences of awe and wonder, and for spiritual strength. Thus the contribution of the Rajayoga knowledge/belief system to the quality of life in the practitioners is substantial.

3.3.5 Wellbeing, proficiency and duration of practice

Rajayoga practice proficiency was correlated with almost all wellbeing outcomes, with the largest correlations for SRPB overall, wholeness, PA, peace, spiritual strength and PWB overall. These show the contribution of practice proficiency on enhanced wellbeing. As expected, progress in wellbeing was also correlated with a number of wellbeing outcomes. The largest correlations were for PA, SRPB overall, wholeness, faith, and PWB overall. This shows a limited extent of convergent validity of the scales. Progress in wellbeing does not necessarily imply higher wellbeing (if the baseline levels prior to Rajayoga practice were lower, for example) but they are likely to be similar. Years of Rajayoga practice were correlated with EG, wholeness and spiritual strength, showing that there are some aspects of wellbeing that benefit from increased years of practice.

Overall, the wellbeing measures indicate that even short-term Rajayoga practice confers benefits of enhancements in subjective wellbeing and psychological wellbeing, and provides a framework to meaningfully engage with life. Sustaining Rajayoga practice over time brings about additional benefits in terms of better engagement and growth, as well as enhanced spiritual strength and an overall sense of wholeness and integration between different aspects of inner and outer life.

4. Overall Discussion

Our findings suggest that BKRY practitioners experience a sense of progress across a number of dimensions in life. This progress in wellbeing is strongly associated with higher levels of proficiency in spiritual study, meditation experience, inculcation of virtues, and service orientation. While individual backgrounds (such as prior religiosity, supportive family etc.) may be of help to the practitioner, anyone who develops proficiency in practice is likely to experience progress in wellbeing.

There are several limitations of this study. Since these were cross-sectional studies, there was no opportunity to make causal inferences. A prospective study could also evaluate the relationship between personality factors and wellbeing by considering the individuals' personality prior to the initiation into BKRY and the changes that have been brought forth after initiation. Such an evaluation would indicate (i) whether there were any particular personality patterns noted in individuals who chose to embrace BKRY meditation, (ii) what kind of personality changes were likely due to practice of BKRY, and (iii) whether personality factors predict progress in wellbeing. However, carrying out such a longitudinal study to consider the effects of long-term practice (such as the LTP group) is not an easy undertaking. A related limitation is that we surveyed only current practitioners. Since we did not survey those who stopped BKRY practice, we cannot rule out any factors that might enable individuals to adapt to the BKRY lifestyle. Another limitation is due to the reliance on only self-report measures, which are vulnerable to reporting biases. A study that simultaneously evaluates physiological variables would be less susceptible to this bias.

Our study makes several contributions to the literature. To the best of our knowledge, this is the first comprehensive report that examines enhancement of wellbeing in practitioners of a school of thought in terms of their proficiency in spiritual lifestyle practices. We have found that proficiency of practice has much better correlation with different facets of wellbeing than duration of practice. We believe that studying different schools of thought and their practices can help unravel different pathways adopted by individuals for enhancement of wellbeing. We recommend that future studies in various schools of spiritual/religious practice incorporate tradition-specific proficiency assessment and suggest that the Progress in Wellbeing scale can be easily adapted for assessing practice-aided improvements in wellbeing.

Authors

Ajay Kumar Nair
National Institute of Mental Health and Neuro Sciences (NIMHANS), India

John P. John
National Institute of Mental Health and Neuro Sciences (NIMHANS), India

Seema Mehrotra
National Institute of Mental Health and Neuro Sciences (NIMHANS), India

Bindu M. Kutty
National Institute of Mental Health and Neuro Sciences (NIMHANS), India
bindu.nimhans@gmail.com

Publishing Timeline
Received 23 November 2017
Accepted 30 July 2018
Published 9 December 2018

References

Agrawal, J., Murthy, P., Philip, M., Mehrotra, S., Thennarasu, K., John, J. P., . . . Isaac, M. (2011). Socio-demographic correlates of subjective well-being in urban India. *Social Indicators Research*, *101*(3), 419–434. https://doi.org/10.1007/s11205-010-9669-5

Awasthi, B. (2013). Issues and perspectives in meditation research: In search for a definition. *Frontiers in Psychology*, *3*, 1–9. https://doi.org/10.3389/fpsyg.2012.00613

Barnard, L. K., & Curry, J. F. (2011). Self-compassion: Conceptualizations, correlates, & interventions. *Review of General Psychology*, *15*(4), 289–303. https://doi.org/10.1037/a0025754

Battista, J., & Almond, R. (1973). The development of meaning in life. *Psychiatry*, *36*(4), 409–427. https://doi.org/10.1080/00332747.1973.11023774

Bharshankar, J. R., Mandape, A. D., Phatak, M. S., & Bharshankar, R. N. (2015). Autonomic functions in Raja-yoga meditators. *Indian Journal of Physiology and Pharmacology*, *59*(4), 396–401.

Brahma Kumaris. (2018). Brahma Kumaris. http://www.brahmakumaris.org/

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *PNAS*, *104*(27), 11483–11488. https://doi.org/10.1073/pnas.0606552104

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences*, *19*(9), 515-523. https://doi.org/10.1016/j.tics.2015.07.001

Davidson, R. J., & Kaszniak, A. W. (2015). Conceptual and methodological issues in research on mindfulness and meditation. *American Psychologist*, *70*(7), 581–592. https://doi.org/10.1037/a0039512

Debats, D. L., van der Lubbe, P. M., & Wezeman, F. R. A. (1993). On the psychometric properties of the life regard index (LRI): A measure of meaningful life: An evaluation in three independent samples based on the Dutch version. *Personality and Individual Differences*, *14*(2), 337–345. https://doi.org/10.1016/0191-8869(93)90132-M

Diener, E., Emmons, R. A., Larson, R. J., & Griffin, S. (1985). The Satisfaction With Life Scale. *Journal of Personality Assessment*, *49*(1), 71–75. https://doi.org/10.1207/s15327752jpa4901_13

Dunn, T. J., Baguley, T., & Brunsden, V. (2014). From alpha to omega: A practical solution to the pervasive problem of internal consistency estimation. *British Journal of Psychology*, *105*(3), 399–412. https://doi.org/10.1111/bjop.12046

Ericsson, K. A. (2006). The influence of experience and deliberate practice on the development of superior expert performance. In A. K. Ericsson, N. Charness, R. R. Hoffman, & P. J. Feltovich (Eds.), *The Cambridge handbook of expertise and expert performance* (Vol. 38, pp. 685–705). New York, NY: Cambridge University Press.

Feldman Barrett, L., & Russell, J. A. (1998). Independence and bipolarity in the structure of current affect. *Journal of Personality and Social Psychology*, *74*(4), 967–984.
https://doi.org/10.1037/0022-3514.74.4.967

Goyal, M., Singh, S., Sibinga, E. M. S., Gould, N. F., Rowland-Seymour, A., Sharma, R., . . . Haythornthwaite, J. A. (2014). Meditation programs for psychological stress and well-being: A systematic review and meta-analysis. *JAMA Internal Medicine*, *174*(3), 357–368. https://doi.org/10.1001/jamainternmed.2013.13018

Gupta, S. K., Sawhney, R. C., Rai, L., Chavan, V. D., Dani, S., Arora, R. C., . . . Nanda, N. C. (2011). Regression of coronary atherosclerosis through healthy lifestyle in coronary artery disease patients: Mount Abu Open Heart Trial. *Indian Heart Journal*, *63*(5), 461–469.

Hills, P., & Argyle, M. (2002). The Oxford Happiness Questionnaire: A compact scale for the measurement of psychological well-being. *Personality and Individual Differences*, *33*(7), 1073–1082. https://doi.org/10.1016/S0191-8869(01)00213-6

Hölzel, B., & Ott, U. (2006). Relationships between meditation depth, absorption, meditation practice, and mindfulness: A latent variable approach. *The Journal of Transpersonal Psychology*, *38*(2), 179–200.

Kaliman, P., Álvarez-López, M. J., Cosín-Tomás, M., Rosenkranz, M. A., Lutz, A., & Davidson, R. J. (2014). Rapid changes in histone deacetylases and inflammatory gene expression in expert meditators. *Psychoneuroendocrinology*, *40*, 96–107. https://doi.org/10.1016/j.psyneuen.2013.11.004

Kannan, D., & Levitt, H. M. (2013). A review of client self-criticism in psychotherapy. *Journal of Psychotherapy Integration*, *23*(2), 166–178. https://doi.org/10.1037/a0032355

Kashdan, T. B. (2004). The assessment of subjective well-being (issues raised by the Oxford Happiness Questionnaire). *Personality and Individual Differences*, *36*(5), 1225–1232. https://doi.org/10.1016/S0191-8869(03)00213-7

Kiran, C. H., Arora, A. K., & Girgila, K. K. (2014). Effect of short-term Rajyoga meditation on anxiety and depression. *Pakistan Journal of Physiology*, *10*(1–2), 18–20.

Kiran, U., Behari, M., Venugopal, P., Vivekanandhan, S., & Pandey, R. (2005). The effect of Autogenic Relaxation on chronic tension headache and in modulating cortisol response. *Indian Journal of Anaesthesia*, *49*(6), 474–478.

Koenig, H. G. (2012). Religion, spirituality, and health: The research and clinical implications. *ISRN Psychiatry*, *2012*, 278730. https://doi.org/10.5402/2012/278730

Lutz, A., Jha, A. P., Dunne, J. D., & Saron, C. D. (2015). Investigating the phenomenological matrix of mindfulness-related practices from a neurocognitive perspective. *American Psychologist*, *70*(7), 632–658. https://doi.org/10.1037/a0039585

Lyubomirsky, S., & Lepper, H. S. (1999). A measure of subjective happiness: Preliminary reliability and construct validation. *Social Indicators Research, 46*(2) 137–155. https://doi.org/10.1023/A:1006824100041

Mandape, A., Bharshankar, J., & Phatak, M. (2015). Effect of Raja Yoga meditation on the lipid profile of healthy adults in Central India. *Journal of Medical Sciences and Health*, *1*(1), 10–13.

Manocha, R., Black, D., & Wilson, L. (2012). Quality of life and functional health status of long-term meditators. *Evidence-Based Complementary and Alternative Medicine, 2012*, 350674. https://doi.org/10.1155/2012/350674

Mehrotra, S., Tripathi, R., & Banu, H. (2013). Psychological well-being: Reflections on an elusive construct and its assessment. *Journal of the Indian Academy of Applied Psychology, 39*(2), 189–195.

Misra, N., Gupta, A., Alreja, S., & Prakash, O. (2013). Effect of Raj Yoga meditation on affective & cognitive functions. *International Journal of Heath Sciences and Research*, *3*(2), 38–46.

Nair, A. K., Sasidharan, A., John, J. P., Mehrotra, S., & Kutty, B. M. (2017). Just a minute meditation: Rapid voluntary conscious state shifts in long term meditators. *Consciousness and Cognition*, *53,* 176–184. https://doi.org/10.1016/j.concog.2017.06.002

Orme-Johnson, D. W., & Dillbeck, M. C. (2014). Methodological concerns for meta-analyses of meditation: Comment on Sedlmeier et al. (2012). *Psychological Bulletin*, *140*(2), 610–616. https://doi.org/10.1037/a0035074

Panda, R., Bharath, R. D., Upadhyay, N., & Mangalore, S. (2016). Temporal dynamics of the default mode network characterize meditation-induced alterations in consciousness. *Frontiers in Human Neuroscience*, *10,* 1–12. https://doi.org/10.3389/fnhum.2016.00372

Ramesh, M. G., Sathian, B., Sinu, E., & Kiranmai, S. R. (2013). Efficacy of Rajayoga meditation on positive thinking: An index for self-satisfaction and happiness in life. *Journal of Clinical and Diagnostic Research*, *7*(10), 2265–2267. https://doi.org/10.7860/JCDR/2013/5889.3488

Ramsay, T., Manderson, L., & Smith, W. (2010). Changing a mountain into a mustard seed: Spiritual practices and responses to disaster among New York Brahma Kumaris. *Journal of Contemporary Religion*, *25*(1), 89–105. https://doi.org/10.1080/13537900903416838

Rao, D., & Mehrotra, S. (2006). Negotiation of life-tasks and subjective well-being in young adults pursuing professional courses. *Psychological Studies, Special issue: Psychology of health and well-being*, *51*(2–3), 144–152.

Ryff, C. D. (1989). Happiness is everything, or is it ? Explorations on the meaning of psychological well-being. *Journal of Personality and Social Psychology*, *57*(6), 1069–1081. https://doi.org/10.1037/0022-3514.57.6.1069

Ryff, C. D., & Keyes, C. L. M. (1995). The structure of psychological well-being revisited. *Journal of Personality and Social Psychology, 69*(4), 719–727. http://dx.doi.org/10.1037/0022-3514.69.4.719

Sedlmeier, P., Eberth, J., Schwarz, M., Zimmermann, D., Haarig, F., Jaeger, S., & Kunze, S. (2012). The psychological effects of meditation: A meta-analysis. *Psychological Bulletin*, *138*(6), 1139–1171. https://doi.org/10.1037/a0028168

Seligman, M. E. P. (2012). *Flourish: A visionary new understanding of happiness and well-being.* New York, NY: Simon and Schuster.

Sharma, R. (2006). Meditation and mental well being. *Indian Journal of Physiology and Pharmacology*, *50*(3), 205–214.

SpARC. (2018). *Spiritual Applications Research Centre.* http://bksparc.in/sparc_wing.html

Telles, S., & Desiraju, T. (1993). Autonomic changes in Brahmakumaris Raja yoga meditation. *International Journal of Psychophysiology*, *15*(2), 147–152. https://doi.org/10.1016/0167-8760(93)90072-W

Telles, S., & Naveen, K. V. (2004). Changes in middle latency auditory evoked potentials during meditation. *Psychological Reports*, *94*(2), 398–400. https://doi.org/10.2466/pr0.94.2.398-400

Thomas, J. W., & Cohen, M. (2014). A methodological review of meditation research. *Frontiers in Psychiatry*, *5*, 74. https://doi.org/10.3389/fpsyt.2014.00074

Vyas, R., & Dikshit, N. (2002). Effect of meditation on respiratory system, cardiovascular system and lipid profile. *Indian Journal of Physiology and Pharmacology*, *46*(4), 487–491.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

WHOQOL SRPB Group. (2006). A cross-cultural study of spirituality, religion, and personal beliefs as components of quality of life. *Social Science & Medicine*, *62*(6), 1486–1497. https://doi.org/10.1016/j.socscimed.2005.08.001

Wiist, W. H., Sullivan, B. M., St. George, D. M., & Wayment, H. A. (2012). Buddhists' religious and health practices. *Journal of Religion and Health*, *51*(1), 132–147. https://doi.org/10.1007/s10943-010-9348-5

Wu, C.-H. (2008). The role of perceived discrepancy in satisfaction evaluation. *Social Indicators Research*, *88*(3), 423–436. https://doi.org/10.1007/s11205-007-9200-9

ARTICLE IN PRESS

Consciousness and Cognition xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Just a minute meditation: Rapid voluntary conscious state shifts in long term meditators

Ajay Kumar Nair[a], Arun Sasidharan[a,1], John P. John[b], Seema Mehrotra[c], Bindu M. Kutty[a,*]

[a] Department of Neurophysiology, National Institute of Mental Health and Neuro Sciences (NIMHANS), Bengaluru, India
[b] Department of Psychiatry, National Institute of Mental Health and Neuro Sciences (NIMHANS), Bengaluru, India
[c] Positive Psychology Unit, Department of Clinical Psychology, National Institute of Mental Health and Neuro Sciences (NIMHANS), Bengaluru, India

ARTICLE INFO

Keywords:
Meditation
Consciousness
Cognition
State changes
EEG

ABSTRACT

Meditation induces a modified state of consciousness that remains under voluntary control. Can meditators rapidly and reversibly bring about mental state changes on demand? To check, we carried out 128 channel EEG recordings on Brahma Kumaris Rajayoga meditators (36 long term: median 14240 h meditation; 25 short term: 1095 h) and controls (25) while they tried to switch every minute between rest and meditation states in different conditions (eyes open and closed; before and after an engaging task). Long term meditators robustly shifted states with enhanced theta power (4–8 Hz) during meditation. Short term meditators had limited ability to shift between states and showed increased lower alpha power (8–10 Hz) during eyes closed meditation only when pre and post task data were combined. Controls could not shift states. Thus trained beginners can reliably meditate but it takes long term practice to exercise more refined control over meditative states.

1. Introduction

Meditation is a set of diverse cognitive-affective techniques that allow voluntary, reversible shifts in mental states that can be objectively characterized by corresponding brain states. The brain state during meditation is distinct from other wake mental states such as rest and alertness (Tang, Rothbart, & Posner, 2012). A trained meditator can enter into a modified state of consciousness at will or on demand, which makes meditation a valuable subject of study. Meditation is known to bring about cognitive enhancements (Delgado-Pastor, Perakakis, Subramanya, Telles, & Vila, 2013; Teper & Inzlicht, 2013; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), enhance emotional management (Farb et al., 2010), regulate sleep and neuro-endocrine function (Nagendra, Maruthai, & Kutty, 2012), reduce anxiety symptoms (Chen et al., 2013), and contribute to an overall sense of well-being (Shapiro, Oman, Thoresen, Plante, & Flinders, 2008). While meditation is often practiced in silent and peaceful environments, the benefits of meditative practice would be especially valuable if the meditator can enter meditative states quickly and under normal work conditions. Indeed, it has been suggested that proficient meditators can meditate in non-ideal environments and that it becomes easier with long term practice (Lutz, Jha, Dunne, & Saron, 2015).

A growing body of evidence suggests that long term meditation practice brings about experience dependent neuro-plastic changes

* Corresponding author at: National Institute of Mental Health and Neuro Sciences (NIMHANS), P.B. No. 2900, Dharmaram P.O, Hosur Main Road, Bengaluru 560029, Karnataka State, India.
E-mail addresses: ajay.nimhans@gmail.com (A.K. Nair), arunsasi84@gmail.com (A. Sasidharan), jpjnimhans@gmail.com (J.P. John), drmehrotra_seema@yahoo.com (S. Mehrotra), bindu.nimhans@gmail.com (B.M. Kutty).
[1] Present address: Axxonet System Technologies Pvt. Ltd., Bengaluru, India.

http://dx.doi.org/10.1016/j.concog.2017.06.002
Received 16 November 2016; Received in revised form 22 May 2017; Accepted 8 June 2017

in specific cortical areas involved in emotion regulation and cognitive control (Hölzel et al., 2011; Kang et al., 2013; Lazar et al., 2005; Luders et al., 2012). These trait effects of long term meditative practices have been explored both in sleep (Pattanashetty et al., 2010; Sulekha, Thennarasu, Vedamurthachar, Raju, & Kutty, 2006) and waking states (Brefczynski-lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Cahn, Delorme, Polich, Diego, & Jolla, 2013; Cahn & Polich, 2006; Manna et al., 2010). Indeed, state changes in long term meditators can be considered to be a combination of state and trait effects (Davidson & Kaszniak, 2015). The extent of clinical efficacy and details of underlying mechanisms are however still under debate and discussion (Chiesa & Serretti, 2011; Goyal et al., 2014; Holzel et al., 2011; Raffone & Srinivasan, 2010; Tang, Holzel, & Posner, 2015; Tomasino, Chiesa, & Fabbro, 2014).

An important consideration is that meditation is an umbrella term. Meditative techniques may be classified into three broad families (Attentional, Constructive and Deconstructive) based on the primary cognitive mechanisms involved (Dahl, Lutz, & Davidson, 2015). In brief, the attentional family involves self-regulation of attentional scope to foster meta-awareness; the constructive family uses cognitive and affective methods such as perspective taking and reappraisal to foster well-being; and the deconstructive family involves self-inquiry into affective and cognitive processes in order to yield insights. Interestingly, a few common state and trait changes emerge at the neural and behavioral levels (Cahn & Polich, 2006; Fingelkurts, Fingelkurts, & Kallio-Tamminen, 2015b, 2016; Sedlmeier et al., 2012). This commonality suggests that meditative techniques can be grouped into one overarching category. However, meditation techniques are very diverse in their detailed practice and philosophical inclinations and these differences need to be taken into account while researching a particular meditative practice (Awasthi, 2013; Lutz, Dunne, & Davidson, 2007; Nash & Newberg, 2013). Attempting to understand the neurobehavioral mechanisms underlying meditation needs to be in the context of the school of meditation under study.

We were interested in evaluating if it is possible to achieve a meditative state quickly and reversibly under a variety of conditions. The Brahma Kumaris Rajayoga meditation recommends one minute meditation techniques that are practiced during different times of the day. Some of the one minute meditations can be found on the 'Just a minute meditation' website (Brahma Kumaris, 2016b) while more detailed introductions to Rajayoga meditation can be found on the organization's main website (Brahma Kumaris, 2016a). Rajayoga can be considered to be in the 'constructive family' of meditation as it employs contemplation and directed thinking in order to reach experiential states for self-development (Kiran, Behari, Venugopal, Vivekanandhan, & Pandey, 2005; Ramesh, Sathian, Sinu, & Kiranmai, 2013). There are several types of meditations that are practiced within this tradition and soul conscious meditation (experiencing the self as a soul, visualized as a star behind the forehead) forms the starting step in all these meditation forms (Hassija, 2001). Rajayoga meditation is typically practiced with open eyes, in contrast to most techniques where meditation is practiced in eyes closed condition.

We wanted to examine if it is indeed possible to attain the benefits of meditation while dealing with day to day challenges where limited time is available. We incorporated both eyes open and closed conditions in the protocol so that participants would have to meditate in familiar (eyes open) and unfamiliar (eyes closed) situations. EEG power spectral density measures were used to ascertain if the participants were able to make the state changes as instructed. Additionally, we wanted to check if the duration of meditation training brought any trait advantages over and above a state effect of following the instructions. We designed a simple rest and meditation EEG protocol that involved both eyes open and closed conditions which we applied before and after a challenging cognitive task (Nair, Sasidharan, John, Mehrotra, & Kutty, 2016). We used this task to simulate real world practical challenges that can keep us engrossed, providing us with the opportunity to realistically test the ability to meditate in different conditions.

2. Materials and methods

2.1. Participants

We recruited three groups of participants ($n = 86$) between the age range 27–65. The Long Term Practice group (LTP, $n = 36$) had a median of 14,240 h of meditation experience and a minimum of ten years of regular meditation practice. The Short Term Practice group (STP, $n = 25$) had a median of 1095 h of meditation with a range of 6 months to 2 years of regular meditation practice. The Zero Term Practice group (ZTP, $n = 25$) had no meditation exposure. None of the participants had exposure to any other form of meditation.

The participants were matched for age, gender, education and monthly family income. Meditation is practiced by people with diverse socio-economic conditions. Our study included participants with diverse education levels. Over a quarter of the participants had less than 12 years of formal education. Though there was a range, most practitioners were from the 'middle-class' as per Indian living standards though two of the meditators (1 LTP and 1 STP) had a very low monthly income at present. Most participants were multilingual. All had basic literacy in at least one language - English, Hindi or Kannada. All participants were right-handed and non-smokers. There were no differences between the groups in terms of exercise levels ($p = 0.67$) or sleep quality ($p = 0.32$). Two of the STP and eight of the ZTP occasionally consumed alcohol and the rest were teetotalers. Participation of pre-menopausal female volunteers was planned to ensure that they were in the follicular phase (within one week after menstruation) at the time of the study to minimize variation in alpha frequency with progesterone levels (Bazanova & Vernon, 2013). All participants provided written informed consent as approved by the NIMHANS Institute Human Ethics Committee and in accordance with the Declaration of Helsinki (1964). Financial compensation was not provided to the meditators and most of the ZTP participants. Towards the end of the study, a token amount of INR 250 (less than USD 5) was offered to the ZTP participants to encourage participation.

Permission for meditator recruitment was obtained from the Spiritual Applications Research Center (SpARC), Mt. Abu, India and the three administrative offices of Brahma Kumaris, Bangalore. LTP and STP were recruited with the help of Brahma Kumaris centers

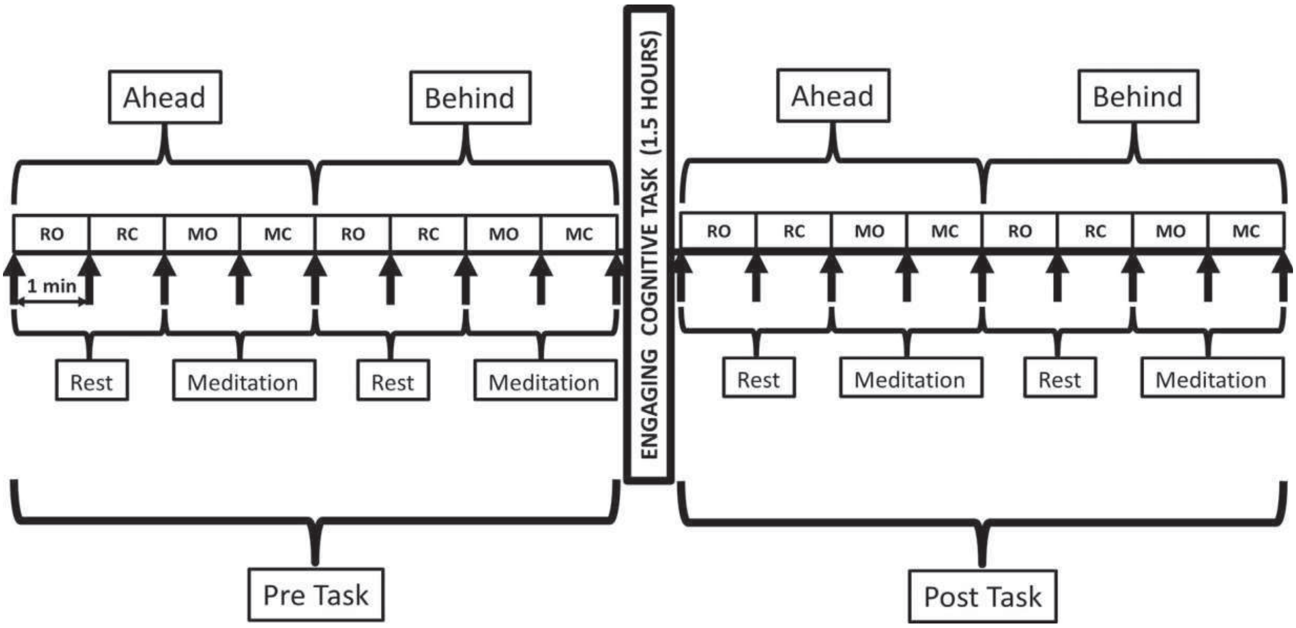


Fig. 1. Rest and Meditation Protocol Design. RO = Rest Eyes Open, RC = Rest Eyes Closed, MO = Meditation Eyes Open, MC = Meditation Eyes Closed. Each state was of one minute duration. Overall, the multi-level cognitive task lasted for one and half hours. The Pre-Task and Post-Task sessions lasted ten minutes each.

in Bangalore. Announcements regarding the study were made by the center administrators and the first author verified if the inclusion and exclusion criteria were met. ZTP were recruited from the community.

2.2. Data acquisition

EEG data were acquired using Geodesic EEG System 300 (Electrical Geodesics, Inc., USA) with 128 Channel HydroCel Sensornets. The acquisition details have been previously reported (Nair et al., 2016). In brief, EEG was acquired using the Net Amps 300 amplifier and Net Station 4.5.7 software, digitized with a resolution of 24 bits and sampling rate of 1 kHz. No notch filters were used. Impedance levels were ensured to be less than 50 KΩ as recommended by the vendor. All acquisitions were done between 2 pm and 6 pm with ambient temperature maintained at 25 °C and humidity ranging between 40 and 60%. Eprime 2.0 stimulus presentation software (Psychology Software Tools, Inc., Sharpsburg, PA, USA) was used for presenting the visual instructions and audio signals (described in the next section). The participants sat in a comfortable chair and viewed the instructions (in English, Hindi or Kannada based on language preference) presented on a 34 cm × 27 cm LCD monitor set at a distance of 90 cm.

2.3. Protocol design

The rest and meditation (REMED) protocol (Fig. 1) was administered in two sessions (each approximately ten minutes long) – before and after an engaging three-level sensory-motor cognitive task.

Both the pre-task (REMED1) and post-task (REMED2) sessions had two sets of rest and meditation states. Each set contained rest eyes open (RO), rest eyes closed (RC), meditation eyes open (MO) and meditation eyes closed (MC) states. Participants were provided with a welcome message with general instructions at the beginning of the task, brief visual instructions (position shown by arrows in Fig. 1) to shift between the different states which lasted one minute each and a final thank you message denoting the end of the task. The start and end of a state was signaled by a brief auditory tone. At the end of a state, the participant was provided visual instructions for the next state (Fig. 2). All participants were briefed before commencing the study and ZTP (who were active controls) were not provided any extra meditation instructions. For the rest states, the participants were instructed to be relaxed and to avoid meditative or emotionally salient thoughts. For the meditation states, participants were instructed to (try to) experience the self as a star behind the forehead. This instruction was to ensure that the meditators would practice only soul conscious meditation and not any other type of meditation within the Rajayoga tradition.

2.4. Data analysis

For preprocessing EEG data, a first order high pass filter of 0.1 Hz was run using Net Station 4.5.7 software and then the data were exported into Net Station Simple Binary format. Further preprocessing and analysis was done using custom scripts written with EEGLAB v13.4.4b (Delorme & Makeig, 2004) as reported earlier (Nair et al., 2016).

There were two REMED (rest and meditation) sessions per participant. The Net Station files for REMED1 and REMED2 were imported into EEGLAB and the channel locations were set as per the 129 channel file supplied by EGI. Since the same event markers were used for rest and meditation conditions that were ahead and behind in sequence, these were renamed appropriately. A 40 Hz

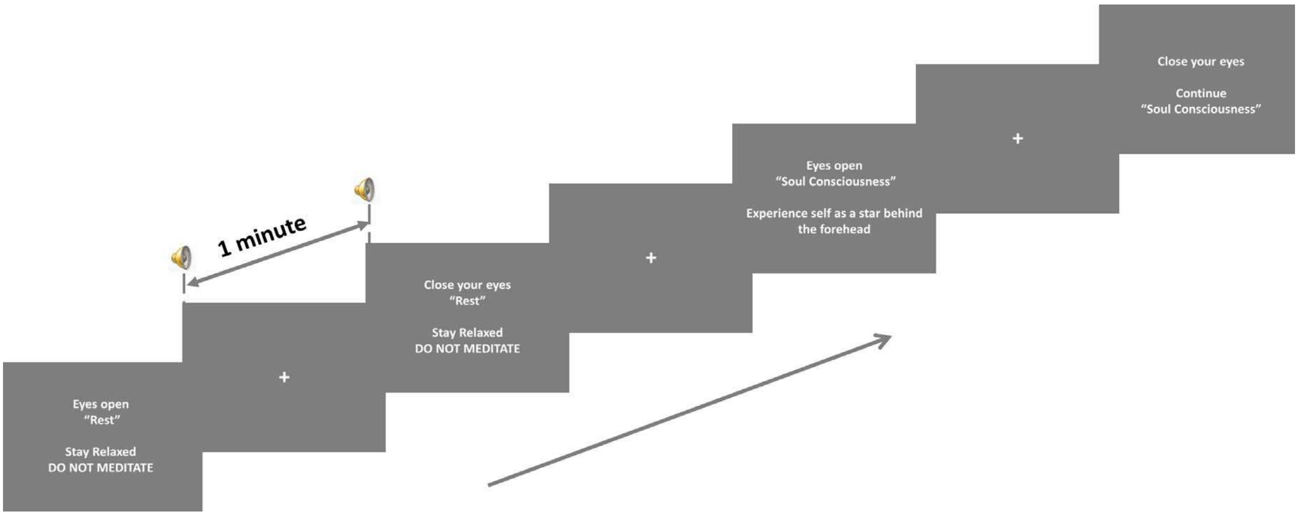


Fig. 2. Instruction sequence for rest and meditation with eyes open and closed states. The 'plus' signs were displayed for one minute each and were marked by a brief auditory tone at the beginning and end. Instructions were presented in English, Hindi or Kannada as per the preferred language of the participant.

low pass filter was applied and then 60 s epochs were extracted following each marker resulting in 16 files per subject for both the REMED sessions. For automatic artifact correction, the artifact subspace reconstruction (ASR) method implemented in the clean_-rawdata plugin ver 1.2 written for EEGLAB was used. As meditation data sometimes contain high amplitude alpha and theta bursts, a high threshold of 20 standard deviations (instead of the default value of 5) was set for artifacts in the Rest and Meditation EEG. After artifact correction, the removed bad channels were interpolated, data were then down-sampled to 250 Hz and re-referenced to average.

For statistical analyses, an EEGLAB STUDY was created with each of the 16 conditions, across two sessions in order to evaluate condition differences for each of the channel level Power Spectra. The power spectral bands were delta (1–4 Hz), lower theta (4–6 Hz), upper theta (6–8 Hz), lower alpha (8–10 Hz), upper alpha (10–12 Hz) and lower beta (12–15 Hz). The decision to split theta and alpha bands into lower and upper segments was done a priori as changes in theta and alpha power are widely reported in meditation studies (Cahn & Polich, 2006; Fingelkurts, Fingelkurts, & Kallio-Tamminen, 2015a). We additionally checked a lower frequency band (delta) and a higher frequency band (low beta) as they are also sometimes reported in meditation studies. We were unable to check for gamma band in the current analysis as we set a low pass filter at 40 Hz to ensure that our artifact correction method provided good quality results.

Data for the conditions were z-scored with respect to corresponding baseline rest states (separately for eyes open and eyes closed) of the same subject to avoid confounds due to individual differences in baseline values. Separate analyses were done for eyes open and eyes closed conditions. The Rest and Meditation states were compared to each other in three ways: collapsing REMED1 and REMED2 sessions together, REMED1 alone and REMED2 alone. Non-parametric permutation based statistical tests were performed by calculating Monte Carlo estimates of significance probabilities on 2000 random partitions and cluster correction for multiple comparisons was done with $\alpha < 0.05$ (Maris & Oostenveld, 2007).

3. Results and discussion

We first collapsed REMED1 and REMED2 sessions to evaluate the global rest vs meditation contrast. Across sessions, in the eyes open (Fig. 3a) meditation condition (vs Rest), LTP showed significantly enhanced upper theta power (6–8 Hz) primarily in the fronto-central and central electrode sites whereas STP and ZTP did not show any changes. During eyes closed (Fig. 3b) meditation (vs Rest), LTP showed significantly enhanced lower theta power (4–6 Hz) and upper theta power (6–8 Hz) extending to most of the scalp regions except the frontal and frontopolar electrode locations. STP showed enhanced lower alpha power (8–10 Hz) in the frontal and occipital regions during eyes closed meditation as compared to rest. ZTP did not show any power spectral changes between rest and meditation. In Fig. 3a and b, the red dots in the bottom panel of each subplot indicate electrodes with statistically significant differences thresholded with p value set at 0.05.

When each REMED session was independently assessed, during eyes open mediation (vs rest), LTP showed significantly enhanced lower alpha power in REMED2 but there were no changes in REMED1. On the other hand, during eyes closed meditation (vs rest), LTP showed significantly enhanced lower and upper theta power in REMED1 but not in REMED2. STP and ZTP did not show any differences between rest and meditation in either REMED1 or REMED2.

Within each REMED session, as compared to baseline rest, in the eyes open condition, the non-parametric permutation based one-way ANOVA revealed that LTP had wide ranging changes during the subsequent states in delta, lower theta, lower alpha and lower beta power. STP showed changes in delta and lower theta power. ZTP did not show any changes. During eyes closed condition, LTP showed changes between rest and meditation states in lower theta and lower beta power, STP and ZTP showed changes in lower theta, upper theta and lower beta power. Fig. 4 shows the within session minute-to-minute changes in lower theta power with eyes

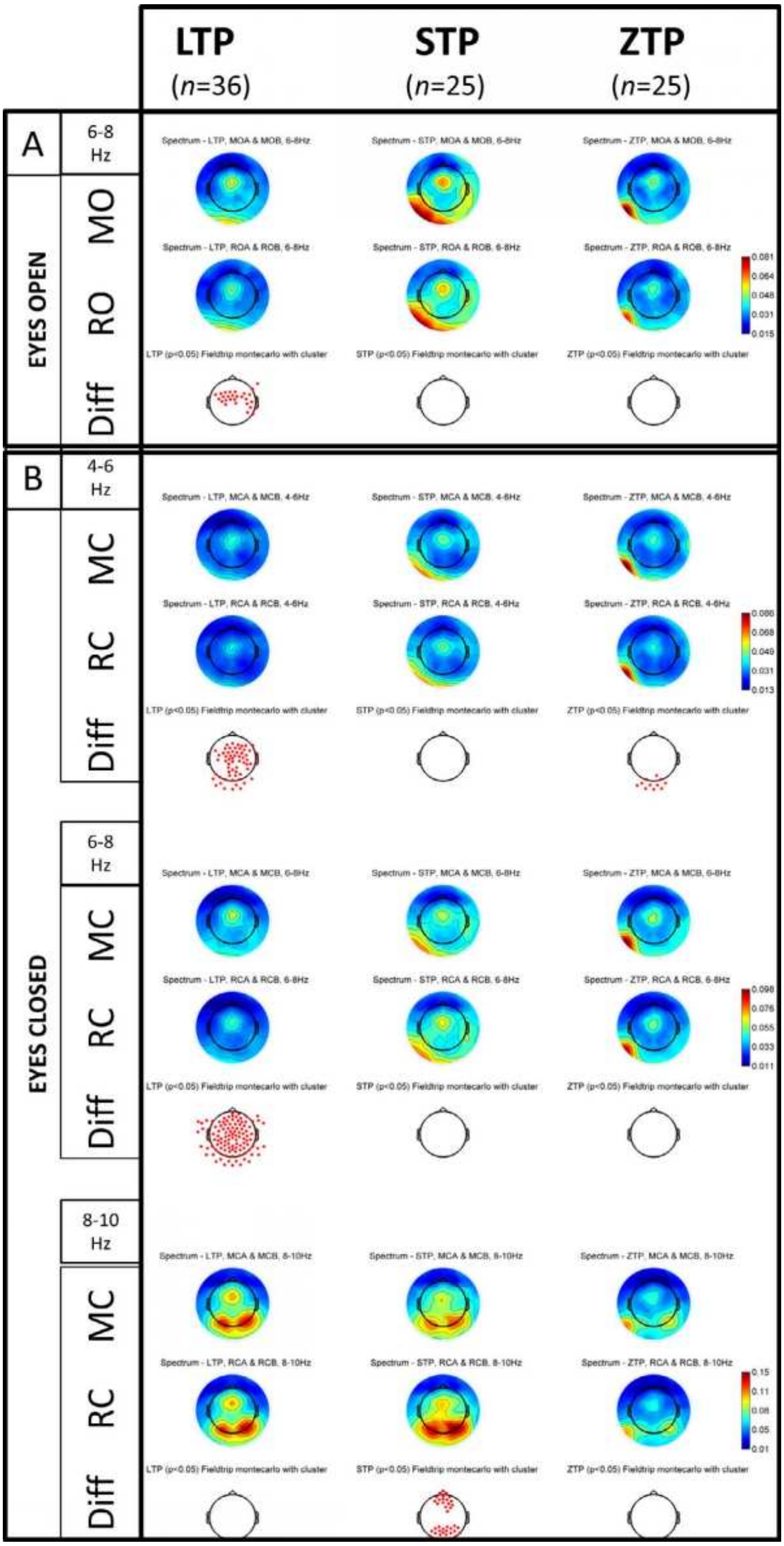


Fig. 3. Meditation vs Rest EEG Topography Comparisons. Average topography plots each using z-score normalized one minute data for each subject. Rows labelled 'Diff' show statistically significant differences across conditions - red dots indicate electrode locations ($p < 0.05$ using Monte Carlo cluster based statistics with 2000 random partitions). RO = Rest Eyes Open, RC = Rest Eyes Closed, MO = Meditation Eyes Open, MC = Meditation Eyes Closed. LTP – Long Term Practice. STP – Short Term Practice. ZTP – Zero Term Practice. Panel A: Eyes Open Condition with LTP showing enhanced upper theta power during meditation. Panel B. Eyes Closed condition with LTP showing enhanced lower and upper theta power during meditation and STP showing enhanced lower alpha power during meditation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

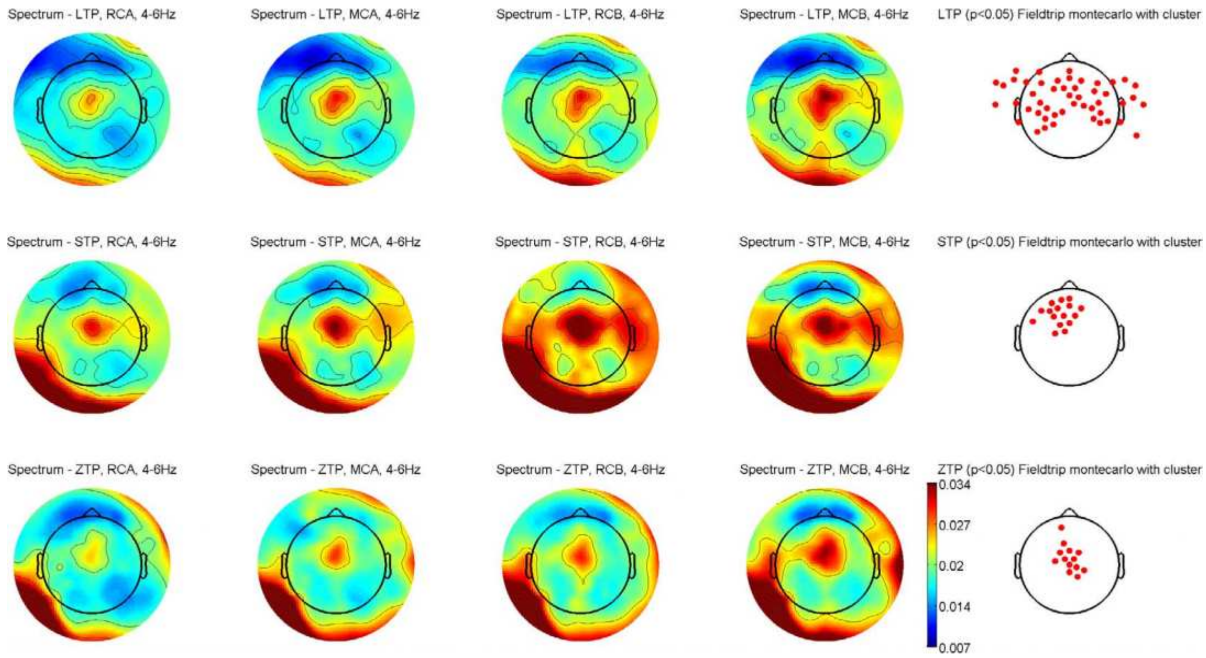


Fig. 4. Baseline Rest vs Other REMED States EEG Topography Comparisons during eyes closed condition. Average topography plots each using z-score normalized one minute data for each subject. Rows labelled 'Diff' show statistically significant differences across conditions - red dots indicate electrode locations ($p < 0.05$ using Monte Carlo cluster based statistics with 2000 random partitions). RCA = Rest Eyes Closed Ahead, RCB = Rest Eyes Closed Behind, MCA = Meditation Eyes Closed Ahead, MCB = Meditation Eyes Closed Behind. LTP – Long Term Practice. STP – Short Term Practice. ZTP – Zero Term Practice. While STP and ZTP show progressive changes across the states, LTP show the ability to shift between rest and meditation states. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

closed condition. We discuss the possible significance of these power spectral changes in the text below. But first, we would like to discuss the relevance of the REMED protocol in assessing the state changes especially in the context of the active controls.

The Rest and Meditation (REMED) protocol was developed for assessing rapid reversible state changes between rest and meditation. A common methodological issue cited with meditation protocols is the lack of active controls and the few studies that do have active controls often ask them to be at rest during the meditation part of the protocol (Awasthi, 2013; Davidson & Kaszniak, 2015; Sedlmeier et al., 2012). In our study, the instructions given to all the three groups were identical and ZTP could follow the instructions without any problem as confirmed by free form (unstructured) verbal reports at the end of the session.

Most studies on meditation techniques are performed in the eyes closed condition which poses problems of drowsiness in novices or controls. The REMED protocol used in our study effectively circumvented the problem as it is short and switches every minute between eyes open and eyes closed conditions – this quick sequence of activities keeps the participants (especially ZTP which is the group that could develop drowsiness confounds) alert. LTP and STP are used to the practice of 'traffic control' meditation which consists of a one minute long open-eyed meditative break from other activities. However doing meditation with eyes closed was new to them. With the REMED protocol, it was possible to dissociate the three groups in terms of their meditative states in contrast to performance of a meditative technique (Awasthi, 2013).

Importantly, there were only a few minor topographical between group differences (as compared to between condition differences) including lower and upper theta power during rest eyes closed condition, upper theta power during meditation eyes closed condition, etc. This is probably due to the short time allocated which precluded achieving deep meditative states. Also, the meditation technique used for the REMED protocol is used at an introductory level and the practitioners usually shift to deeper states of meditation using other techniques. However, for the purposes of our study which focused on rapid state changes, the protocol was effective and there were several large relative differences in how each group changed states across conditions.

The REMED protocol *per se* did not introduce any state shifts between rest and meditation. ZTP did not show any significant power spectral changes from baseline rest during eyes open condition and had some changes during eyes closed condition. But ZTP did not show any state shifts between rest and meditation. STP showed several power spectral changes from baseline rest during eyes open and closed conditions and this did not translate to shifts between rest and meditation states during either REMED1 or REMED2 sessions. However, when both REMED sessions were taken together, STP showed evidence of state shifts between meditation and rest. LTP on the other hand, were able to achieve robust state shifts between rest and meditation in both REMED1 and REMED2 sessions taken separately, in both eyes open and eyes closed conditions, and when data from both sessions were taken together. We can infer from the ZTP results that meditation does require training and the brain state shifts between rest and meditation are not merely due to following the given instructions even though there is probably some relaxation effect while following the protocol. STP had sufficient meditation proficiency and did manage to achieve some level of meditative state (shown by lower alpha enhancements) but were not able to reliably and reversibly reach a restful non meditative state after meditation. As Fig. 4 shows, there is progressive increase in fronto-central theta power even during rest behind in sequence (RCB) which is an order effect as it follows a meditation state (MCA). This is possibly because new meditators require more effort in initiating and sustaining meditation and therefore it might not be easy to quickly switch states (Tang et al., 2012). LTP also experience a slight order effect which is visible in Fig. 4 (compare RCB and RCA) but are able to move in and out of the meditative state quickly enough so that the state shifts between rest and meditation are statistically significant.

Reviews of meditation states and traits (Cahn & Polich, 2006; Fingelkurts et al., 2015a) cite a number of papers suggesting that enhanced alpha power is commonly seen even in early stage meditators (Fell, Axmacher, & Haupt, 2010) and that meditation induced enhancement in theta power can be considered to be a marker for experienced or proficient meditators (Lomas, Ivtzan, & Fu, 2015). Thus the results from the present study are well-aligned with the existing literature. These results are however, very remarkable considering that the meditative state durations are only one minute long in contrast to other studies which evaluate meditation state effects over much longer durations.

While theta and alpha related changes are commonly found in meditation state, the literature is inconsistent regarding proficiency related changes. For example, a recent review suggested that increased frontal lower alpha or alpha1 (which was found in the STP) is a marker of transcendental consciousness in TM meditation and is seen within the first minute of meditation (Travis, 2014). Many reviews have cited increases in alpha and theta powers during a wide variety of meditation techniques (Cahn & Polich, 2006; Fingelkurts et al., 2015a; Rubia, 2009) while also pointing out studies where reductions in alpha and theta powers have been found in some meditation forms. Clearly, meditation techniques vary considerably and effects seen in one technique are therefore not generalizable to all techniques. This however, does not preclude the possibility that different meditation practices can have some neurophysiological changes in common that manifest as similar features at the behavioural level (Berman & Stevens, 2015; Fingelkurts et al., 2015b, 2016). There are, to our knowledge, no previously published studies on EEG changes in Rajayoga practitioners.

The results of the present study indicate that for Rajayoga, state changes in theta power are a marker for LTP while state changes in alpha power could be a considered a sign of initial meditation experience for STP. It is important to note that the REMED protocol is focused on state changes between rest and meditation conditions and not merely a one-time enhancement of alpha and theta power due to meditation. Increased theta is also brought about by attentional demand and increased alpha is also brought about by internal attention and also spontaneous eyes closed relaxation (Basar, Basar-Eroglu, Karakas, & Schurmann, 2001). Changes in both alpha and theta oscillations are seen during cognitive tasks and with memory demands (Klimesch, 1999). In our study, STP showed increased theta power during both rest and meditation (Fig. 4) indicating attentional effort but this increase got nullified when rest and meditation states were contrasted. However, the ability to shift back and forth between rest and meditation states clearly involves meditation proficiency which was shown by LTP who showed enhanced theta during meditation and then reduction in theta when going back to the rest state (Fig. 4). Verbal reports of meditation chronometry in expert Buddhist meditators suggest an ability to switch from neutral to meditative state within 5–15 s (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004) - the results from the present study replicate and validate the notion that expert practitioners are able to make rapid state changes into meditation and back, at will.

The results of the study indicate that STP find it easier to achieve state changes between rest and meditation during eyes closed condition as compared to eyes open condition and that there are important differences between doing meditation in these two conditions. This could potentially be due to the active inhibition of external stimuli (according to the cortical inhibition hypothesis) by the alpha rhythm (Sauseng & Klimesch, 2008). While there have been some studies with eyes open condition (Wong, Camfield, Woods, Sarris, & Pipingas, 2015), the emphasis here is on the ability to rapidly switch states between rest and meditation. A review examining neural underpinnings of state maintenance and switching proposed that the insula is involved in state switching, the anterior cingulate cortex (ACC) is involved in state maintenance and the striatum is related to habit formation which makes state maintenance easier and relatively effortless (Tang et al., 2012). These authors suggested that the shift from rest to meditation is effortful in the early stages with involvement of attentional control and lateral prefrontal cortical regions as well as the parietal cortical areas. However with advanced stage of training (such as with the LTP group), meditative state is maintained by the ACC, insula and striatum and requires much less effort and attentional control (Tang et al., 2012). The ACC is also considered to be a generator of frontal midline theta rhythms (Asada, Fukuda, Tsunoda, Yamaguchi, & Tonoike, 1999) which were also found to be enhanced and more widespread during meditation for the LTP in our study. However, the focus of our study is the ability to shift between rest and meditation and not just the maintenance of meditative state. This ability has not been explicitly studied till date but has great value especially in cognitively demanding situations and in the midst of day to day challenges. Our study provides initial evidence that the long term practice of meditation, at least among Brahma Kumaris Rajayoga practitioners, supports quick state shifts between rest and meditation that is indexed by enhanced theta power while for those with short term meditation practice the shift is slower and indexed by enhanced lower alpha power.

4. Conclusions

The results of our study suggest that even with a few months of meditation practice, it is possible to move into a reliable state of meditation (marked by enhancement of lower alpha power) within a few minutes. However, the ability to shift mental states within very short durations (one minute) under varying external conditions requires longer term practice. The ability of the long term meditation practitioners to change mental states even after being engaged in attention demanding situations indicate neuroplastic changes that facilitate development of mental mastery. Enhanced theta power during meditation seems to be an indicator of long term meditation experience. The fact that these state changes are achievable with open-eyes makes it appealing for potential applications in daily life. This could perhaps contribute to the resilience and well-being often provided in subjective reports of meditators. We suggest that similar studies are needed with other schools of meditation so that this body of evidence can inform policy making in mental health promotion.

Declaration of conflicting interests

The authors declare that there is no conflict of interests regarding the publication of this article.

Funding

This work was supported by the National Institute of Mental Health and Neuro Sciences (NIMHANS) through institute fellowships (A.K.N. and A.S.) and its research facilities, and by a grant from the Department of Science and Technology Cognitive Science Research Initiative (DST-CSI) Government of India to B.M.K (Grant number: SR/CSI/63/2011). None of the funding agencies had any involvement in the research or publication process.

Acknowledgments

We are grateful to all study participants, to the Spiritual Applications Research Centre (SpARC), Brahma Kumaris and the three administrative sub-zones of Brahma Kumaris, Bangalore for their kind cooperation.

References

Asada, H., Fukuda, Y., Tsunoda, S., Yamaguchi, M., & Tonoike, M. (1999). Frontal midline theta rhythms reflect alternative activation of prefrontal cortex and anterior cingulate cortex in humans. *Neuroscience Letters*, *274*(1), 29–32. http://dx.doi.org/10.1016/S0304-3940(99)00679-5.

Awasthi, B. (2013). Issues and perspectives in meditation research: In search for a definition. *Frontiers in Psychology*, *3*(JAN), 1–9. http://dx.doi.org/10.3389/fpsyg.2012.00613.

Basar, E., Basar-Eroglu, C., Karakas, S., & Schurmann, M. (2001). Gamma, alpha, delta, and theta oscillations govern cognitive processes. *International Journal of Psychophysiology*, *39*, 241–248.

Bazanova, O. M., & Vernon, D. (2013). Interpreting EEG alpha activity. *Neuroscience and Biobehavioral Reviews*. http://dx.doi.org/10.1016/j.neubiorev.2013.05.007.

Berman, A. E., & Stevens, L. (2015). EEG manifestations of nondual experiences in meditators. *Consciousness and Cognition*, *31*, 1–11. http://dx.doi.org/10.1016/j.concog.2014.10.002.

Brahma Kumaris (2016a). Brahma Kumaris. Retrieved April 28, 2016, from < http://www.brahmakumaris.org/ > .

Brahma Kumaris (2016b). Just a Minute. Retrieved April 28, 2016, from < http://www.just-a-minute.org/ > .

Brefczynski-lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *PNAS*, *104*(27), 11483–11488.

Cahn, B. R., Delorme, A., Polich, J., Diego, S., & Jolla, L. (2013). Event-related delta, theta, alpha and gamma correlates to auditory oddball processing during Vipassana meditation. *Social Cognitive and Affective Neuroscience*, *8*(1), 100–111. http://dx.doi.org/10.1093/scan/nss060.

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, *132*(2), 180–211. http://dx.doi.org/10.1037/0033-2909.132.2.180.

Chen, K. W., Berger, C. C., Manheimer, E., Forde, D., Magidson, J., Dachman, L., & Lejuez, C. W. (2013). Meditative therapies for reducing anxiety: A systematic review and meta-analysis of randomized controlled trials. *Depression Anxiety*, *29*(7), 545–562. http://dx.doi.org/10.1002/da.21964.Meditative.

Chiesa, A., & Serretti, A. (2011). Mindfulness based cognitive therapy for psychiatric disorders: A systematic review and meta-analysis. *Psychiatry Research*, *187*(3), 441–453. http://dx.doi.org/10.1016/j.psychres.2010.08.011.

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences*, *1–9*. http://dx.doi.org/10.1016/j.tics.2015.07.001.

Davidson, R. J., & Kaszniak, A. W. (2015). Conceptual and methodological issues in research on mindfulness and meditation. *American Psychologist*, *70*(7), 581–592. http://dx.doi.org/10.1037/a0039512.

Delgado-Pastor, L. C., Perakakis, P., Subramanya, P., Telles, S., & Vila, J. (2013). Mindfulness (Vipassana) meditation: Effects on P3b event-related potential and heart rate variability. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, *90*(2), 207–214. http://dx.doi.org/10.1016/j.ijpsycho.2013.07.006.

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, *134*(1), 9–21. http://dx.doi.org/10.1016/j.jneumeth.2003.10.009.

Farb, N.a. S., Anderson, A. K., Mayberg, H., Bean, J., McKeon, D., & Segal, Z. V. (2010). Minding one's emotions: Mindfulness training alters the neural expression of sadness. *Emotion (Washington, DC)*, *10*(1), 25–33. http://dx.doi.org/10.1037/a0017151.

Fell, J., Axmacher, N., & Haupt, S. (2010). From alpha to gamma: Electrophysiological correlates of meditation-related states of consciousness. *Medical Hypotheses*, *75*(2), 218–224. http://dx.doi.org/10.1016/j.mehy.2010.02.025.

Fingelkurts, A. A., Fingelkurts, A. A., & Kallio-Tamminen, T. (2015a). EEG-guided meditation: A personalized approach. *Journal of Physiology-Paris*. http://dx.doi.org/10.1016/j.jphysparis.2015.03.001.

Fingelkurts, A. A., Fingelkurts, A. A., & Kallio-Tamminen, T. (2015b). Long-term meditation training induced changes in the operational synchrony of default mode network modules during a resting state. *Cognitive Processing*. http://dx.doi.org/10.1007/s10339-015-0743-4.

Fingelkurts, A. A., Fingelkurts, A. A., & Kallio-Tamminen, T. (2016). Trait lasting alteration of the brain default mode network in experienced meditators and the experiential selfhood. *Self and Identity*, *15*(4), 381–393. http://dx.doi.org/10.1080/15298868.2015.1136351.

Goyal, M., Singh, S., Sibinga, E. M. S., Gould, N. F., Rowland-Seymour, A., Sharma, R., ... others (2014). Meditation programs for psychological stress and well-being: A systematic review and meta-analysis. *JAMA Internal Medicine*, *174*(3), 357–368.

Hassija, J. C. (2001). *Raj yoga meditation* (Reprint ed.). Mt Abu: Om Shanti Press.

Hölzel, B. K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S. M., Gard, T., & Lazar, S. W. (2011). Mindfulness practice leads to increases in regional brain gray matter density. *Psychiatry Research: Neuroimaging*, *191*(1), 36–43. http://dx.doi.org/10.1016/j.pscychresns.2010.08.006.

Holzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science*, *6*(6), 537–559. http://dx.doi.org/10.1177/1745691611419671.

Kang, D.-H., Jo, H. J., Jung, W. H., Kim, S. H., Jung, Y.-H., Choi, C.-H., ... Kwon, J. S. (2013). The effect of meditation on brain structure: Cortical thickness mapping and diffusion tensor imaging. *Social Cognitive and Affective Neuroscience*, *8*(1), 27–33. http://dx.doi.org/10.1093/scan/nss056.

Kiran, U., Behari, M., Venugopal, P., Vivekanandhan, S., & Pandey, R. (2005). The effect of Autogenic Relaxation on chronic tension headache and in modulating cortisol response. *Indian Journal of Anaesthesia*, *49*(December), 474–478.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Science*.

Lazar, S. W., Kerr, C. E., Wasserman, R. H., Gray, J. R., Douglas, N., Treadway, M. T., ... Dusek, J. A. (2005). Meditation experience is associated with increased cortical thickness. *NeuroReport, 16*(17), 1893–1897.
Lomas, T., Ivtzan, I., & Fu, C. H. Y. (2015). A systematic review of the neurophysiology of mindfulness on EEG oscillations. *Neuroscience & Biobehavioral Reviews*. http://dx.doi.org/10.1016/j.neubiorev.2015.09.018.
Luders, E., Kurth, F., Mayer, E.a., Toga, A. W., Narr, K. L., & Gaser, C. (2012). The unique brain anatomy of meditation practitioners: Alterations in cortical gyrification. *Frontiers in Human Neuroscience*, *6*(February), 1–9. http://dx.doi.org/10.3389/fnhum.2012.00034.
Lutz, A., Dunne, J. D., & Davidson, R. J. (2007). Meditation and the neuroscience of consciousness: An introduction. In P. D. Zelazo, M. Moscovitch, & E. Thompson (Eds.), *The cambridge handbook of consciousness* (pp. 499–551). .
Lutz, A., Greischar, L. L., Rawlings, N. B., Ricard, M., & Davidson, R. J. (2004). Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *Proceedings of the National Academy of Sciences, 101*(46), 16369–16373.
Lutz, A., Jha, A., Dunne, J. D., & Saron, C. D. (2015). Investigating the phenomenological matrix of mindfulness-related practices from a neurocognitive perspective. *American Psychologist*, *70*(7), 632–658. http://dx.doi.org/10.1037/a0039585.
Manna, A., Raffone, A., Perrucci, M. G., Nardo, D., Ferretti, A., Tartaro, A., ... Romani, G. L. (2010). Neural correlates of focused attention and cognitive monitoring in meditation. *Brain Research Bulletin*, *82*(1–2), 46–56. http://dx.doi.org/10.1016/j.brainresbull.2010.03.001.
Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods*, *164*(1), 177–190. http://dx.doi.org/10.1016/j.jneumeth.2007.03.024.
Nagendra, R. P., Maruthai, N., & Kutty, B. M. (2012). Meditation and its regulatory role on sleep. *Frontiers in Neurology*, *APR*(April), 54. http://dx.doi.org/10.3389/fneur.2012.00054.
Nair, A. K., Sasidharan, A., John, J. P., Mehrotra, S., & Kutty, B. M. (2016). Assessing neurocognition via gamified experimental logic: A novel approach to simultaneous acquisition of multiple ERPs. *Frontiers in Neuroscience*, *10*(1), http://dx.doi.org/10.3389/fnins.2016.00001.
Nash, J. D., & Newberg, A. (2013). Toward a unifying taxonomy and definition for meditation. *Frontiers in Psychology*, *4*(NOV), 1–18. http://dx.doi.org/10.3389/fpsyg.2013.00806.
Pattanashetty, R., Sathiamma, S., Talakkad, S., Nityananda, P., Trichur, R., & Kutty, B. M. (2010). Practitioners of vipassana meditation exhibit enhanced slow wave sleep and REM sleep states across different age groups. *Sleep and Biological Rhythms*, *8*(1), 34–41. http://dx.doi.org/10.1111/j.1479-8425.2009.00416.x.
Raffone, A., & Srinivasan, N. (2010). The exploration of meditation in the neuroscience of attention and consciousness. *Cognitive Processing*, *11*(1), 1–7. http://dx.doi.org/10.1007/s10339-009-0354-z.
Ramesh, M. G., Sathian, B., Sinu, E., & Kiranmai, S. R. (2013). Efficacy of rajayoga meditation on positive thinking: An index for self-satisfaction and happiness in life. *Journal of Clinical and Diagnostic Research*, *7*(10), 2265–2267. http://dx.doi.org/10.7860/JCDR/2013/5889.3488.
Rubia, K. (2009). The neurobiology of meditation and its clinical effectiveness in psychiatric disorders. *Biological Psychology*, *82*(1), 1–11. http://dx.doi.org/10.1016/j.biopsycho.2009.04.003.
Sauseng, P., & Klimesch, W. (2008). What does phase information of oscillatory brain activity tell us about cognitive processes? *Neuroscience and Biobehavioral Reviews*, *32*(5), 1001–1013. http://dx.doi.org/10.1016/j.neubiorev.2008.03.014.
Sedlmeier, P., Eberth, J., Schwarz, M., Zimmermann, D., Haarig, F., Jaeger, S., & Kunze, S. (2012). The psychological effects of meditation: A meta-analysis. *Psychological Bulletin*, *138*(6), 1139–1171. http://dx.doi.org/10.1037/a0028168.
Shapiro, S. L., Oman, D., Thoresen, C. E., Plante, T. G., & Flinders, T. (2008). Cultivating mindfulness: Effects on well-being. *Journal of Clinical Psychology*, *64*(7), 840–862. http://dx.doi.org/10.1002/jclp.
Sulekha, S., Thennarasu, K., Vedamurthachar, A., Raju, T. R., & Kutty, B. M. (2006). Evaluation of sleep architecture in practitioners of Sudarshan Kriya yoga and Vipassana meditation. *Sleep and Biological Rhythms*, *4*(3), 207–214. http://dx.doi.org/10.1111/j.1479-8425.2006.00233.x.
Tang, Y.-Y., Holzel, B., & Posner, M. I. (2015). The neuroscience of mindfulness. *Nature Reviews Neuroscience*, *16*(4), 213–225. http://dx.doi.org/10.1038/nrn3916.
Tang, Y.-Y., Rothbart, M. K., & Posner, M. I. (2012). Neural correlates of establishing, maintaining, and switching brain states. *Trends in Cognitive Sciences*, *16*(6), 330–337. http://dx.doi.org/10.1016/j.tics.2012.05.001.Neural.
Teper, R., & Inzlicht, M. (2013). Meditation, mindfulness and executive control: The importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive and Affective Neuroscience*, *8*(1), 85–92. http://dx.doi.org/10.1093/scan/nss045.
Tomasino, B., Chiesa, A., & Fabbro, F. (2014). Disentangling the neural mechanisms involved in Hinduism-and Buddhism-related meditations. *Brain and Cognition, 90*, 32–40.
Travis, F. (2014). Transcendental experiences during meditation practice. *Annals of the New York Academy of Sciences*, *1307*, 1–8. http://dx.doi.org/10.1111/nyas.12316.
Wong, W. P., Camfield, D. A., Woods, W., Sarris, J., & Pipingas, A. (2015). Spectral power and functional connectivity changes during mindfulness meditation with eyes open: A magnetoencephalography (MEG) study in long-term meditators. *International Journal of Psychophysiology*, *98*(1), 95–111. http://dx.doi.org/10.1016/j.ijpsycho.2015.07.006.
Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and Cognition*, *19*(2), 597–605. http://dx.doi.org/10.1016/j.concog.2010.03.014.

frontiers in Neuroscience

METHODS
published: 29 January 2016
doi: 10.3389/fnins.2016.00001

Assessing Neurocognition via Gamified Experimental Logic: A Novel Approach to Simultaneous Acquisition of Multiple ERPs

Ajay K. Nair [1,2†], Arun Sasidharan [1,2†], John P. John [2,3,4], Seema Mehrotra [5] and Bindu M. Kutty [1]*

[1] Department of Neurophysiology, National Institute of Mental Health and Neuro Sciences, Bengaluru, India, [2] Multimodal Brain Image Analysis Laboratory, National Institute of Mental Health and Neuro Sciences, Bengaluru, India, [3] Department of Psychiatry, National Institute of Mental Health and Neuro Sciences, Bengaluru, India, [4] Department of Clinical Neurosciences, National Institute of Mental Health and Neuro Sciences, Bengaluru, India, [5] Department of Clinical Psychology, National Institute of Mental Health and Neuro Sciences, Bengaluru, India

OPEN ACCESS

Edited by:
Ming Hsu,
University of California, Berkeley, USA

Reviewed by:
Lusha Zhu,
Peking University, China
Mark John James Edwards,
University College London, UK

***Correspondence:**
Bindu M. Kutty
bindu.nimhans@gmail.com

[†] These authors have contributed equally to this work and may be considered as joint first authors.

Specialty section:
This article was submitted to Decision Neuroscience, a section of the journal Frontiers in Neuroscience

Received: *15 September 2015*
Accepted: *04 January 2016*
Published: *29 January 2016*

Citation:
Nair AK, Sasidharan A, John JP, Mehrotra S and Kutty BM (2016) Assessing Neurocognition via Gamified Experimental Logic: A Novel Approach to Simultaneous Acquisition of Multiple ERPs. Front. Neurosci. 10:1. doi: 10.3389/fnins.2016.00001

The present study describes the development of a neurocognitive paradigm: "Assessing Neurocognition via Gamified Experimental Logic" (ANGEL), for performing the parametric evaluation of multiple neurocognitive functions simultaneously. ANGEL employs an audiovisual sensory motor design for the acquisition of multiple event related potentials (ERPs)—the C1, P50, MMN, N1, N170, P2, N2pc, LRP, P300, and ERN. The ANGEL paradigm allows assessment of 10 neurocognitive variables over the course of three "game" levels of increasing complexity ranging from simple passive observation to complex discrimination and response in the presence of multiple distractors. The paradigm allows assessment of several levels of rapid decision making: speeded up response vs. response-inhibition; responses to easy vs. difficult tasks; responses based on gestalt perception of clear vs. ambiguous stimuli; and finally, responses with set shifting during challenging tasks. The paradigm has been tested using 18 healthy participants from both sexes and the possibilities of varied data analyses have been presented in this paper. The ANGEL approach provides an ecologically valid assessment (as compared to existing tools) that quickly yields a very rich dataset and helps to assess multiple ERPs that can be studied extensively to assess cognitive functions in health and disease conditions.

Keywords: paradigm design, cognitive functions, decision making, simultaneous ERPs, P300

INTRODUCTION

Neurocognitive studies employ experimental manipulation of variables such as attention, perception, memory, and decision making to elicit details with regard to cortical information processing. Event Related Potentials (ERPs) are electrophysiological correlates of cognitive processing. There are many well established cognitive task paradigms available in the literature for evaluating the cognitive functions in human subjects. One of the most widely used tasks is the oddball paradigm using either visual or auditory stimuli.

A wide variety of ERPs have been studied extensively–for example: the C1, an early visual component that occurs within few milliseconds following the stimulus presentation and not much influenced by the visuospatial attention (Kelly et al., 2008), P50 an early auditory component used for assessment of sensory gating (Smith et al., 2013), MMN—an index of sound discrimination even in the absence of attention(Chen et al., 2014), N1-P2 complex for corollary discharge mechanism—which discriminates sensations generated by one's own action and those generated externally (Wang et al., 2014), N170—a component that marks rapid perception of faces and familiar patterns (Caharel et al., 2013), N2pc—a component that reflects focus of attention on a potential target during visual search (Cespón et al., 2013), LRP—a component that indicates cortical readiness to motor response (Vainio et al., 2014), P300—an indicator of cognitive discrimination based on sustained attention and memory mechanisms (Shaikh et al., 2013), and ERN—a component that reflects error detection (Arbel and Donchin, 2014) etc.

However, most of the existing methodological approaches (including oddball tasks) provide experimental stimulus manipulations to elicit one or two ERPs at a time. Studying multiple variables one at a time does not provide details of interaction effects among neurocognitive variables and hence provides only little data on overall neurocognitive processing capabilities of the brain. Secondly, if the effect size is small, many trials are needed to be carried out to ensure sufficient statistical power. In reality, we encounter multi-sensory information simultaneously and the brain is capable of carrying out multiple ways of information processing. Newer innovative techniques are hence warranted to make the tasks more realistic and ecologically valid. An innovative approach, "Manipulation of Orthogonal Neural Systems Together in Electrophysiological Recordings" (MONSTER) developed by Kappenman and Luck (2012) introduced the concept of studying multiple ERPs (four) by stimulating orthogonal neural systems. However, the problems associated with lack of ecological validity still remains with the procedure.

The ANGEL ("Assessing Neurocognition via Gamified Experimental Logic") approach has been designed to overcome these limitations and has been designed by gamifying the MONSTER framework while building a logical experimental framework for dissociating multiple ERPs simultaneously. Gamification is the use of aspects of game design in non-game contexts (Deterding et al., 2011). The ANGEL paradigm uses the visual oddball paradigm as its base and employs a number of game elements to make the task engaging and allow the study of decision making in a variety of contexts. ANGEL simultaneously employs multiple audio and visual stimuli so that participants engage in decision making in the presence of multiple distractors. This is more representative of real life situations and therefore more ecologically valid than the approaches taken by cognitive assessments that minimize the number of stimuli and explicitly focus on the variable to be assessed.

The ANGEL paradigm allows assessment of 10 neurocognitive variables, as it is possible to elicit the following ERPs: C1, P50, MMN, N1, N170, P2, N2pc, LRP, P300, and ERN. The paradigm design provides the flexibility to ascertain the main and interaction effects of the variables using over 500 conditions. ANGEL employs an audiovisual sensory motor design and as the approach involves three game levels of increasing complexity, the subjects are motivated to carry out the task efficiently. Using automated scripts, it is possible to selectively analyze the variables of interest while reducing analysis time and minimizing potential researcher bias.

In this paper, we discuss the details of ANGEL design as well as the rationale behind it. We also present sample results from a proof of concept study to demonstrate the validity of the approach. The details of possible data analyses are also provided to highlight various aspects of cognitive information processing. This approach can be used to provide information with regard to dysfunctional brain mechanisms associated with mental/cognitive disorders, understand the cognitive reserve capacities of normal human brain as well as following mind training conditions such as meditation. Additionally, the approach is useful in outcome studies following cognitive remediation training and other interventions.

The design goals of the ANGEL paradigm were: (1) allow simultaneous acquisition of multiple ERPs; (2) provide opportunity to study how these cognitive measures vary with different levels of complexity and indeed how they interact with each other; (3) reuse of a common paradigm (stimulus presentation as well as analysis methods) across a large variety of target populations and study if and how they differ in terms of the cognitive measures; (4) keep the task simple yet engaging for the participant, and (5) minimize the literacy and language requirements for participation.

MATERIALS AND METHODS

Participants

A total of 18 participants from both sexes (8 females and 10 males) between 27 and 59 years of age took part in the study. All participants were right handed, non-smokers, and provided written informed consent as approved by Institute Human Ethics Committee (NIMH/DO/SUB-COMMITTEE/2011/Sl.No.1, Basic Sciences) and in accordance with the Declaration of Helsinki (1964). Fourteen participants were healthy and without any medication and four were under stable medication for hypertension ($n = 3$) and for diabetes ($n = 1$). Financial compensation was not provided to the participants. Pre-menopausal female participants were in the follicular phase (within 1 week after menstruation) at the time of the study. Participants had refrained from caffeinated beverages for at least 4 h prior to the recording. All acquisitions were done between 2 and 6 p.m.

EEG Acquisition and Data Processing

All recordings were conducted in a sound attenuated cabin in the human cognitive research laboratory of the department of Neurophysiology, NIMHANS, with ambient temperature maintained at 25°C. Humidity was not controlled and ranged between 40 and 60%.

During the session, the participants sat comfortably in a chair with armrest in front of a 34 × 27 cm LCD monitor set 90 cm away from the participant. They responded by pressing the first two buttons of the four choice Response Pad (Electrical Geodesics

Inc., Eugene, OR, USA) with left or right index fingers. Localized visual instructions were presented as per the participants' language preference. The participants were informed about the rules of ANGEL task before the EEG acquisition for cognitive task performance. In addition, participants were provided with visual instructions as well as a practice session at the beginning of each game level.

EEG was acquired using 128 channel HydroCel Geodesic Sensor Nets connected to the 128 channel Geodesic EEG System 300 acquisition system with Net Amps 300 amplifier and Net Station 4.5.7 software (Electrical Geodesics, Inc., Eugene, OR, USA). Before placing the Sensor Net, scalp preparation was done by gentle scrubbing with cotton dipped in the Potassium Chloride and shampoo solution. EEG was digitized with a resolution of 24 bits with a sampling rate of 1 KHz and corresponding anti-aliasing filter of 500 Hz. No notch filters were used. Impedance for all electrodes was maintained at less than 50 KΩ as recommended by the vendor. Eprime 2.0 stimulus presentation software (Psychology Software Tools, Inc., Sharpsburg, PA, USA) was used for presenting the audio-visual stimuli.

ANGEL Paradigm Design

The ANGEL paradigm is a gamified adaptation of the visual oddball paradigm. The task is carried out in three levels with increasing complexity: "Learn and Do" (*Learn*), "Whodunnit" (*Who*), and "Discern and Decide" (*Discern*). Each level has 448 trials (16 blocks each comprising of 25 stimulus trials and 3 baseline trials) and takes about 15 min to complete.

Trial Details

Before the trial starts, a white plus sign (+, for fixation) appears in the center of the screen against a gray background along with black and white checkerboards on either side of the plus sign. During the trial, one of the checkerboards is briefly replaced (240 ms duration) in a pseudorandom manner, with one of four types of salient black and white visual stimuli: a Mooney face (Mooney and Ferguson, 1951) or a distorted version of it (randomly picked from a set of 30 each); a Kanizsa triangle (Kanizsa, 1979) or a distorted image with the same components as the Kanizsa triangle (randomly picked from a set of two each) as shown in **Figure 1**. In each block, a different version of the oddball paradigm is used by presenting the salient image types as follows: One of the four salient image types is presented on one side of the fixation sign for 80% of the time (*Frequent* image category) while two other image types are presented on the other side for a total 20% of the time (10% for each type, forming the *Rare* category). **Figure 2**. shows two examples of blocks with different stimulus types.

Additionally, each trial is presented with multiple audio-visual distractors as detailed in **Figure 3**. Auditory tones (75 dB) are delivered using earphones with disposable ear plugs. *Standard* auditory tones (80% trials, 1000 Hz, 15 ms long, 500 ms apart) and *Deviant* auditory tones (10% trials, 1500 Hz, 15 ms long) are presented in each block. The auditory tones are presented

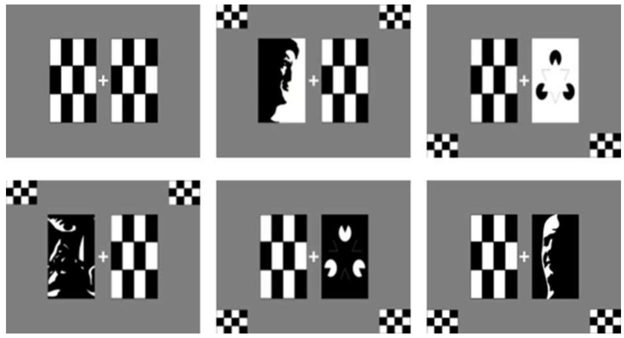


FIGURE 1 | ANGEL stimulus types. Clockwise from top left—Checkerboard mask, Mooney face white background, Kanizsa triangle white background, distorted image of Mooney face, distorted image of Kanizsa triangle, and Mooney face on dark background.

in one of three sets timed with reference to the visual stimulus onset: 240 ms before, 40 ms before, or 160 ms after, the start of the visual oddball trial. In addition, small checkerboards appear bilaterally on top or bottom (randomly allocated) for different trials as visual distracters as can be seen in **Figure 1**.

Each trial is 1550 ms long on average (varied between 1200 and 1900 ms). Participants have up to 700 ms to respond (using the index fingers of both hands) to the stimuli after which it is considered a missed response.

In each block, there are 25 active trials followed by three baseline trials [where only the fixation sign (+ sign) is presented on a gray background, without any checkerboard masks].

The average luminous intensity was tested to be similar across blocks using the SHINE Toolbox (Willenbockel et al., 2010) and MATLAB Image processing toolbox. The Mooney face images and their distorted versions were kindly provided by Peter Uhlhaas (Uhlhaas et al., 2006). We prepared the Kanizsa triangles and their distorted versions using the open source graphics editor Inkscape (http://www.inkscape.org/).

Game Level Details

During *Learn*, for half the alternate blocks (eight, odd numbered blocks), participants are asked to passively fixate on the centrally located plus sign without any button press response associated with stimulus presentation while mentally identifying which side of the fixation sign the salient stimuli appear during a trial. However, for the alternate even numbered blocks, participants have to respond to the presentation of the salient stimuli by a button press on the corresponding side. They are also asked to stay focused on the task and ignore all auditory and visual distractors.

During *Who*, participants have to provide a button response during all blocks. However, in this level, for half of the pseudo-randomly allocated blocks, whenever the subject makes a button response, a brief polysyllabic tone (230 ms long) is immediately generated by the system while for the remaining blocks, the tone

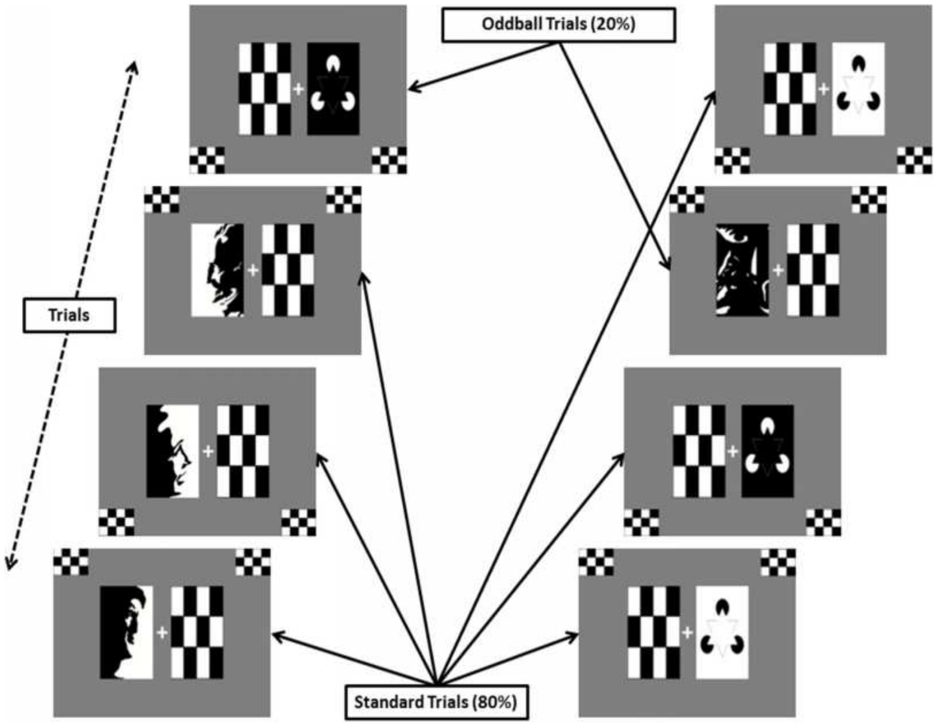


FIGURE 2 | ANGEL trial blocks. The block of trials on the left has Mooney face on left side of the fixation sign as standard image type. The block of trials on the right has Kanizsa triangle on right of the fixation sign as standard image type.

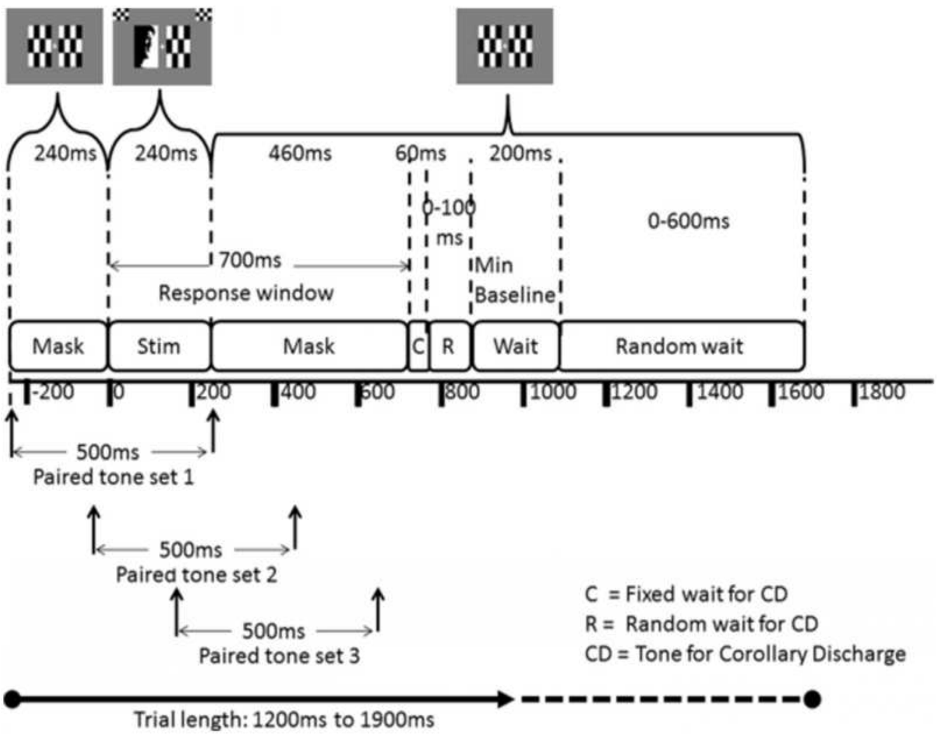


FIGURE 3 | Structure of an ANGEL trial. The visual stimulus (Stim) has a pre-stimulus mask (where paired tone stimuli may begin) and a post stimulus mask during which the subject may respond. The tone for Corollary Discharge (CD) may be presented (C) as soon as the subject responds or after a random interval (R) at the end of the response window timeout. Only one of the three paired tone sets are presented in a trial. Every paired-tone trial is followed by three trials with just a blank sound clip. There is a fixed minimum baseline (with mask) of 200 ms at the end of each trial which may be randomly extended by up to an additional 700 ms. Average trial length is 1550 ms (ranging from 1200 to 1900 ms).

is generated after the stimulus presentation with a randomly introduced delay. For these latter blocks, if the subject does not make a response, the tone is generated after the timeout period.

During *Discern*, participants are instructed to indicate the salient image type as "meaningful" by pressing the left button or "ambiguous" by pressing the right button. Halfway through the level, following completion of eight blocks, the participants are instructed about rule reversal that they need to press the right button for meaningful images and left button for ambiguous images.

After every two blocks, participants are provided with a feedback on their performance (accuracy and speed). If the accuracy falls below 85%, the feedback text shows "Well tried! Try to respond more accurately." If the accuracy is in the range of 85–95%, the feedback is "Good job, Keep it up!" For accuracy levels greater than 95% the feedback given is "Outstanding! Now try to respond a bit faster."

The investigator also has the facility to monitor the subject's response accuracy for each trial and the opportunity to pause the game during the feedback presentations in order to clarify anything or answer any questions.

Data Analysis

The acquired raw EEG data were run through the following processing pipeline. A 0.1 Hz first order high pass filter was run using Net Station 4.5.7 and then the files were exported in Net Station Simple Binary epoch marked format. The events were separately exported as ASCII files. Further ERP preprocessing and analysis was done using custom scripts using EEGLAB v13.4.4b (Delorme and Makeig, 2004)—an open source toolbox and MATLAB version R2013a (MathWorks Inc., Natick, MA, USA).

In brief, the Net Station simple binary files were imported into EEGLAB ".set" format and the channel locations were set as per the 129 channel file supplied by EGI. For ease of discussion, the channel locations compatible to the 10–20 system were renamed while the rest of the channels retain the EGI nomenclature. Events were imported after handling the jitter for sound marker latencies and inserting "S2" sound events 500 ms after "S1" events (these are related to the P50. This step is needed as both the sounds are presented together as one sound clip to avoid timing delays during stimulus presentation). A 40 Hz low pass filter was applied and then artifact correction and removal was done for bad channels, eye blinks, and movement artifacts using the artifact subspace reconstruction (ASR) method implemented in the clean_artifacts function of the clean_rawdata plugin of EEGLAB. We used a threshold of 5 standard deviations for the artifact correction. Independent Component Analysis (ICA) was performed on the cleaned data (down-sampled to 500 Hz and epoched from −0.5 to 0.8 s) using the "runica" algorithm and the ICA weight matrices were saved.

Separately, on the cleaned data files, the removed bad channels were interpolated, data were then down-sampled to 250 Hz and re-referenced to average. Peri-stimulus epoching was done from −1 to 2 s. The saved ICA weight matrices were copied onto the corresponding epoched files. An EEGLAB STUDY was created for C1, P50, MMN, N170, N2pc, CD, LRP, ERN, and P300 in order to evaluate condition differences for each of the following channel measures: ERP, Power Spectra, Event Related Spectral Perturbations (ERSP), and Inter Trial Coherence (ITC).

Statistical significance was set at $p < 0.05$ tested using paired t-test (One-way repeated measures ANOVA for N170) with 2000 permutations and False Discovery Rate (FDR) correction for multiple comparisons.

Clustering of Independent Components for source analysis was done using the Measure Projection Toolbox (MPT; an EEGLAB plugin) which uses mutual information similarity between component sources for each measure and identifies spatial domains where these values are consistently found (Bigdely-Shamlo et al., 2013). Statistical significance level was set at $p < 0.01$ with 2000 permutations (default setting). The Measure Projection Analysis (MPA) was done for each of the measures—ERP, Power Spectra, ERSP, and ITC and the anatomical information for each domain was obtained.

ERPLAB v4.0.3.1 (Lopez-Calderon and Luck, 2014), an EEGLAB plugin, was used for visualization of ERP waveforms and comparison of ERPs across multiple game levels.

RESULTS

Figure 4 shows the ERP waveforms of nine neurocognitive measures elicited by ANGEL in the set of healthy participants recruited for the proof of concept study. Regions of interest for each ERP are indicated by arrows. In addition to the conventional ERPs, the study demonstrates the details of other measures such as the corollary discharge mechanism. While it is not possible to fully provide all possible results within journal length limitations, we present a subset of results in order to demonstrate the validity of the ANGEL paradigm using a sample of the variety of analyses that can be performed.

Event Related Potential Waveforms

Figures 5–8 show the ERP waveforms at different latencies obtained using the ANGEL approach: the early (C1), mid (N170), and late latency ERPs (P300) that are stimulus locked and an ERP that is response locked (ERN). The black bars at the bottom show the regions with significant differences between the conditions ($p < 0.05$, using robust measure of paired t-test or One-way repeated measures ANOVA as applicable; computed with 2000 permutations and FDR corrected for multiple comparisons).

The C1-P1 complex ranges from 40 to 120 ms. **Figure 5** shows the typical C1-P1 waveforms at the electrode POz for the game level *Who*. The distractor stimuli presented bilaterally at the top of the screen have a negative going peak while the distractors at the bottom of the screen show a positive peak that merges with the P1 component.

The N170 waveforms (with a negative going dip between 170 and 250 ms) at electrode PO8 for four different stimuli types (*FacePresent, FaceAbsent, ShapePresent,* and *ShapeAbsent*)

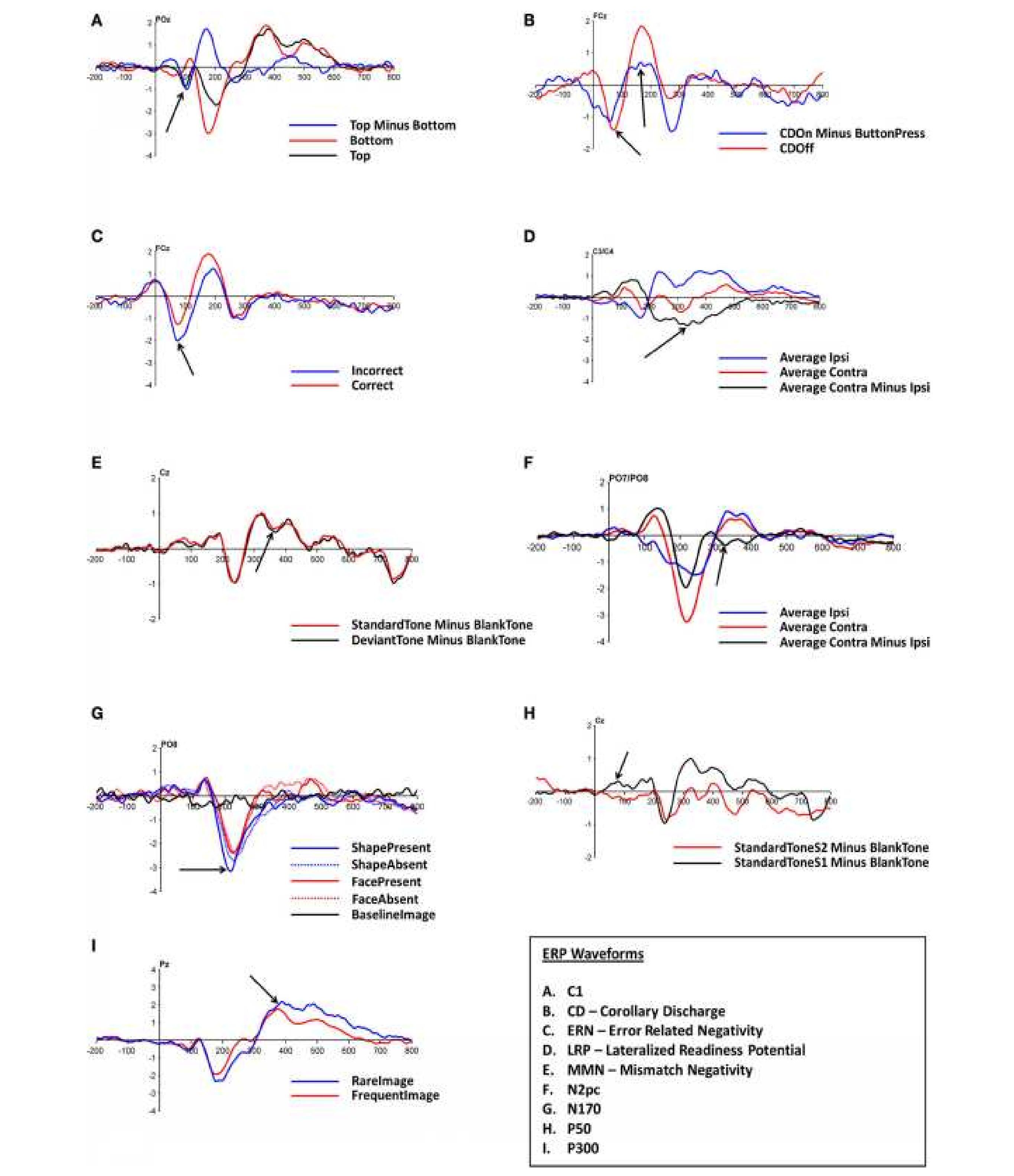


FIGURE 4 | ERP waveforms for (A) C1-P1 complex for level *Who*, (B) Corollary Discharge (N1-P2) complex for level *Who*, (C) ERN (Error Related Negativity) for level *Discern*, (D) LRP for level *Who*, (E) MMN (Mismatch Negativity) collapsed across all levels, (F) N2pc for level *Who*, (G) N170 for level *Discern*, (H) P50 collapsed across all levels, (I) P300 for level *Who*. Arrows indicate the region of interest for the specific ERP.

for game level *Discern* are shown in **Figure 6**. Note that the N170 is more prominent for Shapes (Kanizsa triangles and their distorted versions) than for Faces (Mooney faces and their distorted versions). Also note that the N170 waveform in our study has its greatest negative peak close to 220 ms rather than at 170 ms.

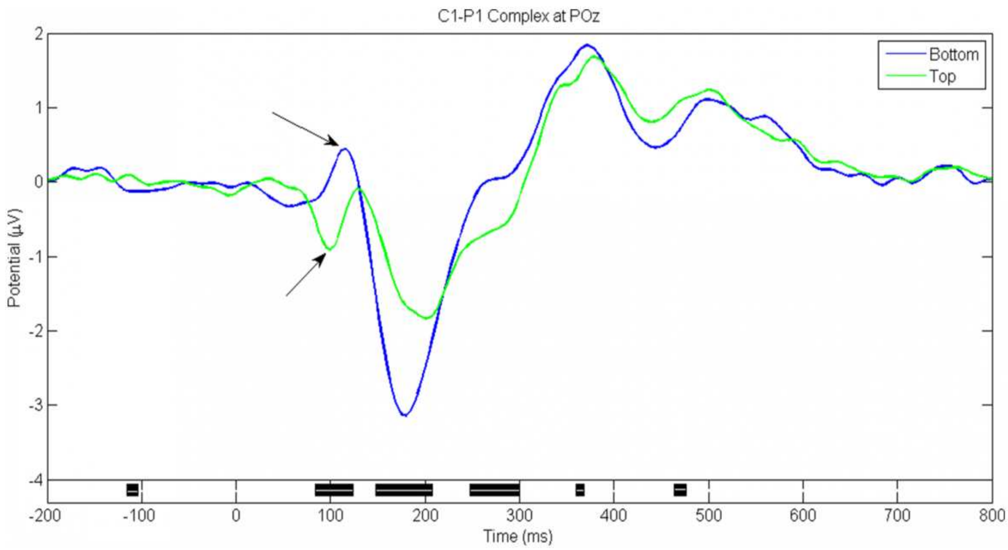


FIGURE 5 | C1-P1 Complex for game level *Who*. Seen at electrode POz around 100 ms post stimulus. Note the opposite polarities seen for Top and Bottom stimuli. Black bars in the bottom panel indicate regions of significant difference between conditions ($p < 0.05$, Paired t-test with 2000 permutations with FDR correction).

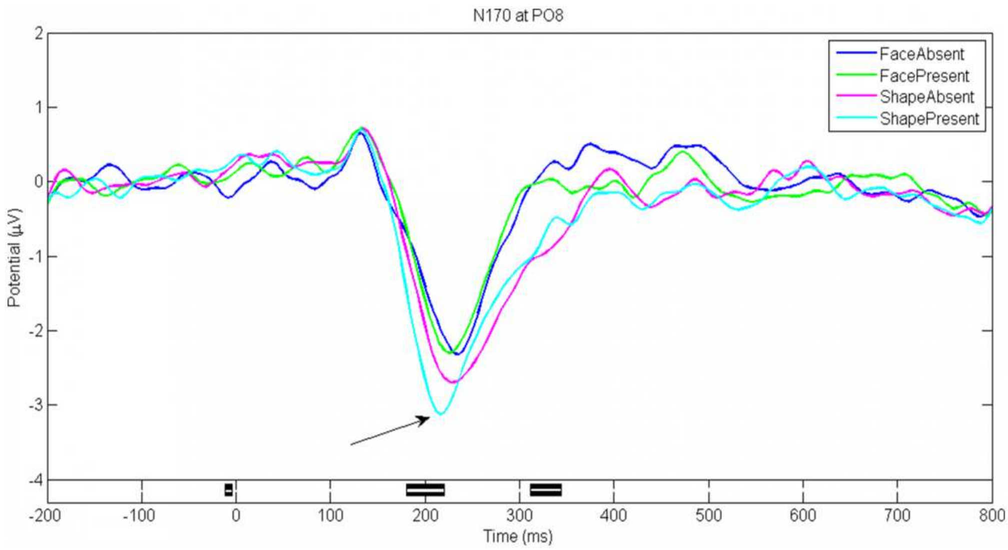


FIGURE 6 | N170 for game level *Discern*. Seen at electrode PO8 between 200 and 250 ms post stimulus. Black bars in the bottom panel indicate regions of significant difference between conditions ($p < 0.05$, Repeated measures One-way ANOVA with 2000 permutations with FDR correction).

The ERN waveforms (with a negative dip before 100 ms followed by a positive peak) at electrode FCz for the trials with *Correct* and *Incorrect* responses for the game level *Discern* are shown in **Figure 7**. These epochs are response locked unlike the other ERPs. Note that the dip is greater for *Incorrect* trials.

The P300 waveforms (large positive peak around 400 ms) at electrode Pz for trials with *Rare* and *Frequent* stimuli for the game level *Who* are shown in **Figure 8**. The *Rare* stimuli elicit a larger peak.

Impact of Task Complexity

The effect of task complexity across the game levels for N170 *FacePresent* trials is shown in **Figure 9**. The N170 amplitude increases with complexity with ANGEL level 1 (*Learn*) having the lowest amplitude (i.e., smallest dip) and ANGEL level 3 (*Discern*) having the maximal amplitude.

Event Related Spectral Perturbations

Between-condition differences in the ERSPs are shown for N170 (**Figure 10**) and P300 (**Figure 11**) components. The brown colored areas on the rightmost panel show the regions with significant differences between the conditions ($p < 0.05$, using robust measure of paired t-test or One-way repeated measures ANOVA as applicable; computed with 2000 permutations and FDR correction for multiple comparisons).

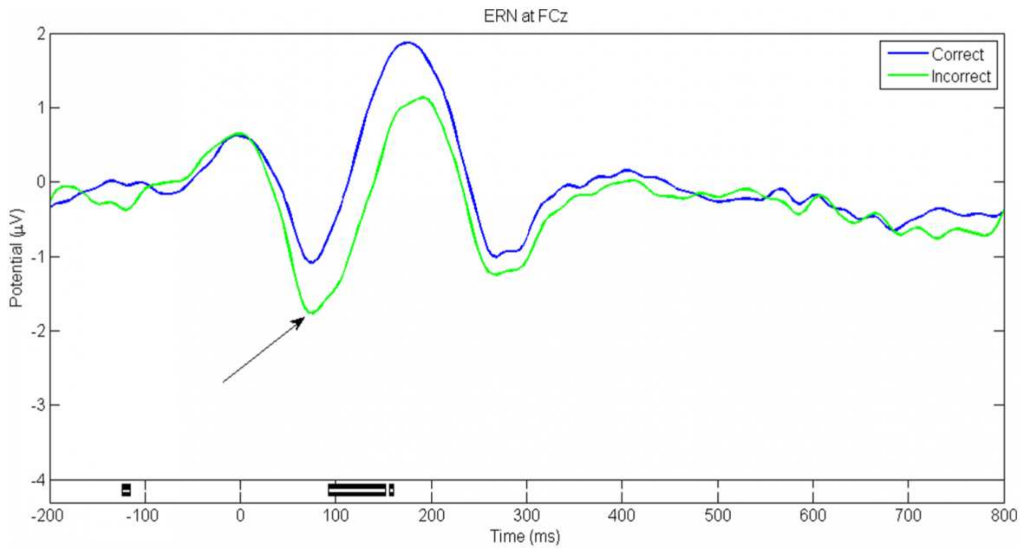


FIGURE 7 | ERN for game level Discern. This is response locked and seen at electrode FCz as a negative deflection about 100 ms post response followed by a positive going potential. The negative dip for the correct responses indicates ongoing conflict whereas the larger negative dip indicates the error related negativity. Black bars in the bottom panel indicate regions of significant difference between conditions ($p < 0.05$, Paired *t*-test with 2000 permutations with FDR correction).

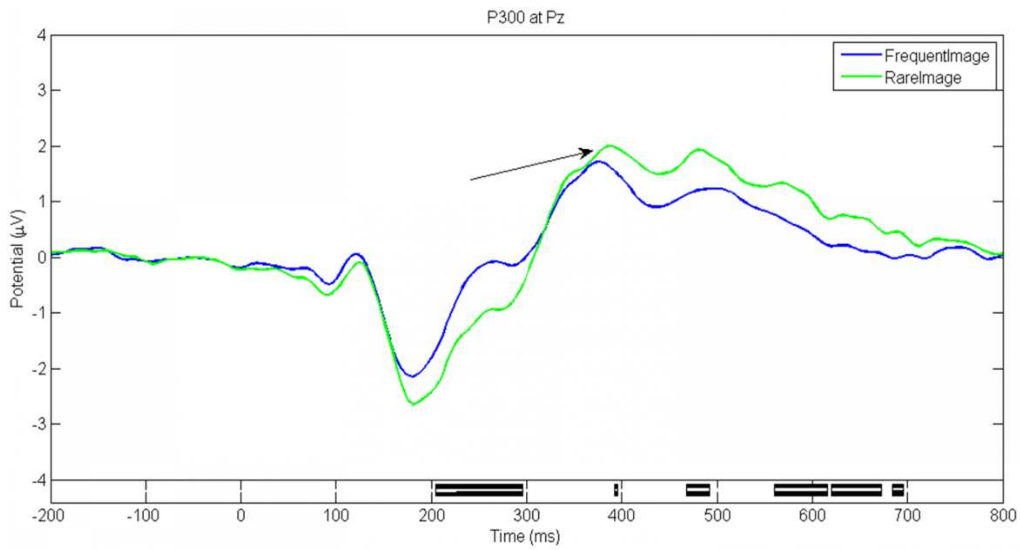


FIGURE 8 | P300 for game level *Who*. Seen at electrode Pz. Rare stimuli evoke a larger P300 peak as compared to frequent stimuli. Black bars in the bottom panel indicate regions of significant difference between conditions ($p < 0.05$, Paired *t*-test with 2000 permutations with FDR correction).

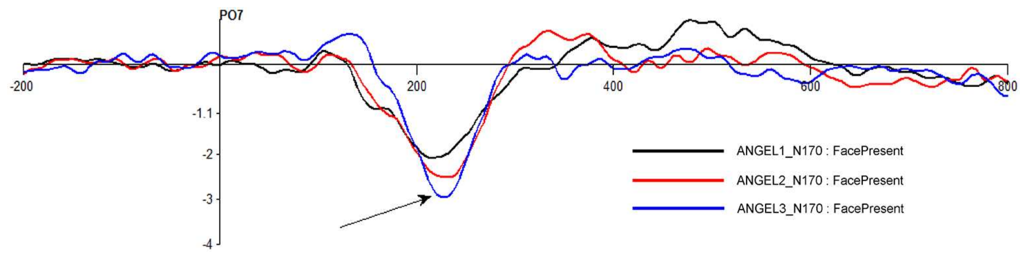


FIGURE 9 | Effect of task complexity for N170 at electrode PO7 for *FacePresent* stimuli across ANGEL game levels *Learn, Who,* and *Discern.*

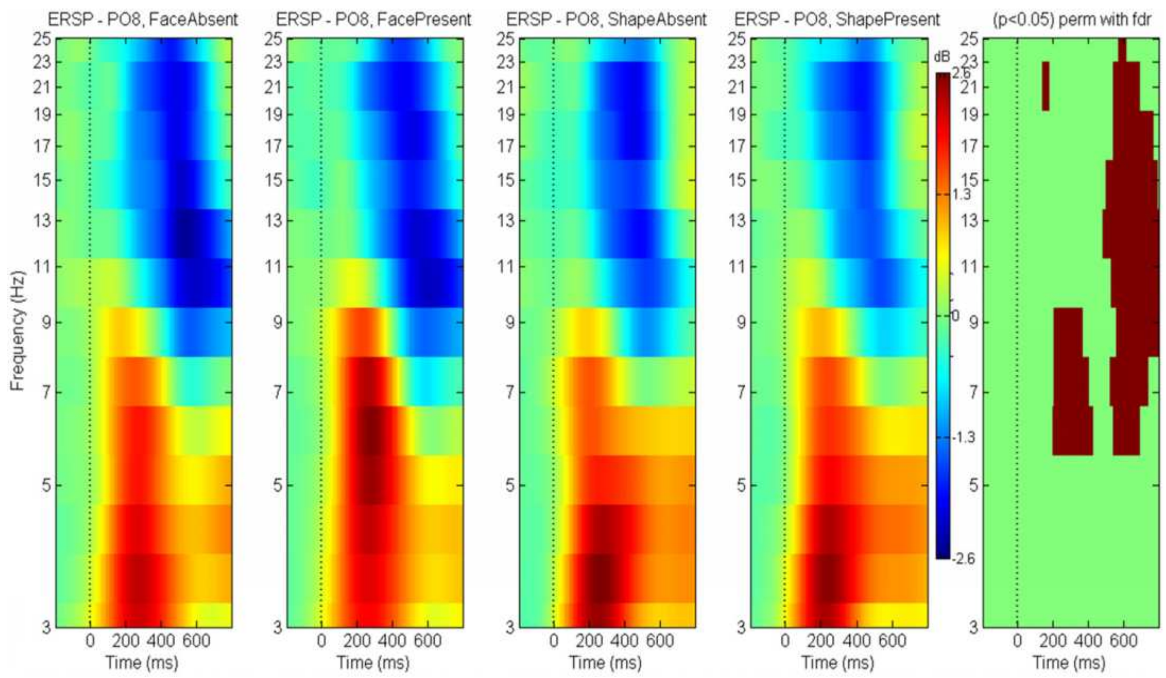


FIGURE 10 | ERSP for N170. Event Related Spectral Perturbations for N170 at electrode PO8 for game level *Discern.* Panel on the right indicates the regions with significant differences across conditions ($p < 0.05$ repeated measures One-way ANOVA with 2000 permutations and FDR correction).

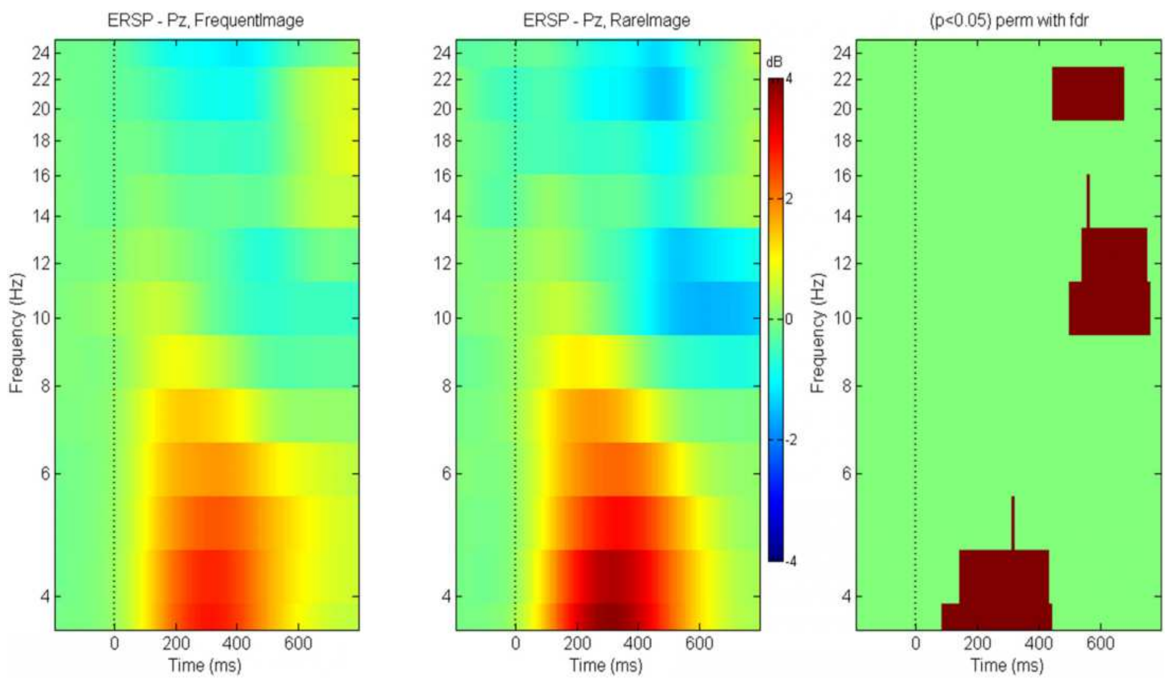


FIGURE 11 | ERSP for P300. Event Related Spectral Perturbations for P300 at electrode Pz for game level *Who*. Panel on the right indicates the regions with significant differences across conditions ($p < 0.05$ Paired t-test with 2000 permutations and FDR correction).

The N170 between-condition differences for ERSP show greater theta-alpha power for *FacePresent* trials followed by suppression across a wide frequency band (higher theta to beta). The P300 between-condition ERSP differences show delta-lower theta enhancement for *rare* stimuli followed by localized alpha and beta suppression.

Inter-Trial Coherence

Between-condition ITC differences are shown for ERN (**Figure 12**) and P300 (**Figure 13**) components. The brown colored areas on the rightmost panel show the regions with significant differences between the conditions ($p < 0.05$, using robust measure of paired t-test; computed with

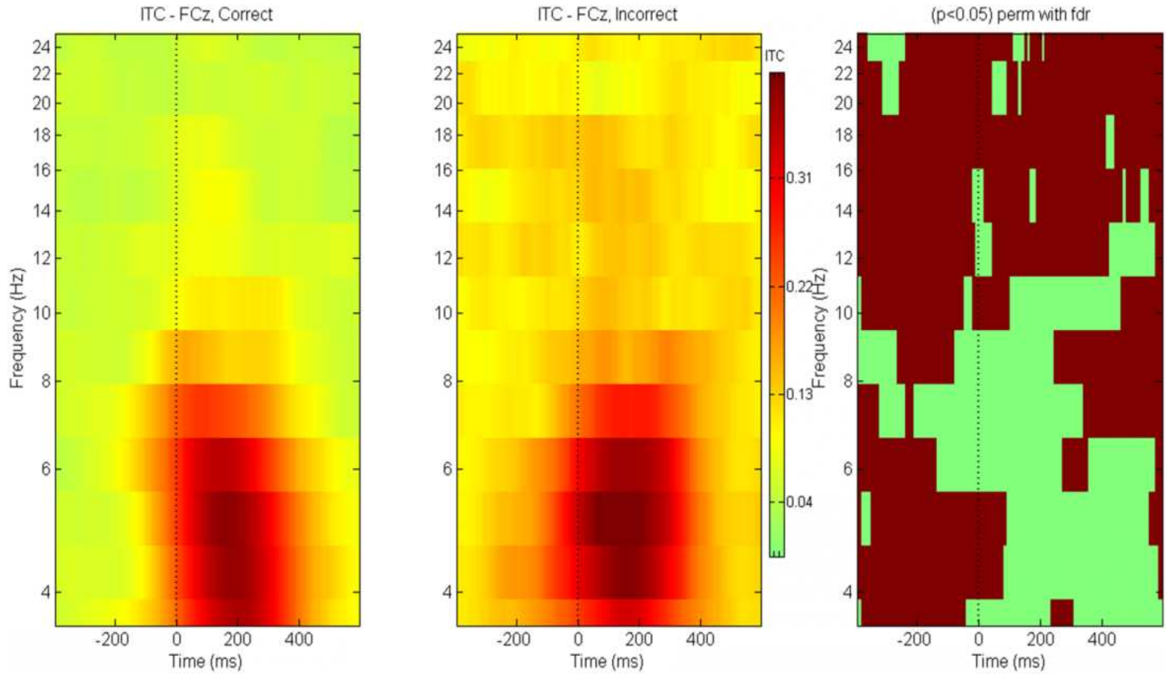


FIGURE 12 | ITC for ERN. Inter trial coherence for ERN at electrode FCz for game level *Discern*. Panel on the right indicates the regions with significant differences across conditions ($p < 0.05$ Paired t-test with 2000 permutations and FDR correction).

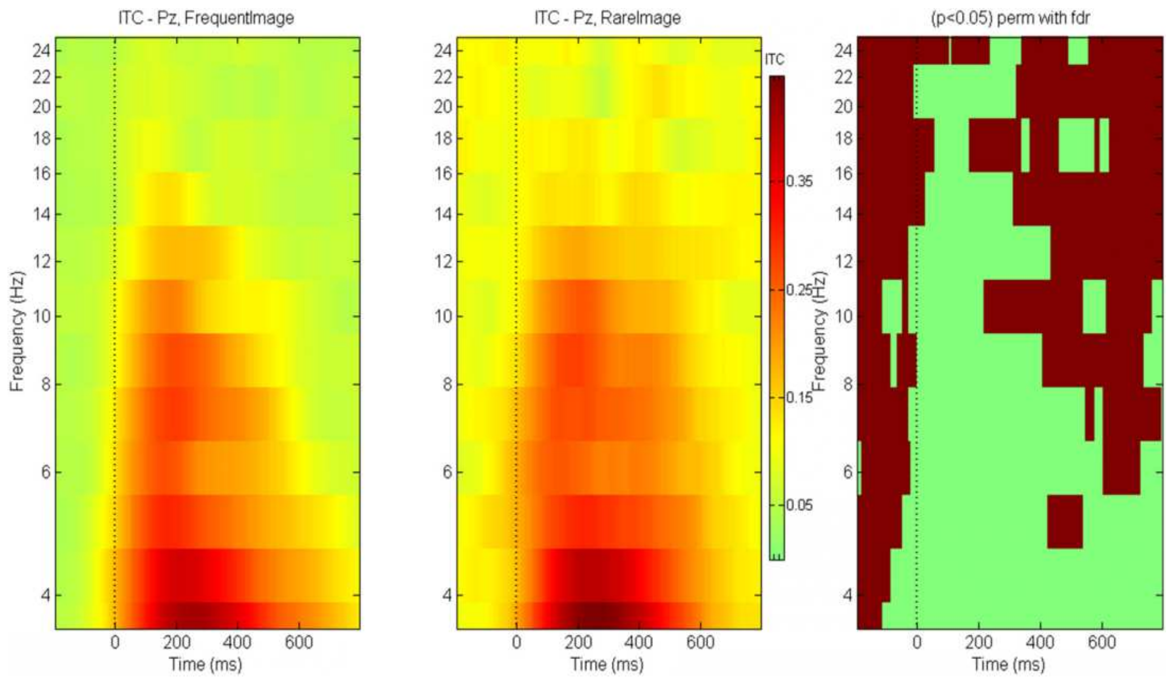


FIGURE 13 | ITC for P300. Inter trial coherence for P300 for game level *Who*. Panel on the right indicates the regions with significant differences across conditions ($p < 0.05$ Paired t-test with 2000 permutations and FDR correction).

2000 permutations and FDR correction for multiple comparisons). The ITC for ERN at electrode FCz is globally enhanced for trials with *Incorrect* responses as compared to those with *Correct* responses. The response locked ITC is similar across both kinds of trials in the theta-lower alpha frequency range after about 100 ms post response.

For P300 at electrode Pz, trials with *Rare* stimuli have greater inter-trial coherence (as compared to trials with *Frequent* stimuli) at baseline and at all frequencies except during 0–600 ms post

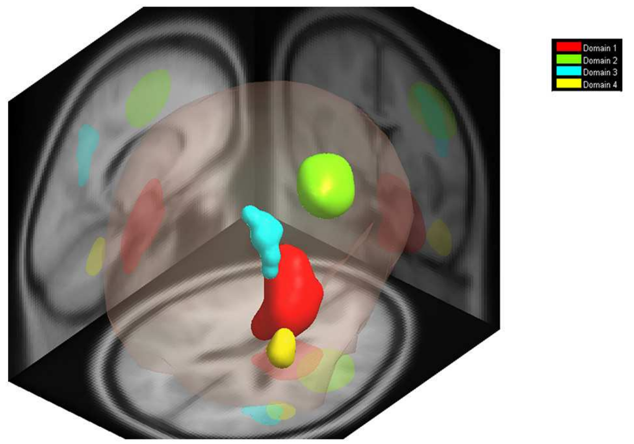


FIGURE 14 | Measure Project Analysis for P300. Measure Projection for localizing component dipoles into four significant domains for the P300 ERP measure [$p < 0.01$ Paired t-test (right-tailed) with 2000 permutations—default settings]. The prominent anatomical regions include the Right Hippocampus, Right Precentral Gyrus, Right Angular Gyrus, and the Cerebellum.

stimulus where the trials are equally coherent for both types of stimuli.

TABLE 1 | Quantitative comparison of sample ERPs with existing literature.

	Our study	Other studies
Number of ERPs assessed	10	Four: Kappenman and Luck, 2012, typically One or Two
Sample ERP	**Effect sizes of example ERP components**	
C1	$-1.0 \pm 0.44\ \mu V$ $N = 18$ (Cohen's $d = 2.27$)	$-3.2 \pm 0.4\ \mu V$ $N = 18$ (Cohen's $d = 8$), Fu et al., 2010
N170	$3.43 \pm 2.38\ \mu V$ $N = 18$ (Cohen's $d = 1.44$)	$-7.85 \pm 1.43\ \mu V$ $N = 14$ (Cohen's $d = 1.73$), Rossion and Caharel, 2011
ERN	$-2.3 \pm 1.42\ \mu V$ $N = 18$ (Cohen's $d = 1.62$)	$-3.65 \pm 2.10\ \mu V$ $N = 40$ (Cohen's $d = 1.74$), Hajcak and Simons, 2008
P300	$3.23 \pm 1.49\ \mu V$ $N = 18$ (Cohen's $d = 2.17$)	$10.75 \pm 4.63\ \mu V$ $N = 15$ (Cohen's $d = 2.32$), Shaikh et al., 2013

Measure Projection Analysis (MPA)

MPA for P300 yielded four domains as shown in **Figure 14**. The prominent anatomical regions included the Right Hippocampus, Right Precentral Gyrus, Right Angular Gyrus, and the Cerebellum.

Quantitative Comparisons with Previous ERP Studies

Table 1 shows amplitude effect sizes (Cohen's d calculated as compared to baseline) of C1, N170, ERN, and P300 from our study and representative results from existing literature focused on these particular ERPs. While our study is able to simultaneously elicit more ERPs than any other approach, the amplitude effect sizes are comparable to those in studies that assess one or two ERPs at a time.

Qualitative Feedback from Participants

The qualitative feedback from the gamified approach has been compelling. All subjects during the study and subsequent acquisitions (over 200 acquisitions done so far for various ongoing studies in our lab) have liked the ANGEL paradigm. Sample feedback: "I enjoyed it"; "I have learnt a lot about myself"; "My concentration is good but I found that I can improve"; "Awesome!"; "Great new experience"; "The last level was a little difficult, but fun". So far, we have had only one mixed feedback from a subject who said: "I feel sleepy when I concentrate." This subject was part of a different ongoing study and his acquisition had to be stopped at the third level.

DISCUSSION

The present study validated the usefulness of the ANGEL paradigm design for simultaneous recording of multiple ERPs and the multiple analysis possibilities. Our study demonstrates that the ANGEL approach is able to simultaneously elicit multiple ERPs in a significantly reduced time frame, elicit the chosen ERPs in a reliable manner and is also ecologically valid as it is more representative of real-world task performance in the presence of multiple audio-visual distracters. The ERP waveform morphology is as expected with statistically significant between-condition differences seen in the various measures.

The ANGEL design introduces a number of gamification elements to the typical oddball paradigm. These are—clear rules that change with context, variety of stimuli, progressive complexity, regular feedback for performance monitoring and improvement, achievable but challenging self-driven goals. Specifically:

1. The task provides variety in terms of rules that bring changes at each level. The task starts with alternating blocks requiring response inhibition (discrimination with passive observation) and speeded up response in the presence of mild distractors, then the number of distractors is increased and finally the rules of the game are changed twice requiring complex discrimination and rapid decision making.
2. To sustain interest, a variety of stimuli are presented in an unpredictable manner (the oddball experience is at an abstract/category level rather than with a finite/concrete set of known images).

3. The visual stimuli are two-tone images that require gestalt perception and so add to the level of challenge at the final level especially when "*FaceAbsent*" stimuli are presented.
4. The complexity levels are scaled to generate and maintain motivation. The easiest level is fast paced but easy so as to provide high initial motivation. The toughest level is quite challenging and yet the rules are simple so the participants stay engaged and feel that they can perform well if they try hard.
5. We provide quantitative speed and accuracy feedback along with messages that encourage better performance in terms of either accuracy or speed depending on the level of accuracy.

The ERPs waveforms obtained by ANGEL are in line with the existing literature—(Luck and Kappenman, 2012) provides a comprehensive review of several of the neurocognitive variables that can be studied using ANGEL. The paradigm simultaneously assesses multiple neural processes such as: auditory and visual perception, attention, set shifting, memory, discrimination, corollary discharge, motor readiness, conflict processing, and multiple levels of decision making under changing rules.

While collecting reaction time and accuracy for providing feedback and as behavioral measures, the ERPs (and associated cognitive parameters) that are assessed are: C1 for early visual processing (Kelly et al., 2008), P50 for early auditory processing (Smith et al., 2013), MMN for discriminative auditory processing (Chen et al., 2014), the N1-P2 complex as a marker of corollary discharge—for self-inference or agency detection (Wang et al., 2014), N170 for recognition and differential object perception (Caharel et al., 2013), N2pc for covert attention shift (Cespón et al., 2013), LRP for motor readiness (Vainio et al., 2014), P300 for sustained attention, working memory, context updating and discrimination (Shaikh et al., 2013), and finally ERN for self-regulation and performance monitoring (Arbel and Donchin, 2014). We discuss the results for four of these ERPs in more detail below:

In ANGEL, the C1 wave is generated by visual distracters (unattended stimuli)—the stimulus in the upper visual field generates a negative potential and the stimulus in the lower visual field elicits a positive potential which is often indistinguishable from P1 as expected. The peak amplitude is quite small as is expected from early visual processing of unattended stimuli (Kelly et al., 2008) lending support to the hypothesis that attention modulates early visual processing.

The N170 was generated by covert detection of patterns (faces and shapes and their distorted forms). The overall amplitude for covert shape detection was greater than for covert face detection. This is in contrast with the N170 face-effect that is cited in the literature (See Caharel et al., 2013 and its references). We attribute this difference to the fact that our stimuli require gestalt perception of two-tone images rather than simple and clear images. Additionally, most of our subjects reported that Kanizsa triangles are much easier to perceive rapidly than Mooney faces. The N170 waveform in our study has its greatest negative peak close to 220 ms rather than at 170 ms. The waveform morphology is similar to that in the literature and is consistent and complexity dependent across different game levels which demonstrates the reliability and shows that face/object detection is modulated by task complexity. However, the reason for the delay needs to be further explored.

The ANGEL game provides scaled complexity levels. The first two levels are simple and errors committed are infrequent. However, the third level, *Discern and Decide,* is highly complex and participants commit more errors as evident by the larger ERN response for incorrect responses (Arbel and Donchin, 2014). *Incorrect* trials show enhanced inter trial coherence across all observed frequencies during the baseline (prior to button response) as compared to the *Correct* trials which is a remarkable indicator of greater cerebral resource allocation during conflicts or uncertain situations.

In ANGEL, an abstract version of the oddball paradigm has been used with different *Standard* and *Rare* stimulus types presented for each block. We find that the P300 waveform is elicited at the single block levels even when the type of the *Standard* stimuli changes in every block. The attention and working memory related aspects are seen via the theta enhancement and concomitant alpha-beta suppression. Interestingly, for *Rare* stimuli, we see a significant global rise in baseline inter-trial coherence (i.e., are phase-locked) across all observed frequencies. This could be due to the expectancy effect that builds up in the oddball paradigm. We have also observed right hemisphere dominance in the P300 ERP sources. The gamified version of a typical oddball paradigm of the ANGEL appears to be engaging. Keeping the "game" simple enables simultaneous study of multiple canonical ERPs without introducing confounds. Providing speed and accuracy scores along with motivational feedback after every two blocks avoids confounds of boredom and fatigue.

In ANGEL, we assess more simultaneous ERP components than any other known approach used in ERP studies (**Table 1**). While larger effect sizes are better, quantitative evaluation of amplitude effect sizes reveal that the effect sizes in our study are comparable to other studies that are focused on the ERP in isolation. For C1, the effect size in our study is much lesser than the referenced paper but it is a good effect size in itself and the difference is most probably due to the fact that we used distracter (non-attended) images to elicit this ERP.

We have not needed to adapt the ANGEL paradigm to suit different populations. Subjects with widely differing backgrounds have been able to perform the task and enjoy it. Examples of diversity include: *Mental health*: patients with schizophrenia, healthy subjects, meditators; *Education*: low/no literacy levels to PhDs; *Age*: from twenties to late seventies; *Computer familiarity*: computer naïve to professional programmers.

We believe patients with neurological diseases may also be able to perform the task depending on their level of sensorimotor difficulties. In the various ongoing studies in our lab, the participant with the lowest WAIS III (Wechsler Adult Intelligence Scale for Matrix Reasoning) score (8), was also able to complete the task. Those with greater cognitive difficulties may be able to perform the first two levels of the task—but this needs to be assessed.

Participants found their performance scores improving during the first two levels with almost everyone being able to achieve 100% accuracy for at least one block and many people able to regularly achieve full accuracy while reducing reaction times. These two levels provide participants with an opportunity for steady improvement in their performance both in terms of accuracy and speed of response in spite of visual and auditory distractors. This helped in maintaining high motivation levels to start the complex third level of task. The third level is more challenging and we find that participants make more errors and take additional time to respond. Having such scaled complexity levels allows sufficient number of trials with correct and incorrect responses.

Apart from the obvious benefits of studying multiple ERPs simultaneously, one can study other cognitive functions using the ANGEL approach. We can evaluate the effects of changing individual elements of the game such as difference between passive observation vs. active response, presence vs. absence of response locked distractors (to study the corollary discharge mechanism), and the set-shifting ability when rules are changed while performing a challenging task. The power of such multilevel gamified approach is that we can examine each ERP at different levels of complexity and examine changes if any across levels. The results of N170 changes across the levels of the game provide a counterintuitive example of how game complexity impacts covert pattern detection. The impact of cognitive loading on other ERPs can similarly be examined.

Importantly, the design provides the flexibility to analyze the data under many different conditions that may not have been originally planned for the study or may be required based on initial analysis. For example, one can study the error related negativity (ERN) averaged from all rare trials that elicited an incorrect response to a meaningful gestalt stimulus.

The ANGEL approach has already been used in multiple studies in our lab with several hundred participants across different study populations, with multiple acquisition systems, and multiple acquisition domains like ERP and fMRI. While the ANGEL paradigm allows us to study many ERPs simultaneously, several ERPs of interest remain unexplored—for example, we might be interested in the N400 to study semantic processing (Duncan et al., 2009). It is possible to look at experimentally manipulating additional neurocognitive variables or to replace some of the existing variables with new ones. This, however, needs a lot of care to avoid the introduction of confounds.

We freely provide the source code (https://github.com/nphynimhans/ANGEL) for our design and software to the community so that others can use it to study different populations of interest and adapt or extend the code according to their research interests. We anticipate that a gamified approach to assessing neurocognition can be a big step forward for our research field.

CONCLUSION

This paper on the ANGEL approach describes the paradigm design and demonstrates its validity and utility in the study of multiple neurocognitive variables such as auditory and visual perception, attention, set shifting, memory, discrimination, corollary discharge, motor readiness, conflict processing, and multiple levels of decision making under changing circumstances.

The assessment of neurocognition with the ANGEL approach: is ecologically more valid (realistic sensory-motor activity); intrinsically motivating (game, performance reward); highly efficient (multifold reduction in overall acquisition time) considering the number of variables assessed; and having high statistical power (increased number of trials and decrease in possible confounds).

ANGEL provides an opportunity to evaluate influences (isolate main and interaction effects of different variables) and provides spectrum coverage (whole brain neurocognition study) while being user friendly (for subject and investigator) and automatable (over 500 event markers) to allow focusing on the relevant area of interest with desired extent of granularity.

Thus, the ANGEL framework allows simultaneous assessment of several ERPs providing an opportunity for a more holistic neurocognitive study.

AUTHOR CONTRIBUTIONS

AN, AS, and BK conceptualized the study; AN carried out the data acquisition and analysis; AN and AS designed the task; AN and AS wrote the data analysis scripts; BK, JJ, and SM critically evaluated the study; all authors contributed to writing the manuscript.

ACKNOWLEDGMENTS

We would like to acknowledge with thanks the financial support provided by the Department of Science and Technology, Cognitive Science Research Initiative (DST-CSRI), Government of India, New Delhi (No.SR/CSI/63/2011). We greatly acknowledge the National Institute of Mental Health and Neuro Sciences (NIMHANS) for institute fellowships (AN and AS), Indian Council for Medical Research (ICMR), Government of India (Ref. No.: 3/1/3/37/Neuro/2013-NCD-I) for Senior Research Fellowship (AS). We thank Prof. Peter Uhlhaas for kindly providing us with the Mooney face images and their distorted versions that we have used in our work. We are grateful to all the participants who participated in the study.

REFERENCES

Arbel, Y., and Donchin, E. (2014). Error and performance feedback processing by children with Specific Language Impairment-An ERP study. *Biol. Psychol.* 99, 83–91. doi: 10.1016/j.biopsycho.2014.02.012

Bigdely-Shamlo, N., Mullen, T., Kreutz-Delgado, K., and Makeig, S. (2013). Measure projection analysis: a probabilistic approach to EEG source comparison and multi-subject inference. *Neuroimage* 72, 287–303. doi: 10.1016/j.neuroimage.2013.01.040

Caharel, S., Leleu, A., Bernard, C., Viggiano, M.-P., Lalonde, R., and Rebaï, M. (2013). Early holistic face-like processing of Arcimboldo paintings in the right occipito-temporal cortex: evidence from the N170 ERP component. *Int. J. Psychophysiol.* 90, 157–164. doi: 10.1016/j.ijpsycho.2013.06.024

Cespón, J., Galdo-Álvarez, S., and Díaz, F. (2013). N2pc is modulated by stimulus-stimulus, but not by stimulus-response incompatibilities. *Biol. Psychol.* 93, 75–80. doi: 10.1016/j.biopsycho.2013.01.010

Chen, J. C., Hämmerer, D., Strigaro, G., Liou, L. M., Tsai, C. H., Rothwell, J. C., et al. (2014). Domain-specific suppression of auditory mismatch negativity with transcranial direct current stimulation. *Clin. Neurophysiol.* 125, 585–592. doi: 10.1016/j.clinph.2013.08.007

Delorme, A., and Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *J. Neurosci. Methods* 134, 9–21. doi: 10.1016/j.jneumeth.2003.10.009

Deterding, S., Dixon, D., Khaled, R., and Nacke, L. (2011). "From game design elements to gamefulness: defining "Gamification"," in *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments - MindTrek'11* (Tampere), 9–11.

Duncan, C. C., Barry, R. J., Connolly, J. F., Fischer, C., Michie, P. T., Näätänen, R., et al. (2009). Event-related potentials in clinical research: guidelines for eliciting, recording, and quantifying mismatch negativity, P300, and N400. *Clin. Neurophysiol.* 120, 1883–1908. doi: 10.1016/j.clinph.2009.07.045

Fu, S., Fedota, J. R., Greenwood, P. M., and Parasuraman, R. (2010). Dissociation of visual C1 and P1 components as a function of attentional load: an event-related potential study. *Biol. Psychiatry* 85, 171–178. doi: 10.1016/j.biopsycho.2010.06.008

Hajcak, G., and Simons, R. F. (2008). Oops!.. I did it again: an ERP and behavioral study of double-errors. *Brain Cogn.* 68, 15–21. doi: 10.1016/j.bandc.2008.02.118

Kanizsa, G. (1979). *Organization in Vision: Essays on Gestalt Perception*. New York, NY: Praeger.

Kappenman, E. S., and Luck, S. J. (2012). Manipulation of orthogonal neural systems together in electrophysiological recordings: the MONSTER approach to simultaneous assessment of multiple neurocognitive dimensions. *Schizophr. Bull.* 38, 92–102. doi: 10.1093/schbul/sbr147

Kelly, S. P., Gomez-Ramirez, M., and Foxe, J. J. (2008). Spatial attention modulates initial afferent activity in human primary visual cortex. *Cereb. Cortex* 18, 2629–2636. doi: 10.1093/cercor/bhn022

Lopez-Calderon, J., and Luck, S. J. (2014). ERPLAB: an open-source toolbox for the analysis of event-related potentials. *Front. Hum. Neurosci.* 8:213. doi: 10.3389/fnhum.2014.00213

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

Mooney, C. M., and Ferguson, G. A. (1951). A new closure test. *Can. J. Psychol. Can. Psychol.* 5, 129.

Rossion, B., and Caharel, S. (2011). ERP evidence for the speed of face categorization in the human brain: disentangling the contribution of low-level visual cues from face perception. *Vision Res.* 51, 1297–1311. doi: 10.1016/j.visres.2011.04.003

Shaikh, M., Hall, M.-H., Schulze, K., Dutt, A., Li, K., Williams, I., et al. (2013). Effect of DISC1 on the P300 waveform in psychosis. *Schizophr. Bull.* 39, 161–167. doi: 10.1093/schbul/sbr101

Smith, D. M., Grant, B., Fisher, D. J., Borracci, G., Labelle, A., and Knott, V. J. (2013). Auditory verbal hallucinations in schizophrenia correlate with P50 gating. *Clin. Neurophysiol.* 124, 1329–1335. doi: 10.1016/j.clinph.2013.02.004

Uhlhaas, P. J., Linden, D. E. J., Singer, W., Haenschel, C., Lindner, M., Maurer, K., et al. (2006). Dysfunctional long-range coordination of neural activity during Gestalt perception in schizophrenia. *J. Neurosci.* 26, 8168–8175. doi: 10.1523/JNEUROSCI.2002-06.2006

Vainio, L., Heimola, M., Heino, H., Iljin, I., Laamanen, P., Seesjärvi, E., et al. (2014). Does gaze cueing produce automatic response activation: a lateralized readiness potential (LRP) study. *Neurosci. Lett.* 567, 1–5. doi: 10.1016/j.neulet.2014.03.015

Wang, J., Mathalon, D. H., Roach, B. J., Reilly, J., Keedy, S. K., Sweeney, J. A., et al. (2014). Action planning and predictive coding when speaking. *Neuroimage* 91, 91–98. doi: 10.1016/j.neuroimage.2014.01.003

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., and Tanaka, J. W. (2010). Controlling low-level image properties: the SHINE toolbox. *Behav. Res. Methods* 42, 671–684. doi: 10.3758/BRM.42.3.671

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DRDO Project Report

STUDY ON THE EFFECT OF RAJAYOGA MEDITATION ON PHYSIOLOGICAL, AFFECTIVE & COGNITIVE FUNCTIONS

A Joint Study by Life Sciences Labs, DRDO & Brahma Kumaris, Mount Abu

The conceptual beginning:

SpARC has always been longing to take up applied research projects on RajYog meditation. There are several experiments done by SpARC earlier. What was missing was the structured scientific protocol for the project. It was therefore needed to partner with a research organization which has the expertise in defining the research protocol. This is how the association with the Life Sciences labs of DRDO happened.

Objective of the study:

The objective of this pilot study was to understand the effect of RajYog meditation (RY) on the physiological, cognitive and affective states of healthy adults. The above study was of mutual interest of Brahma Kumaris and DRDO. Wherein BKs were interested to see the applied effects of RY on individuals and learn in structing the experimental protocol, the DRDO team was keen to see the effects of RY on adults and extrapolate the scenario healthy adult individuals on high-altitude low-density combat regions.

The inspiration and initiation of the project was from the two leading members of the DRDO, Dr.VKSaraswat-Scientific Advisor to RakshaMantri and DR.W.Selvamoorthy-CCLS. The experimental protocol was completely structured by DRDO teams from three departments under the division of Life Science; the departments were- DIPAS (Physiological related), DIPR (Psychological related) and INMAS (Neuro/Cognitive Related). The Project ownership is with DRDO with active participation of BK members for the meditation part of the content and also for lining up volunteers with RY experience.

The Experimental Protocol:

The Experiment was designed to have four groups of which three were experimental groups and one was a reference control group.

Groups	No. of Partcipants	criteria
Experimental Group-I	30	Upto 1 year of RY practice experience.
Experimental Group-II	30	Above 1 year but within 5 years of RY practice experience.
Experimental Group-III	30	Above 5 years of RY practice experience.
Experimental Group-IV	30	No RY practice exposure.

Participants were a mix of male and female adults from various age group and educational qualifications.

Total duration of the experiment was 60 days in which there were three tests administered at start, after 30 days of start and after 60 days of start.

1st Visit

- Reading before start of the study.
- Start.

2nd Visit

- After 30 days of 1st visit.
- Reading after 1 month of practice.

3rd Visit

- After 3o days of 2nd visit.
- Reading after 2nd months of RY Practice.

All the experimental readings were conducted by DRDO respective lab scientists & associates. The tests were conducted at Derawal Centre-Delhi of the Brahma Kumaris.

About the Meditation:

All participants were provided with a pre-recorded meditation audio commentary in a CD which they were asked to practice during the tenure of the experimental period of 60 days. This was to standardize practice method and eliminate method subjectivity. The meditation involved attaining seed stage (Nirakariswaroop) and Angelic stage (AakariFarishtaswaroop) alternately for 6 times each stage. Duration of the pre-recorded meditation was of 15 minutes.

1. Invocation	2. Seed	3. Angelic	4. PMA
5. Seed	6. Angelic	7. PMA	8. Seed
9. Angelic	10. PMA	11. Seed	12. Angelic
13. PMA	14. Seed	15. Angelic	16. PMA
17. Seed	18. Angelic	19. PMA	20. Gratitude Expression

Note – The numbers show the sequence of practice in the form of schematics

Participants had to practice this meditation twice daily during this period. Participants had the choice to use or discontinue using the audio CD after some time as long as the approach of the meditation was maintained.

There was a face to face demonstration of the experimental approach and the meditation for all the experimental participants one week before the start of the experiment.

Participation Details for experimental Group:

BRAHMAKUMARIS CENTRE (SHAKTI NAGAR / DERAWAL NAGAR)				
	Phase I	Phase II	Phase III	Remarks
No. of Participants	129	104	104	Volunteers Who participated in all the three Phases = 102
Duration of Study	Feb 22 - Mar 07, 2011	Apr 07 - 18, 2011	May 19 - Jun 01, 2011	

The results were presented by the DRDO team at SpARC Annual Conference (SIR) at Brahma Kumaris, Shantivan, Abu Road in 2011.

The results are presented in three sections as there were three departments from the DRDO conducting the tests on respective parameters. These are the synopsis and inferences. for detail report interested readers can approach the office bearer of SpARC at Brahma Kumaris, GyanSarovar - Mount Abu, Academy hall #13.

The outcome:

DIPAS Report (related to physiological parameters)
The parameters checked by DIPAS lab for the physiological aspects were:

- Resting Heart Rate
- Heart Rate Variability
- Blood Pressure
- Peripheral Arterial Oxygen Saturation
- Peripheral Temperature
- Skin Conductance
- Resting EEG

The observation was as follows-

- Blood pressure reduction indicates better cardiac function perhaps attained as a result of Rajyoga meditation practice.

- Improved parasympathetic dominance is reflected by HRV in terms of reduced VLF, LF and HF % Powers.

- Trend of reduction in LF/Hf ratio symbolizes sympathy-vagal balance.

- Better relaxation is indicated by decreased skin conductance.

- Significant improvement in relaxed wakefulness is implicated by improved alpha and reduced beta.

The results after 60 days of experimental period are depicted in the below table-

PARAMETERS	BK (0-1 YEARS)	BK (1-5 YEARS)	BK (> YEARS)	DIPAS Personnel
Weight	↔	↔	↔	↔
Heart Rate & SpO2	↔	↔	↔	↔
Blood Pressure				
• Systolic	↓	↓	↓	↔
• Diastolic	↓	↓	↓	↓
Heart Rate Variability				
• VLF	↓	↓	↓	↔
• LF	↓	↓	↓	↔
• HF %	↓	↓	↔	↔
• LF / HF Radio	↓	↔	↔	↔
Skin Conductance	↓	↔	↔	↓
Temperature	↔	↔	↔	↔
Occipital EEG				
• Eyes Open	↑ α and β ↓	↑ α and β ↓	↑ α and β ↓	↑ α and β ↓
• Eyes Closed	↑ α and β ↓	↑ α and β ↓	↑ α and β ↓	↑ α and β ↓

↓ Significant Reduction ↑ Significant increase ↔ No Significant Change

DIPR report (related to cognitive and affective parameters)

The Defence institute of Psychological Research (DIPR) Carried out the tests on the following parameters-

Affective Parameters:

1. NEO-PI R (Neuroticism Scale) (Costa & McCrae, 1992).
2. Happiness Scale (Lyubomirsky & Lepper, 1999).
3. The Adult Hope Scale (Snyder, Harris & Anderson, 1991).
4. Quality of life (Burakhardt, 2003).

Cognitive Parameters:

1. Memory (Verbal and non - Verbal) Rey Verbal Learning Test and Rey Osterith Complex Figure Test from NIMHANS Neuropsychological Battery.

2. Attention & Concentration (Letter Cancellation Test) From NIMHANS Neuropsychological Battery.

The results obtained were very interesting and revealing. We take the results one by one. Let us first look at the results of affective state of beginners (within 1 year of RY Practice) vs experts (above 5 years of RY practice). The table below shows that in all the seven affective parameters the experts had statistically significant better state.

Variable	Beginner	Expert	t
Anxiety	14.71 + 5.01	9.42 + 4.51	4.31**
Angry Hostility	13.05 + 5.14	8.73 + 3.81	3.65**
Depression	14.00 + 6.09	9.69 +4.26	3.11**
Self Consciousness	13.44 + 4.39	9.50 + 4.12	3.61**
Impulsiveness	13.65 + 4.26	10.07 + 3.03	3.68**
Vulnerability	11.84 + 5.42	6.57 + 3.61	4.33**
Total	80.71 + 24.00	54.00 + 17.48	4.85**
*=.05, **=.01, NS = Not Significant			

The next results were on the effect of RY on hope happiness & quality of life scales. Here, the experts were higher on hope & happiness aspects significantly.

Variable	Beginner	Expert	t
Hope	53.10 $\pm$ 7.42	56.92 $\pm$ 6.32	2.14*
Happiness	5.03 $\pm$ 1.27	5.99 $\pm$ 1.02	3.17**
QOL	85.76 $\pm$ 13.77	84.80 $\pm$ 15.18	0.26^{NS}

There was no significant performance difference between the cognitive functions of beginners and experts. However, the groups showed statistically significant improvement in cognitive functions between the initial test readings and the final test readings (i.e. Phase-I & phase-III).

In was inferred that the RY lifestyle (regular spiritual study {murli} and other discipline) is having a profound positive effect on the expert RY practitioners which could be seen in the comparative results of the beginners and experts; the meditation session per se did not have any statistically significant impact in the performance of individuals over 60 days.

It was therefore recommended to have longitudinal studies and also studies with participants with cognitive deficit.

INMAS report (related to cognitive function for a small experimental group of 18 participants)
The aim of this experimental work is to evaluate the enhancement of the neuro-cognitive abilities through rajyoga meditation.

Protocol Used:

- Training period: 30 days (using the same meditation CD)
- Number of subjects: 6 from each group (total=18)

This part of the test was conducted INMAS lab at Timarpur road, Delhi. The details of experience structure of the 18 participants were as mentioned below.

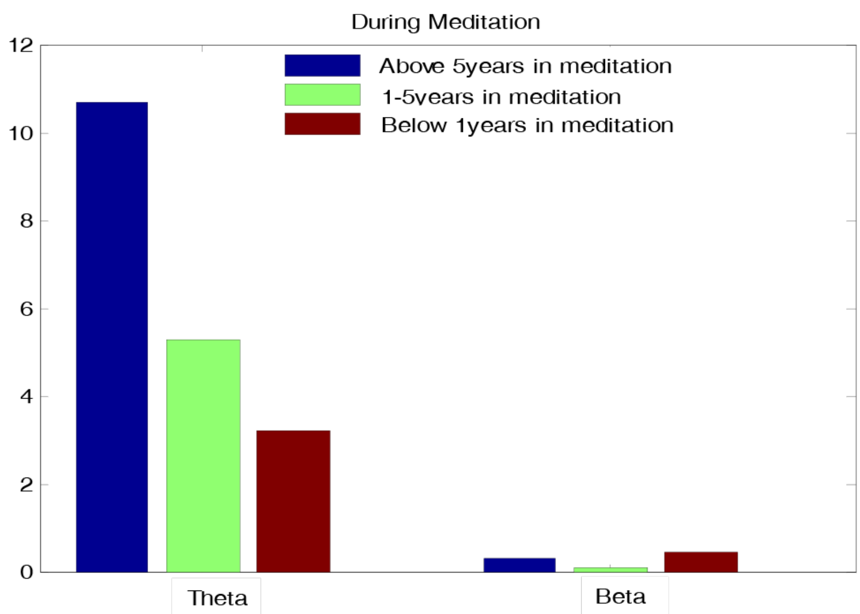
Age Group	Males	Females
0 -1 Year	1	5
1 - 5 Years	2	4
Above 5 Years	3	3

These participants underwent an EEG test under the following test conditions-

* 20 minutes open eye RY Meditation
* 5 minutes video watch. (combat scene with extreme situations of violence)

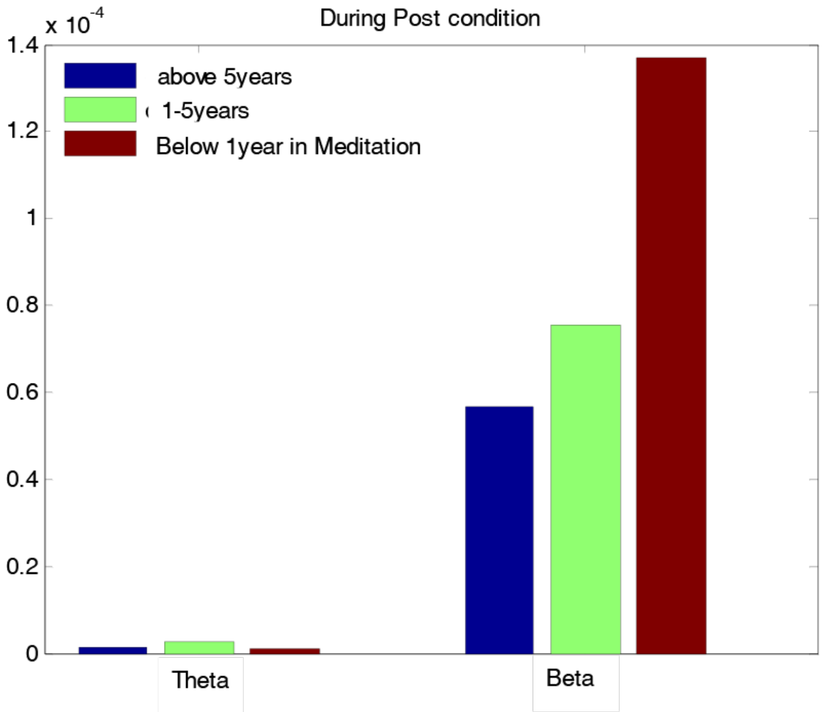
EEG from Frontal & Occipital lobes as frontal lobe is associated with reasoning, planning, emotions, attention etc., and occipital lobe is associated with visual information processing.

The effects of the experiment are depicted in the below graph-



The above shows the EEG average responses of the frontal lobe during meditation. It is noticed that participants above 5 years of RY meditation experiences has a predominant theta rhythm.

The graph beneath shows the EEG response of the frontal lobe. This is during the period when the participants were exposed to a violent combat scene in normal consciousness, immediately after the meditation. Here it can be seen that the mental stability level of RY meditation practitioners above 5 years (depicted in blue) shows significantly low levels of beta brain waves as compared to novice practitioners. The ability to manage anxiety is much developed in the above 5 years RY experience category participants.



Inference & way ahead:

The results of all the three labs had generated good interest to look into the effects of RY mediation in a deeper manner, particularly in areas of cognitive and Affective aspects. It is under consideration to expand the pilot into a bigger experiment that would have larger number of participants. The experiment is likely to be of longer as the effects of RY meditation alone for 60 days may be inadequate; RY lifestyle considerations also to be explored.

IJHSR International Journal of Health Sciences and Research
www.ijhsr.org ISSN: 2249-9571

Original Research Article

Effect of Raj Yoga Meditation on Affective & Cognitive Functions

Nishi Misra*@, Arunima Gupta**, Sarika Alreja***, Om Prakash****

*Scientist 'E', **Scientist 'F', ***Ph.D Clinical Psychology, ****M.Phil Medical & Social Psychology

Defence Institute of Psychological Research (DIPR), Defence Research and
Development Organization, Lucknow Road, Timarpur, Delhi-110054.

@Correspondence Email: nishi.nishi067@gmail.com

Received: 21/01//2013 *Revised: 21/02/2013* *Accepted: 22/02/2013*

ABSTRACT

Context: Raj Yoga is the supreme or the highest yoga that empowers the self to rule the mind, sense-organs and the body. There are several psychological benefits incurred by raj-yoga which have not been highlighted due to scarcity of scientific studies. **Aims:** The present study examined the effect of duration of Raj Yoga Meditation practice on affective & cognitive functions in terms of attention/concentration, memory, visual processing, neuroticism, hope and happiness. **Materials and Methods:** Sixty- four healthy volunteers practicing Raj yoga from 1 month to more than 10 years were segregated into two groups of beginners and practitioners and their psychological and affective functions assessed using standard measures at a Raj Yoga Centre in Delhi, India. **Results and Conclusions:** Results suggest that the group practicing Raj Yoga for longer duration had significantly less neurotic symptoms, scored higher on hope and happiness and higher on cognitive functions in comparison to the group practicing Raj Yoga for shorter duration. These results may be due to personality development, self-actualization and better attention and concentration achieved due to training in Raj Yoga.
Key-words: Raj Yoga, Affective & Cognitive Functions

INTRODUCTION

The word 'Raj' means the king, sovereign or the supreme. Raj Yoga is the supreme or the highest yoga that empowers the self to rule the mind, sense-organs and the body. Raj-Yoga also implies that even a person who is a king and who is very busy can practice it, as this practice does not involve any acts of austerities or penances or renouncing one's household. Raj-Yoga meditation is different from all other forms of meditation; although contemplation, reflection, imagination, concentration, etc. are employed in its practice.

Raj-Yoga is based on the understanding that every person has two aspects of personality – body (outer sheath) and a conscient entity which is a metaphysical or spiritual being or soul. It is this which thinks, understands, reflects and has emotions. Brain is one of its mechanisms and its switchboard or control apparatus. However, in the course of time, certain factors have led the conscient entity to identify itself with the brain or the body. This wrong identification has caused suffering in various forms and has led the society to the path of struggle for existence and peacelessness.

The practice of Raj Yoga results in alertness and awareness of the mind and illusions of material consciousness, frees one from fear of the unknown, gives clarity and certainty about what lies beyond the immediate perceivable world. It can also be practiced for maintaining sound health, improving concentration for better performance in any field, overcoming character defects, developing personality, etc.

There are several psychological benefits incurred by yoga which have been highlighted in the studies conducted in the field. It increases somatic and kinesthetic awareness, improves mood, [1] increases subjective well-being of the individuals, [2] increases self-acceptance and self-actualization, increases social adjustment, decreases anxiety, depressive symptoms and hostility. [3, 4] There are reports of benefits of yoga seen in the treatment of anxiety disorders, obsessive-compulsive disorder, and schizophrenia. Kundalini meditation and relaxation have been used for anxiety disorders and obsessive-compulsive disorder. [5] The best studies of mood changes associated with Yoga were carried out on Hatha-Yoga, a form of Yoga that involves a strong exercise dimension. [6] It involves stretching, balancing, and breathing routines. After practicing Hath Yoga, subjects reported being less anxious, tense, angry, fatigued, and confused. Yoga has a very significant role in the treatment of psychosomatic disorder which is precipitated due to stress. [7-10]

Yoga has also been described as training in awareness which produces definite changes in perception, attention and cognition. [11] It has been shown that processing of sensory information at the thalamic level is facilitated during the practice of pranayama (breathing exercises) [12] and meditation. [13] Integrated approach of yoga that combines physical postures, pranayama and meditation together with the notional correction based on philosophy of yoga was found to improve both cognitive (visual perception) and motor functions (hand steadiness in college students following 10 days of yoga practice). [14] This improvement was believed to be due to improved eye hand coordination, attention, concentration and relaxation. [13]

Among the various types of Yoga, very few studies have been documented regarding the practice of Raj Yoga and its effects. Changes in various autonomic and respiratory variables during the practice of Brahmakumaris Raja yoga meditation in 18 males with 5-25 years of experience in meditation were reported in a study [13] which revealed that heart rate during the meditation period was increased. There was no significant change during meditation, for the group as a whole, in palmar GSR, finger plethysmogram amplitude, and respiratory rate. The individual level analysis revealed that changes in autonomic variables suggestive of both activation and relaxation occurred simultaneously in different subdivisions of the autonomic nervous system in a subject. Apart from this, there were differences in patterns of change among the subjects who practiced the same meditation.

With this background, the present study was conducted to know: (i) The impact of duration of Raja Yoga Meditation practice on affective and cognitive functions and (ii) To compare the beginners and experts of Raja Yoga Meditation on affective and cognitive functions in terms of attention/concentration, memory, visual processing, neuroticism, hope, and happiness.

SUBJECTS AND METHODS

This study was conducted at BramhaKumari Raj Yoga Centre, Delhi. 100 Participants were interviewed and screened initially. The Inclusion and Exclusion criteria for the participants were age group of twenty five to fifty years, at least educated up to High School, residing in North Delhi and nearby areas, not having any significant physical or psychiatric illness and given informed consent to participate in the study. After screening according to the exclusion and inclusion criteria, sixty four individuals were selected for the study. Informed consent was taken from each participant. The nature and purpose of the study was explained to them. Thereafter, the drawn sample was randomly divided into two groups. The first group consisted of thirty eight individuals who were practicing raj yoga for the last two years and the second group consisted of twenty six individuals who were practicing raj yoga for ten or more years. Mean age of the participants in group I and group II was 38.42±9.78 and 40.38±8.34 years respectively. In both groups majority of the participants were married, employed and from urban background. Most of the participants' income was above 3 Lac rupees per year. No significant difference was found between the groups on any of the socio demographic characteristics i.e., education, marital status, occupation and socio-economic status and income.

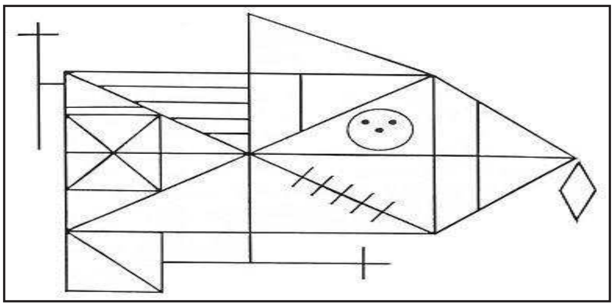
Socio- demographic and Clinical Data Sheet were filled for initial information. Assessment of all the participants was done using the NEO-PI R (Neuroticism Scale for assessing neuroticism),Happiness Scale, The Adult Hope Scale and Quality of Life Scale which were used to assess psychological and affective functioning. Rey Verbal Learning Test, Rey Osterrieth Complex Figure Test and Letter Cancellation Tests of NIMHANS Neuropsychological Battery were administered to assess cognitive functions.

Tools used:

- Neuroticism scale of NEO-PI R: [15] The scale is characterized by a general tendency to experience negative affects such as fear, sadness, embarrassment, anger, guilt and disgust. Individuals high in this factor are also prone to have irrational ideas, are less able to control their impulses and cope more poorly than others with stress. Six facets of neuroticism that are assessed include: anger, anxiety, hostility, depression, self-consciousness, impulsiveness and vulnerability. Each facet contains six items. The domain scales show internal reliabilities ranging from 0.87 to 0.92. The facet scales show internal reliability ranging from 0.58 to 0.82.
- The Adult Hope Scale: [16] The adult hope scale measures Snyder's cognitive model of hope which defines hope as "a positive motivational state that is based on an interactively derived sense of successful (a) agency (goal-directed energy) and (b) pathways (planning to meet goals)". The adult hope scale contains 12 items. Four items measure pathways thinking, four agency thinking and four items are fillers. Participants respond to each

item using an eight point scale, ranging from definitely false to definitely true and the scale takes only a few minutes to complete.

- Happiness Scale: [17] is a four item scale of global subjective happiness. Two items ask respondents to characterize themselves using both absolute ratings and ratings relative to peers, whereas the other two items offer brief description of happy and unhappy individuals and ask respondents the extent to which each characterization describes them.
- Quality of Life Scale: [18] It assesses an individual's quality of life through self-report of the importance they attach to each of six life domains, on a seven-point rating scale. The six domains are: material and physical well-being, relationships with other people, social, community and civic activities, personal development and fulfillment, recreation and independence or the ability to do for yourself. The QOLS has low to moderate correlations with physical health status and disease measures. The QOLS is a valid instrument for measuring quality of life across patient groups and cultures and is conceptually distinct from health status or other causal indicators of quality of life.
- Rey'sauditory verbal learning test (RAVLT) [19] from NIMHANS Neuropsychological Battery is a measure of verbal learning and memory. It is a measure of immediate memory, acquisition or new learning, retention, primacy, and recency effect, susceptibility to proactive and retroactive interference.
- Letter Cancellation Test (From NIMHANS Neuropsychological Battery): [19] This test assesses visual scanning, response speed and sustained attention. The subject is presented with letters of English alphabet, and is instructed to cancel out specific letters. In addition, the numbers of different errors (omissions and commissions) done by the subject are counted.
- Rey Osterith Complex Figure Test [20]from NIMHANS Neuropsychological Battery
  ROCFT is a "pen and paper" neuropsychological test used to evaluate neurological dysfunction in visual perception and long term memory. The test requires the subject to copy a complex figure and later produce from memory.



Statistical analysis

The results were analyzed using the statistical package of social sciences-version 16.0 for windows. Socio-demographic variables were analyzed using the x^2 and independent sample t-test. Performance of both the groups on study variables were compared using the independent sample t-test.

Table 1: Socio-demographic characteristics of the sample: Group I (N=38) and Group II (26)

		Group 1(38)	Group2(26)	X^2
Gender	Male	19	15	.36 NS
	Female	19	11	
Education	High School	2	3	3.59 NS
	Intermediate	5	1	
	Graduate	20	13	
	Postgraduate	6	7	
	Professional	5	2	
Marital Status	Unmarried	9	12	3.53 NS
	Married	29	14	
Occupation	Student	5	1	2.67 NS
	Service	16	15	
	Business	10	7	
	Housewife	7	3	
Average no of hours	1 to 5	22	7	9.16 NS
	6 to 10	9	9	
	11 to 15	5	7	
	16 to 20	1	1	
	21 to 25	1	0	
	26 to 30	0	2	
*=.05, **=.01, NS= Not Significant				

Table-1 shows the significance of difference between the beginners and practitioners on socio-demographic characteristics. The table reveals that beginners and practitioners did not differ significantly on any of the socio-demographic variables, i.e. gender, education, occupation, marital status and average number of hours of Raj Yoga practice.

Table 2. Comparison of Raj Yoga Practitioners on NEO-PIR, hope, happiness and QOL: Group I (N=38), Group II (N=26)

	Group 1 (38)	Group 2(26)	
	M±SD	M±SD	t
N1	14.71±5.01	9.42±4.51	4.31**
N2	13.05±5.14	8.73±3.81	3.65**
N3	14.00±6.09	9.69±4.26	3.11**
N4	13.44±4.39	9.50±4.12	3.61**
N5	13.65±4.26	10.07±3.03	3.68**
N6	11.84±5.42	6.57±3.61	4.33**
Total	80.71±24.00	54.00±17.48	4.85**
Hope	53.10±7.42	56.92±6.32	2.14*
Happiness	5.03±1.27	5.99±1.02	3.17**
QOL	85.76±13.77	84.80±15.18	0.26 NS
*=.05, **=.01, NS= Not Significant			

Table 2 presents the comparison of both groups' scores on the subscales of NEO-PI R i.e. anxiety, anger, hostility, self-consciousness, impulsivity and vulnerability. Findings suggest that the differences between both groups were found to be statistically significant at .01 level on all the subscale of NEO-PI R. The mean total scores for the group I and group II were 80.71±24.00 and 54.00±17.48 respectively. The difference between these was also found to be statistically significant at .01 level. These findings suggest that the group practicing raj yoga for longer duration had significantly less neurotic symptoms in comparison to the group practicing raj yoga for shorter duration. The differences between both the groups' scores were also found to be significantly different for hope and happiness scales. These findings suggest that the group practicing raj yoga for longer duration had significantly more amount of hope and happiness in comparison to the group practicing raj yoga for shorter duration. However, no significant differences were found between both groups' scores on Quality of Life Scale.

Table 3. Comparison of Raj Yoga Practitioners on Cognitive functions: Group I (N=38), Group II (N=26)

	Group 1 (38)	Group 2(26)	
	M±SD	M±SD	t
Verbal learning	7.39±2.18	7.00±2.13	.71 NS
Visual perception	8.44±4.67	8.92±4.21	.41 NS
Attention	6.02±7.38	6.23±5.90	.11 NS
	1.25±6.50	.04±.020	.92 NS
*=.05, **=.01, NS= Not Significant			

Table -3 shows that in visual and verbal memory, no significant difference was found between the groups and neither was there any difference in attention i.e., errors of omission or commission.

DISCUSSION

The findings of the present study suggest that the group practicing raj yoga for longer duration had significantly less neurotic symptoms in comparison to the group practicing raj yoga for shorter duration. These findings are consistent with the findings of other studies revealing that normal healthy volunteers practicing yoga show reduced neuroticism, anxiety and hostility. [21,22] There is an increase in expressiveness or catharsis, indicating decreased emotional complexes. [22,23] Others have reported that yoga exercises help to release muscle tension [24] and improve muscular efficiency as seen in enhanced strength, tone, flexibility and work output. [25-28] Due to improved functions of the entire muscular system, build up of chronic muscle tension is avoided, thus helping to promote a state of mental relaxation.

Comparative studies have shown meditation and yogic therapeutic techniques to be better and more efficacious than psychoanalysis or behaviour therapy. Yoga practices serve as effective therapy to cure hypertension, anxiety and psychoneurotic symptoms. [21,29]

The differences between both the groups' scores were also found to be significantly different for hope and happiness scales. These findings suggest that the group practicing raj yoga for longer duration had significantly more amount of hope and happiness in comparison to the group practicing raj yoga for shorter duration. These findings are consistent with the findings of other studies revealing that practicing yoga improves mood, [1] increases subjective well-being of the individuals, [2] increase self-acceptance and self-actualization, increases social adjustment. [3,4]

However, no significant differences were found between both groups' scores on quality of life scale. Some studies have specifically demonstrated potential benefits of yoga on quality of life in various clinical populations, including patients with depression, stress, and anxiety. However, the results of these studies need to be interpreted carefully since many of the published studies regarding yoga are small and lack meticulous design. It may also be difficult to compare studies that evaluate different patient populations. Only a few systematic and comprehensive reviews of scientific research on yoga for patients have been published. Also, none of the previously published reviews addresses the quantitative magnitude of the identified effects.

This result might also have been obtained because of the complexity of the concept of quality of life for normal individuals. The concept of quality of life has many more domains than only hope and happiness and is determined by many other moderator variables like age and other socio-demographic variables in normal population. Studies controlling the moderator effects of other socio-demographic and psychological variable will be needed in future to exactly find out the status of quality of life in different groups of normal yoga practitioners.

In visual and verbal memory, no significant difference was found between groups and neither was there any difference on errors of omission or commission. These findings are consistent with the findings of Oken, et al. (2006) [30] who found no effects from either of the active interventions on any of the cognitive and alertness outcome measures.

Whereas the difference between the two groups for the error of omission is negligible, the difference between the two groups for the error of commission is comparatively large showing that the people practicing raj yoga for 10 or more years have falsely hit only few targets in comparison to the people who have been practicing raj yoga for 0-2 years. This is also a very significant finding indicating that there has been a large although not statistically significant difference in one aspect of attention in favor of people practicing raj yoga for a longer time. This finding is also supported by findings of the previous studies indicating improvement in some aspect of attention with raj yoga. [31] The reason for the differences not becoming statistically significant may be the nature of task used in the study.

A suggestion for future studies on this topic may be using finer measures of cognitive functions as the subjects participating in these studies are normal individuals who can perform equally on these very basic cognitive tasks. Hopefully, finer measures of the cognitive functions will be able to differentiate between the experts and beginners of Raj Yoga.

ACKNOWLEDGEMENTS

Our grateful acknowledgements to all who helped in this project. We are grateful to Brahmkumari Raj Yoga Centre, Delhi for supporting in the conduct of this study in a big way. We thank the volunteers and supporters who participated in this study.

REFERENCES

1. Shapiro D Cline K. Mood changes associated with Iyengar Yoga

practices: A Pilot Study. International Journal of Yoga Therapy 2004; 14: 35-44.
2. Nathawat SS, Kumar P. Influence of meditational techniques and Jacobson's progressive muscular relaxation on measures of mental health. Indian Journal of Clinical Psychology 1999; 26: 192- 199.
3. Janakiramaiah N, Gangadhar BN, Murthy PJ. Antidepressant efficacy of SudarshanKriya Yoga (SKY) in melancholia: A randomized comparison with electroconvulsive therapy (ECT) and imipramine. Journal of Affective Disorder2000; 57:255-259.
4. Kumar, S.S., Kaur, P. and Kaur, M.S. Effectiveness of Shavasana on depression among university students. Indian Journal of Clinical Psychology 1993; 20: 82-87.
5. Shannahoff - Khalsa, DS, Ray LE, Levine S. Randomized controlled trial of yogic meditation techniques for patients with obsessive-compulsive disorder CNS Spectrums 1999; 4: 34-47.
6. Berger BG, Owen DR. Mood alteration with yoga and swimming: Aerobic exercise may not be necessary. Perceptual and Motor Skills 1992; 75: 1331-1343.
7. Balakrishna V, Sanghvi LD, Runs K, Doongaji DR, Vahia NS. The comparison of psycho physiological therapy with drug therapy. Indian journal of psychiatry1979;19:2,87-91.
8. Grover P, Verma VK, Pershad D. Verma SK. Role of yoga in the treatment of psychoneurosis. PGI Bulletin 1986; 22:68-77
9. Sahasi S, Mohan D, Kacker C. Effectiveness of yogic techniques in the Management of anxiety. Journal of Personality and Clinical Studies 1999; 5: 1,51-56.
10. Verma SK, Rao S. Recent trends in clinical psychological intervention (methods based on other than behaviour therapy). NIMHANS Journal 1996; 14:307-314.
11. Brown D P. A model for the levels of concentrative meditation. International Journal of Clinical and Experimental Hypnosis. 1977; 25: 236–73.
12. Telles S, Joseph C, Venkatesh S, Desiraju T. Alteration of auditory middle latency evoked potentials during yogic consciously regulated breathing and attentive state of mind. Int J Psychophysiol 1992; 14:189–98.
13. Telles S, Desiraju T. Autonomic changes in Brahmakumaris raja yoga meditation. Int J Psychophysiol 1993; 15:147–52.
14. Telles S, Nagarathna R, Nagendra HR. Autonomic changes during ‘OM’ meditation. Indian J PhysiolPharmacol 1995; 39:418–20.
15. Costa PT, McCrae RR. NEO PI-R professional manual. Odessa, FL: Psychological Assessment Resources, Inc; 1992.
16. Snyder CR, Harris C, Anderson J R, Holleran SA, Irving LM, Sigmon, ST, Yoshinobu L, Langelle C, Harney P. The will and the ways: Development and validation of an individual differences measure of hope. Journal of Personality and Social Psychology,1991; 60: 570-585.
17. Lyubomirsky S, Lepper H S. A measure of subjective happiness: Preliminary reliability and construct validation. Social Indicators Research 1999;46: 137-155.

18. Burckhardt CS, Anderson, KL.The Quality of Life Scale (QOLS): Reliability, Validity, and Utilization. *Health and Quality of Life Outcomes* 2003, 1:60
19. Mukundan CR. NIMHANS neuropsychological battery: test descriptions, instructions, clinical data and interpretation: NIMHANS publications, Oct 1996. Proceedings of the National Workshop in Clinical Neuropsychology
20. A. Rey and P. Osterrieth. Translations of excerpts from Rey's 'Psychological Examination of Traumatic Encephalopathy' and Osterrieth's 'The Complex Figure Test'. *The Clinical Neuropsychologist*, 7:2–21, 1993.
21. Kocher, H.C. (1972) Mirror tracing test as a measure of steadiness among values.*YogaMimansa,'* 19,4,1-15.
22. Kocher, H.C. &Pratap, V. (1971) Neurotic trend and yogic practices. *Yoga Mimansa,* 14, 1 & 2, 34-40.
23. Sahu, RJ. &Bhole, M.V. (1983) Effect of three week yogic training program on psychomotor performance. *Yoga Mimansa,* 22, 18, 2, 59-62.
24. Karambelkar PV, Bhole MV, Gharote ML, Muscle activity in some asanas:a pilot study *Yoga Mimans 1969; 12,1, 1-13.*
25. Gharote ML, Effect of yogic training on physical fitness. *Yoga Mimansa, 1973;* 15: 4,31-34.
26. Gharote ML, Ganguly SK, Moorthy AM. Effect of yogic training on minimum muscular fitness, *Yoga Mimansa*1976-77; 17: 3 &4,12-20.
27. MoorthyAM, Detraining effect of yogic and non yogic exercises on minimum, muscular fitness. *Yoga Mimansa* 1982-83; *21:3*& 4,49-54.
28. Salgar DC, Bisen VS, Jinturkar MS. Effect of Padamasana - A Yogic exercise on muscular efficiency. *Indian Journal of MedicalResearch 1975;* 63: 768-772.
29. Naug RN, Yogic therapy of neurotic *diseases.Indian Journal of Clinical Psychology 1975;* 2:1,87-91.
30. Oken BS, Zajdel D, Kishiyama MA, Flegal K, Dehen C, Haas M, Kraemer DF, Lawrence J, Leyva J. Randomized, controlled, six-month trial of yoga in healthy seniors: effects on cognition and quality of life. 2006;12(1):40-47.
31. Manjunath, NK, Telles S. Saptial and verbal memory test scores following yoga and fine arts camps for school children. Indian Journal of Physiological Pharmocology 2004; 48:353-356.

How to cite this article: Misra N, Gupta A, Alreja S et. al. Effect of Raj Yoga Meditation on Affective & Cognitive Functions. Int J Health Sci Res. 2013;3(2):38-46.

****

Attention profiling in Long term Rajayoga Meditators

BK Shrikant, National Co-ordinator
Spiritual Applications Research Center (SpARC) of,
Rajayoga Education and Research Foundation (RERF),
Mount Abu, Rajasthan, India

This paper was presented in a poster session during 28th ANT Neuromeeting on "Scientific & Social Program" 16-19 January 2019, Beaune, Burgundy, France.

Poster Sessions

Thursday 17 January, 18:30 - Friday 18 January, 18:45

An overview of all posters presented can be found at: neuromeeting@ant-neuro.com/poster-sessions

P5: Source Localization During Meditation: Traces of Long-Term Practice of Meditation

Representative: BK Shrikant
Author(s): BK Shrikant, Sushil Chandra
Organization: Institute of Nuclear medicine and Allied Science, Biomedical Engineering
E-mail address: bksparc@gmail.com

Prominent functional and anatomical changes due to exposure of meditation practice have been observed in the past few decades. In addition, methods adopted in various type of meditation incur changes in cognitive processing. Such changes can be assessed through physiological devices, for instance, EEG, which is a promising technique for temporal assessment in real time. It displays transient changes in different frequency bands due to meditation practice. Raj yoga meditation is taught by Brahmakumaris and has been followed by more than one million followers across the globe. Rajayoga Meditation is a practice of self-regulation of mind, intellect, and subconsciousness by engaging in a specific attentional set. Attention is a state of mind that links alertness, orientation, and executive control. Meditation primarily enhances the efficiency of brain regions, which govern attention. This study examines the effect on the attentional network of long-term raj yoga meditators using a single attention network task and dynamics of 64 channel high density EEG. Here we investigated the brain activations during meditation for long-term meditators and resting state for non-meditators using sLORETA. EEG was recorded for ten volunteers (five meditators and five control subjects). Control subjects had no prior experience of any kind of meditation practice. Higher activations were observed on the parietal region for long-term meditators. Parietal activation is related to alerting and orientation. Anterior cingulate and Angular gyrus were among other activated regions. Brain activation pattern indicates higher self-awareness and alertness in long-term Rajayoga meditators. The behavioural study shows higher accuracy in the attention network task in long-term meditators when compared to control subjects. Overall findings suggested a positive impact of meditation on frontal and parietal areas of the brain, involved in processes of regulation of selective attention and sustaining it. Limitation of this study was the small sample size.

For the poster details please see the next page.

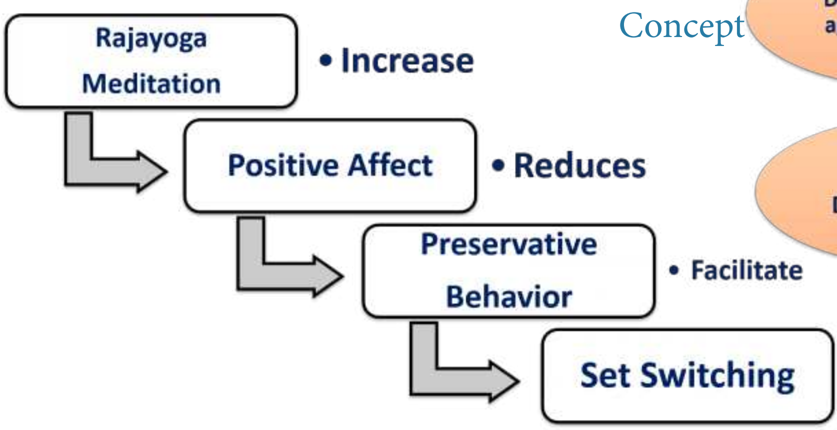
Abstract

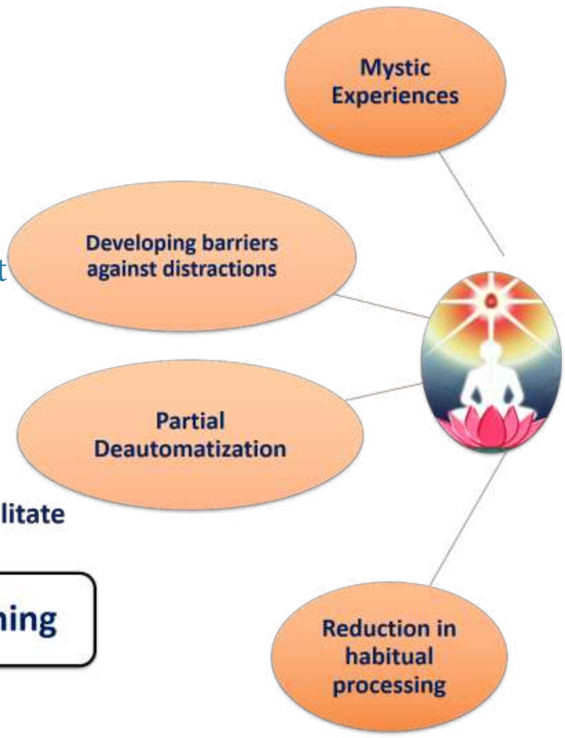
Attention is a state of mind that links alertness, orientation and executive control. Meditation primarily enhances efficiency of brain regions, which govern attention. This study examines the effect on the attentional network of long-term raj yoga meditators using a single attention network task and dynamics of 64 channel EEG. Rajayoga Meditation taught by Brahmakumari's is a practice of self-regulation of mind, intellect and sub consciousness by engaging in a specific attentional set. Here we investigated the brain activations during meditation for long-term meditators and resting state for non-meditators using sLORETA. Higher activations were observed on the parietal region for long-term meditators. Parietal activation is related to alerting and orientation. Anterior cingulate and Angular gyrus were among other activated regions. Brain activation pattern indicate higher self-awareness and alertness in long-term Rajayoga meditators. The behavioral study shows higher accuracy in the attention network task in long-term meditators when compared to control subjects.

Introduction

Rajayoga is a regulated exercise in which recollection, contemplation, concentration and attention are used in a methodical way to achieve blissful state. While doing practice of Rajayoga one has to detach from mundane the gross and material. Mind, intellect and emotions are being used for a special theme in a special way. It may be practiced at progressive levels of knowledge, faith, energy and consciousness. Technique of self exploration, leading to the experience of heightened and expanded awareness reaching to supreme and bridging itself to soul's awareness. It is based on thought generation and propagation of mind to blissful state using the same thought. During this practice meditators gets mind transformed into a reservoir accepting positive thoughts and neglecting negative thoughts. Present research is a quasi experimental study with Long Term Rajayoga meditators. It aims to find brain dynamics of this specific type of Meditation. Performance in Attention network Test (CRSD-ANT) quantified. A model has also been provided to understand effects of this positive emotions based meditation.

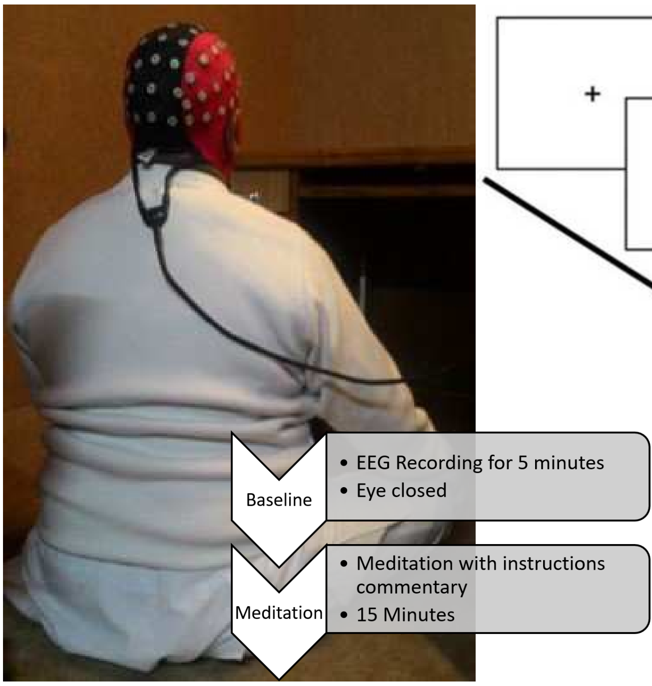
Concept



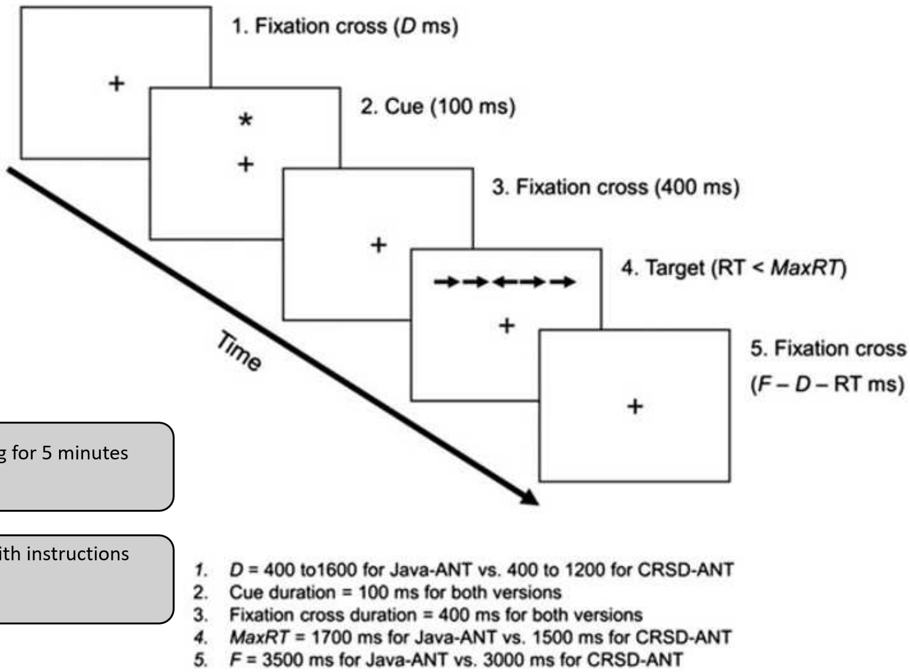


(Sharma K et al., 2015)

Experimental Methods



64 Channel EEG Recording During Meditation



CRSD-ANT Paradigm (Weaver et al., 2013)

Set up and Procedure

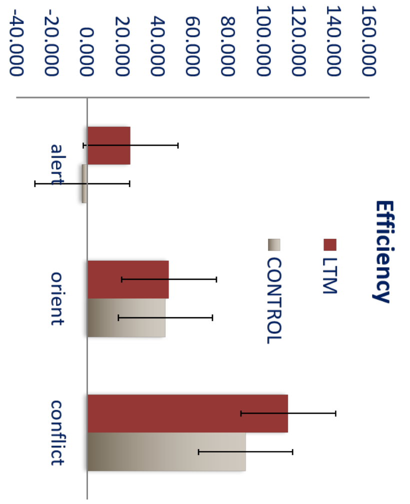
Total 10 subjects were selected in LTM group with specific inclusion criteria. A total 10 Controls were selected within same criteria except meditation experience. Age was 30-50 Yrs. (for Meditators group mean age = 44.6 yrs., control mean age = 42.1 yrs.) 64 channel portable EEG (ANT corp.) was used for data acquisition. Impedance was kept below 10 K Ohms. Cz was used as ground. Data of Meditators was recorded in controlled environment room at Gyansarovar Complex, Mt. Abu, India. Data for controls was recorded at Bio Medical Engg. Lab, INMAS, Delhi, India, keeping the same conditions as Mt. Abu.

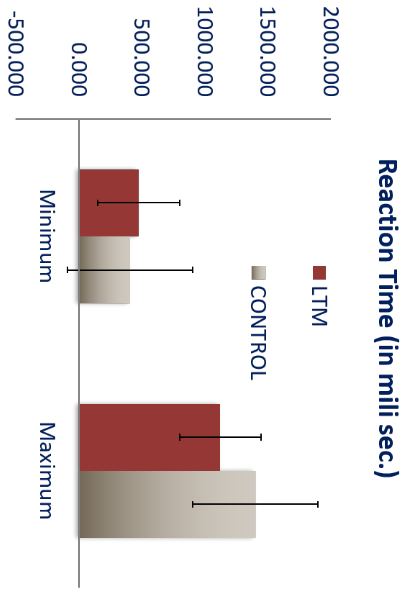
Post recording, the Signals were preprocessed to remove artifacts. Notch filter was used to 50 Hz power line noise removal. Butterworth band pass filter with a cut off frequency of 0.2 to 80 Hz was used to get diff. frequency bands. The blind source separation approach using ICA was implemented to remove EEG artifacts (Delsanto et al., 2003). EEGLAB, an interactive Open Source Matlab toolbox was used to run ICA (http://sccn.ucsd.edu). The data from 64 channels were preprocessed followed by artifact removal using ICA. For Brain activation, sLORETA was used to compare the cortical distribution of electric activity (Pascual-Marqui, 2002), generated due to the oscillatory activity in the bands between the meditation, baseline, and the rest condition for control subjects.

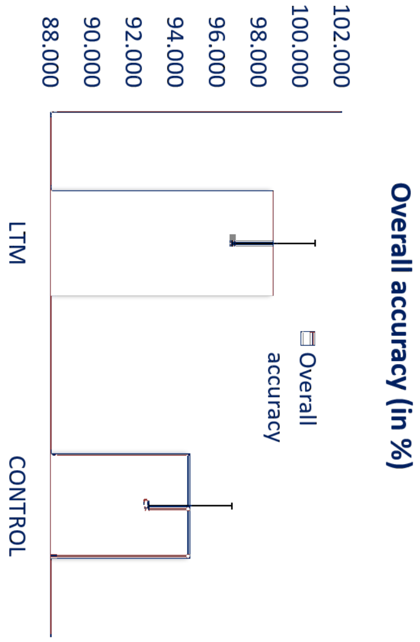
Figures and Tables

* P< 0.05

* P< 0.05







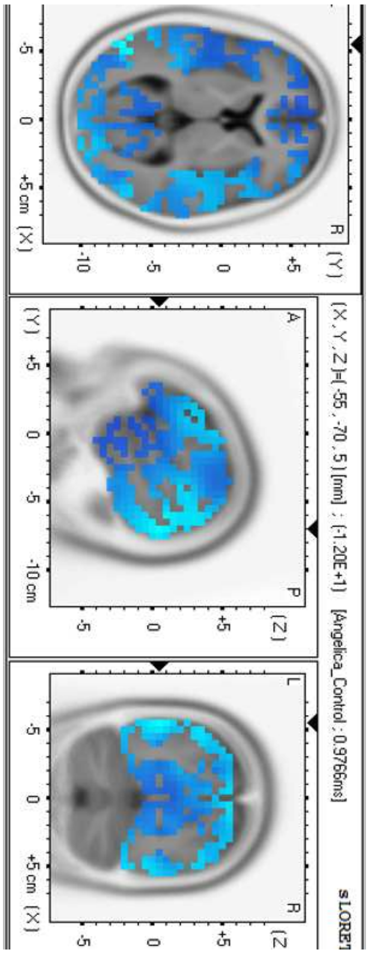


Fig:- Comparison of Brain activity b/w LTM group during Meditation and Control during rest.

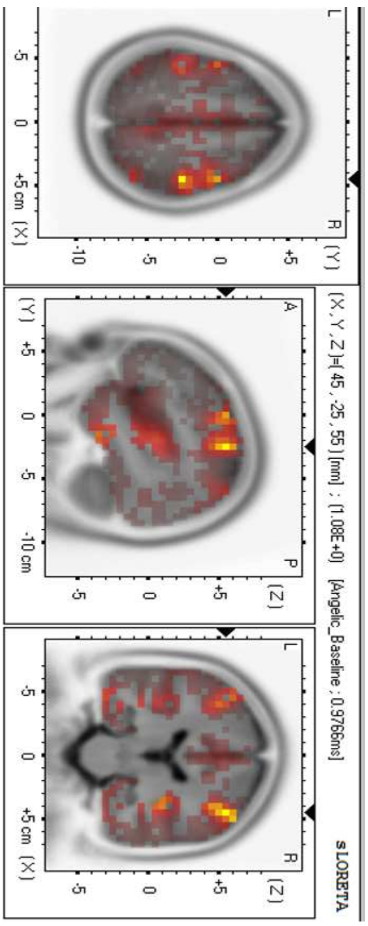


Fig:- Comparison of Brain activity b/w Meditation and Baseline of LTM group.

Table 1:- Meditation and Baseline (within group LTM)

Brain Area	Band	p
Parietal lobe, Postcentral gyrus (BA 2)	Theta	<0.05
Sub lobar, Insula (BA 13)	Theta	<0.05
Parietal lobe, Inferior Parietal lobule (BA 40)	Theta	<0.05
Parietal lobe, Superior Parietal lobule (BA 7)	Theta	<0.05
Frontal lobe, Middle frontal gyrus, (BA 6)	Theta	<0.01
Temporal Lobe, Transverse Temporal gyrus, (BA 41)	Theta	<0.01
Frontal lobe, precentral gyrus, (BA 6)	Theta	<0.05
Temporal lobe, Inferior Temporal gyrus, (BA 20)	Theta	<0.05
Parietal lobe, Postcentral gyrus, (BA 2)	Theta	<0.01
Parietal lobe, Postcentral gyrus (BA 2)	Alpha	<0.05
Frontal lobe, Middle frontal gyrus, (BA 6)	Alpha	<0.05

Table 2:- Meditation and Control (Between LTM and control groups)

Brain Area	Band	p
Occipital lobe, Middle Occipital gyrus (BA 19)	Theta	<0.05
Temporal lobe, Middle temporal gyrus, (BA 37	Theta	<0.05
Parietal lobe, Precuneus, (BA 7)	Theta	<0.05
Temporal lobe, Middle temporal gyrus, (BA 39)	Theta	<0.05
Sub-lobar, Insula, (BA 13)	Alpha	<0.01
Parietal lobe, Precuneus (BA 7)	Alpha	<0.01
Temp. lobe, Transverse Temporal gyrus, (BA 41)	Alpha	<0.01
Parietal lobe, Precuneus, (BA 7)	Theta	<0.01
Parietal lobe, Inferior parietal lobule (BA 40)	Theta	<0.01
Parietal lobe, Inferior parietal lobule (BA 7)	Theta	<0.01
Temporal lobe, Middle temporal gyrus, (BA 39)	Theta	<0.01
Sub-lobar, Insula, (BA 13)	Alpha	<0.05
Parietal lobe, Precuneus,(BA 7)	Alpha	<0.05

Results

Performance in Attention Network Test

1. Efficiency for alertness, conflict monitoring was higher in Long term Meditators (LTM) compared to controls.
2. Minute change has seen in orientation efficiency.
3. Maximum RT was significantly lower (better) in LTM as compared to controls. Minimum RT found no difference.
4. Overall accuracy was also significantly higher in LTM as compared to controls.

LORETA Brain activation

1. Only Alpha and Theta bands were significantly differed at voxel activation threshold required for significance was t = 2.27 for $p > 0.05$.
2. Current density increased in Alpha and Delta freq. bands during meditation.
3. Significant activations were found in right hemisphere.
4. Regions activated above threshold are shown in Table 1 and 2 .

Acknowledgement

- Volunteers participated in this study.
- Mr. Shashi Prakash Khaitan for travel support

Conclusion

- Meditators have outperformed control subjects in ANT. Even with less usage of computer in daily routine, they were able to learn quick and perform well.
- Right hemispherical activity in alpha and theta band was prominent possibly due to alterations in processes regulating consciousness (Pagano & Frumkin, 1977)
- DMN activity was higher in Controls during rest condition (BA 40, 29, 30, 31, 23, 21, 24) which increased brain activity in theta and alpha band.
- Anterior cingulate cortex was activated in LTM, possibly with attained efficiency of conflict resolution in LTM (Fan et al., 2005).
- Activation of Insula ascertains enhanced error perception in meditators (Ullsperger et al., 2010).

Reference/Additional Readings

- Bruce Weaver, Michel Bédard & Jim McAuliffe (2013) Evaluation of a 10-minute Version of the Attention Network Test, The Clinical Neuropsychologist, 27:8, 1281-1299
- Delsanto, S., F. Lamberti,. Automatic ocular artifact rejection based on independent component analysis and eye blink detection. in First International IEEE EMBS Conference. 2003.
- Sccn.ucsd.edu,.'EEGLAB – Open Source Matlab Toolbox for Electro-physiological Research'. N.p., 2015.Web. 15 Aug.2015
- Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. Neuroimage, 26(2), 471-479.
- Fuchs, M., Kastner, J., Wagner, M., Hawes, S., & Ebersole, J. S. (2002). A standardized boundary element method volume conductor model. Clinical Neurophysiology, 113(5), 702-712.
- Pagano, R. R., & Frumkin, L. R. (1977). The effect of transcendental meditation on right hemispheric functioning. Biofeedback and self-regulation, 2(4), 407-415.
- Sharma K., Trivedi R., Dubey A.K., Chandra S. (2015) Gone with the mind: Thought based meditation and its implications to attention strategies. Poster presented at International Conference: Consciousness, Cognition and Culture: Implications for the 21st century; Proceedings of Conference by Nature India; 2015 Dec 9-11; Bengaluru
- Ullsperger, M., Harsay, H. A., Wessel, J. R., & Ridderinkhof, K. R. (2010). Conscious perception of errors and its relation to the anterior insula. Brain Structure and Function, 214(5-6), 629-643.

Quick and Easy Meditation: Rapid state changes in Rajayoga practitioners

Ajay Kumar Naira, Arun Sasidharana, John P Johnb,c,d, Seema Mehrotrae, Bindu M Kuttya

[a]Department of Neurophysiology, [b]Department of Psychiatry, [c]Multimodal Brain Image Analysis Laboratory (MBIAL), [d]Department of Clinical Neuroscience, [e]Department of Clinical Psychology, National Institute of Mental Health and Neuro Sciences (NIMHANS), Bengaluru, India

Introduction

Meditation is known to provide parasympathetic activation and relaxation effects. Easy Rajayoga meditation1 (Brahma Kumaris) has attracted practitioners in over a 100 countries.

We examined if new and experienced Rajayoga meditators could rapidly bring about meditation related state changes and if they could achieve state changes after engaging with cognitively demanding tasks.

Methods

Rajayoga Meditation Practitioners (age range 29- 64) were recruited from meditation centers in Bangalore. Long term practitioners (LTP) had >10 years of daily meditation practice. Short term Practitioners (STP) had between 6 months to 2 years of meditation experience.

Long Term Practitioners (LTP)

n=37, 15 Females,
14,600 hours of meditation experience

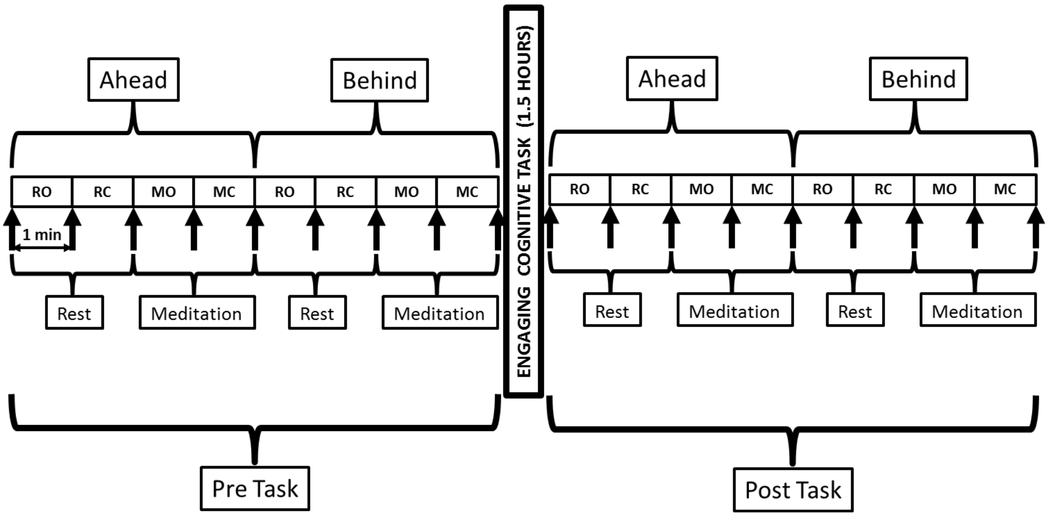
Short Term Practitioners (STP)

n=21, 8 Females,
1,095 hours of meditation experience

Eprime 2.0 stimulus presentation software (Psychology Software Tools, Inc., Sharpsburg, USA)

128 Channel Geodesic EEG System 300 (Electrical Geodesics, Inc., USA)

Rest and Meditation Protocol



RO = Eyes Open Rest, RC = Eyes Closed Rest, MO = Eyes Open Meditation, MC = Eyes Closed Meditation
Rest and Meditation Protocol (8 minutes) administered before and after cognitive task.

Data Analysis: Matlab 2012b (Mathworks, USA), EEGLAB toolbox v13.3.2 for data processing, Open Source software R ver 3.1.1 and Rstudio 0.98. 953, 'WRS' package for robust statistics2, ggplot2 for statistical visualizations.

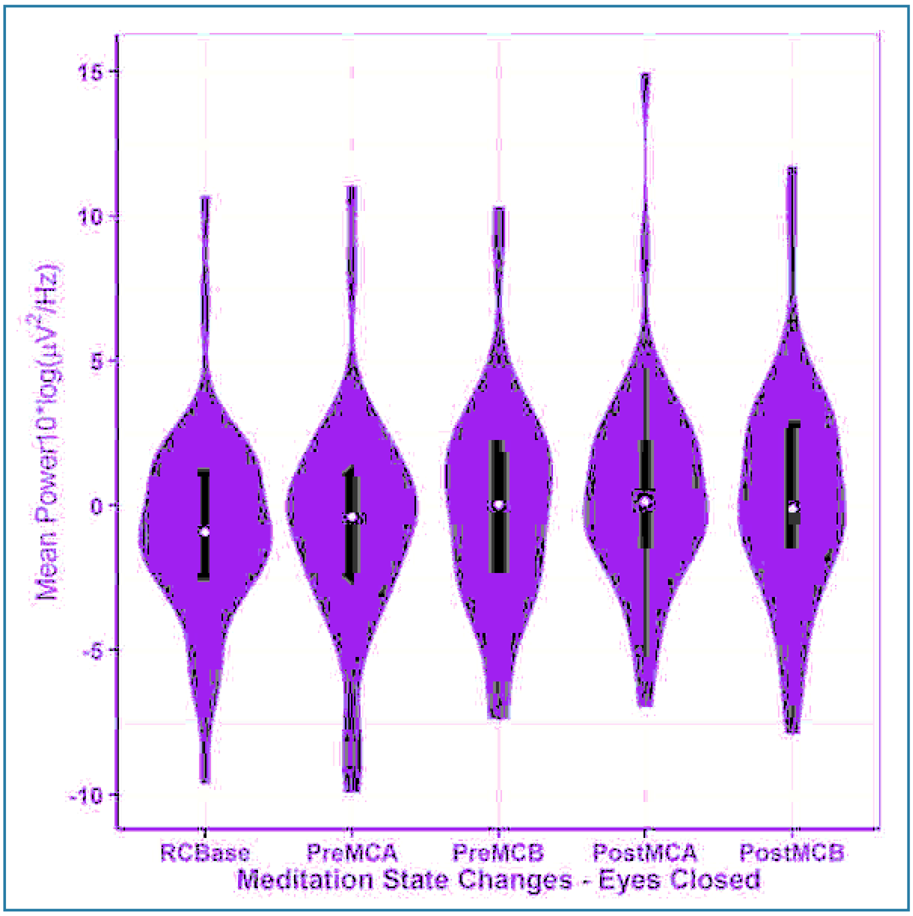
RESULTS & DISCUSSION - A

Rajayoga practitioners demographics : A random sample of long term participants is also taken for comparative analysis.

The Meditation practitioners were of a similar background with respect to age range language, education and income. The LTP group had at least ten fold meditation experience than STP group.

The meditators rapidly shifted states3 (evidenced by changes in theta, thetaalpha and alpha power) but had wide variability amongst them.

This variability is seen in the violin plot for eyes closed meditation states compared to the resting base state with eyes closed.



Meditation state changes – Long Term Practitioners – Theta power

Meditation Category		Gender		Language			Education			Income(INR)			AGE (Years)						Meditation Experience ('000)					
	No.	F	M	En	Hi	Ka	Sch.	Grad.	>=PG	<3K	3-60k	>60k	Min.	1stQ.	Med.	Mean	3rdQ.	Max.	Min.	1stQ.	Med.	Mean	3rdQ.	Max.
All LTP	37	15	22	26	3	8	11	14	12	1	24	11	31.0	34.0	44.0	44.6	53.0	60.0	7.3	12.0	14.6	17.3	23.4	35.0
Random LTP	21	6	15	14	2	5	7	10	4	1	13	7	31.0	34.0	42.0	43.6	53.0	58.0	8.0	11.0	14.6	17.3	23.4	33.9
All STP	21	8	13	10	3	8	9	9	3	1	14	6	29.0	36.0	45.0	44.2	53.0	61.0	0.3	0.7	1.1	1.1	1.1	2.2

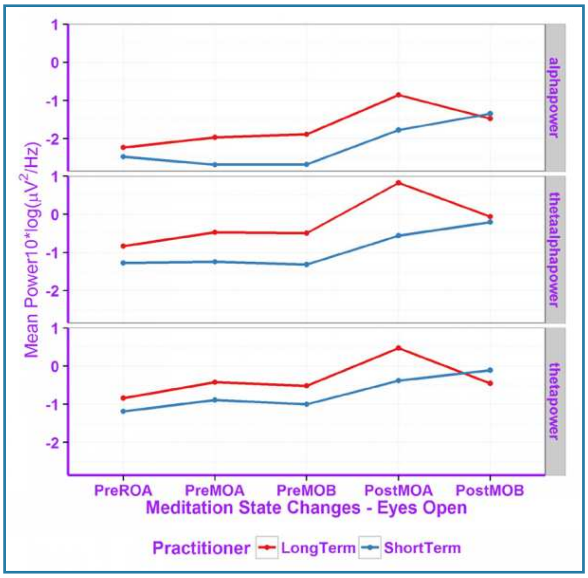
RESULTS & DISCUSSION - B

Meditation States vs Baseline Rest States	Pre-Task Condition												Post-Task Condition											
	Ahead in Sequence						Behind in Sequence						Ahead in Sequence						Behind in Sequence					
Practitioner Category	Eyes Open			Eyes Closed			Eyes Open			Eyes Closed			Eyes Open			Eyes Closed			Eyes Open			Eyes Closed		
	θ	θ α	α	θ	θ α	α	θ	θ α	α	θ	θ α	α	θ	θ α	α	θ	θ α	α	θ	θ α	α	θ	θ α	α
Long Term (All)	✓	-	-	-	-	-	-	-	-	✓	-	-	✓	✓	✓	✓	✓	✓	-	-	✓	✓	✓	✓
Long Term (Random)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-
Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	✓	-	-	-

Both LTP and STP showed significant changes across meditation states. The table shows the state shifts (robust version of repeated measures ANOVA followed by Hochberg's corrections for multiple comparisons, p-values <0.05).

LTP (full group) showed a more robust change than the STP category. The state changes in the random sample were significant in the robust repeated measures ANOVA but the differences did not survive multiple comparison corrections with trimmed means. The differences were more apparent after cognitive task performance as can be seen in the figure below.

Meditation included changes as a function of proficiency



Both STP and LTP (random sample shown in figure) demonstrate changes across theta (4-8Hz), theta-alpha (6-10Hz) and alpha (8-12Hz) power bands – induced by eyes open meditation states as compared to eyes open resting base state

Conclusion

We found that both long term and short term Rajayoga practitioners exhibited EEG state changes during their meditation as compared to rest states but these were qualitatively and quantitatively different.

These results suggest that brain functions are amenable to quick changes even with short term meditation practice and that long term practice yields significant benefits in bringing about state related changes as well as trait effects for handling challenging tasks.

ACKNOWLEDGEMENTS and REFERENCES

We acknowledge funding from Indian Council for Medical Research (Grant No:55/2/2012BMS to B.M.K., SRF to A.K.N.) and Department of Science and Technology Cognitive Science Initiative (Grant No: SR/CSI/63/2011 to B.M.K.), and the facility provided by NIMHANS.

References

1. Brahma Kumaris, Just-a-minute, (2006). http://www.just-a-minute.org/ (accessed October 07, 2014). 2. F.D. Wilcox, R.R., & Schönbrodt, The WRS package for robust statistics in R, (2014) 3. Y.-Y. Tang, M.K. Rothbart, M.I. Posner, Neural correlates of establishing, maintaining, and switching brain states, Trends Cogn. Sci. 16 (2012) 330–337. doi:10.1016/j.tics.2012.05.001.Neural.

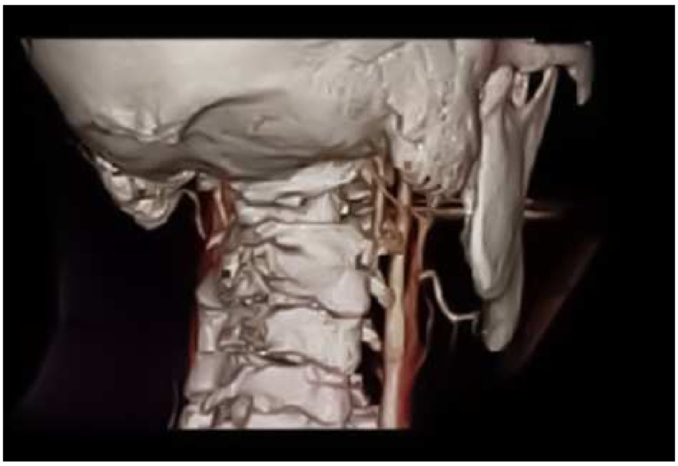
Journal of Neuroimaging Vol 24 No. 3 May 2014.

Effects of Rajyoga Meditation: A Resting State Simultaneous EEg-fMRI Study

Rajanikant Panda, Rose Dawn Bharath, Mangalore Sandhya, Neeraj Upadhyay, Silpa Kanunga, Arunmugam Thamodharan, Shobini L Rao, Arun Kumar Gupta. Dept. of Neuroimaging & Interventional Radiology, National Institute of Mental Health and Neuro Science Bangalore, India, Clinical Psychology, National Institute of Mental Health and Neuro Science Bangalore, India.

Background and Purpose:
Understanding the role of brain in bringing about awareness and consciousness has always been a challenging area of neuroscience and an impressive debate on effect of meditaion in various aspects. Our study aims at understanding the effect of Rajyoga-Meditaion may be Visualized using EEG-fMRI as changes in neuro-hemodynamic correlates.

Methods:
We studied twenty male long term (more than 10 years) Rajyoga Meditators (RMs) and twenty healthy control (HCs) with the mean age of 30 (SD 10) year using EEG-fMRI. We use functional magnetic resonance imaging (fMRI) for examining the default mode network (DMN) and Electroencephalography (EEG) derived quasi-stable states known as EEG-microstates were convolved with resting fMRI to understand the changes in meditators compared with healthy controls.



Results:
We noted that the long term meditators have lower intensity with lesser number of voxel in medial prefrontal cortex (MPFC), posterior cingulate cortex (PCC) as compared to healthy people at rest and this activity was further reduced during meditation where as incresed in medial temporal cortex (MTC). The average duration of EEG-microstate corresponding to DMN, in healthy control was 80ms (30ms to 240ms) and mediators was 90ms (50ms to 310ms). This significantly increased to 120ms (70ms to 370ms) during meditation.

Conclusions: EEG-fMRI is a valuable in understanding the effects of meditation. Decrease DMN and Increase in the duration of EEG-microstates could suggest increased brain stability, less ruminative thought in meditators. Increased MTC in DMN network is indicative of a better cognitive process.

Brain Functional Connectivity of Learning Memory: An fMRI Study

Rajanikant Panda, Rajakumari P Reddy, Neeraj Upadhya, Thamodharan Arunmugam, Silpa Kanungo, Shobini L Rao, Jamuna Rajeswaran, Arun Kumar Gupta, Rose Dawn Bharath

Dept. of Neuroimaging & Interventional Radiology, National Institute of Mental Health and Neuro Science (NIMHANS) Bangalore, India, Dept. Clinical Psychology, National Institute of Mental Health and Neuro Science (NIMHANS) Bangalore, India.

Background & Purpose:
Learning memory is a crucial cognitive function. We aimed to examine brain connectivity for visual learning memory encoding and retrieval using functional magnetic resonance imaging (fMRI).

Methods:
Thirty right handed healthy normal volunteers in the mean age of 23.67 + 4.53 years and no of years of education was 16.58 + 2.8 years were recruited. A block design paradigm consisting of four active blocks and four rest block was presented. First active block had ten pictures representing visual learning in which the

subject was instructed to remember each of the pictures (encoding) in order to identify the similar picture in the next active block (retrieval). In response to a repeating picture in the retrieval block the subject was instructed to give the response. fMRI with EPI Sequence (TR: 3000, 160 dynamics) and MPRAGE were acquired. Region of interest based (ROI) connectivity of fMRI was processed using SPM8 CONN toll box with $p<0.05$ false Discovery Rate (FDR) correction.

Results:

We noted that there was greater connectivity during retrieval than encoding. posterior cingulate cortex (PCC) ROI was connected with many regions especially dorso-lateral prefrontal region (DLPFR) and supramarginal gyrus as evidenced by their positive correlation and negative correlation of PCC region and MPFC which associate with Default mode network (DMN). Inhibition of DMN was more in encoding compare to retrieval in other hand the DLPFR and supramarginal gyrus activations were found to be Increased in retrieval.

Conclusions:

Our results suggest that the associative brain areas for retrieval are greater than encoding. Higher level of cognitive process such as retieval will reduce negative inhibition of DMN.

Clinical eHealth 5 (2022) 58–66

Contents lists available at ScienceDirect

Clinical eHealth

journal homepage: www.keaipublishing.com/CEH

Stress and the impact of stressful events are lesser among raja yoga meditators – A cross sectional study during COVID-19 pandemic from India

Shobhika Madhu [a], Ramajayam Govindaraj [b], Prashant Kumar [a,c,*], Sushil Chandra [d]

[a] Academy of Scientific & Innovative Research-CSIO, Ghaziabad 201002, India
[b] Centre for Consciousness Studies, Dept of Neurophysiology, National Institute of Mental Health & Neurosciences, Bengaluru 560029, India
[c] CSIR-Central Scientific Instruments Organisation, Chandigarh 160030, India
[d] Institute of Nuclear Medicine & Allied Sciences-DRDO, Delhi 110054, India

ARTICLE INFO

Article history:
Received 30 March 2022
Revised 3 July 2022
Available online 9 July 2022

Keywords:
Raja yoga
Meditation
Stress
COVID-19
Mental health

ABSTRACT

This research work presents a study on the relationship between stress & related events with meditation practice and other socio-demographic variables during COVID 19 pandemic among healthy adults. In this cross-sectional survey design, healthy adults with and without practice of Raja yoga meditation completed stress, anxiety & depression related questions (Depression Anxiety & stress Scale, DASS 21) and its impact (Impact of Event Scale-Revised, IES-R) along with other socio-demographic including COVID infection or contact related information. Data was assessed for difference in DASS 21 scores and IES-R scores between Raja yoga meditators (n = 802) & non-meditators (n = 357). An analysis was performed to study the predictors of DASS 21 and IES-R scores. We conclude that healthy Raja yoga meditation practitioners differ from non-meditators in terms of stress/anxiety/depression and its impact during COVID 19 pandemic and meditation practice predicts mental health better along with other sociodemographic variables.

Introduction

Stress is a dynamic concept that involves interaction with multiple factors. Globally, the COVID-19 pandemic has subjected the entire humanity to an unprecedented stress. Sudden enforcement of lockdown, widespread infodemic in media, lack of adequate medical facilities, loss of near and dear ones, etc. had contributed to stresses not only in India [1] but all over the world [2,3]. Earlier studies also had reported increased post-traumatic stress disorder (PTSD) after natural calamities (like earth quake) and epidemic/-pandemic, including [4,5]. Recent large-scale surveys had shown greater amount of stress, anxiety & depression among general public, especially among younger population [6].

COVID-19 and mental health

Individuals having mood disorders are more susceptible to COVID-19 events and fatalities [7]. These findings point to the need to prioritize the COVID-19 vaccination by classifying people with mental disorders as an at-risk population for COVID-19 hospitalization and mortality. As part of the post-COVID-19 syndrome, depressive symptoms and clinically severe depression were often reported by people [8]. Priority study areas should include the overlap of depressive symptoms in people with post-COVID-19 syndrome and their distinction from manifestations of long COVID syndrome. A systematic review provided the overview of PTSD, depression and other psychological distress symptoms in general population during COVID-19 [9]. In the majority of investigations, unfavorable psychiatric symptoms were shown to be highly prevalent among many countries. The study stressed upon the prevention of mental illnesses to be the top priority. A cross-sectional study with proposed chain mediation model compared the psychological states of general population in Asia, Europe, and North America and established correlation between COVID-19 symptoms and adverse mental health outcomes [10,11]. The findings revealed that Vietnam had the lowest mean scores in these categories, while Poland and the Philippines had the greatest levels of stress, despair, and anxiety. The desire for health information and the pandemic's perceived impact were mediators between the COVID-19 symptoms and the ensuing mental health condition. A similar study sought to examine the disparities across seven Asian MICs and

* Corresponding author at: Technology Block, CSIO, Chandigarh 160030, India.
E-mail address: prashantkumar@csio.res.in (P. Kumar).

https://doi.org/10.1016/j.ceh.2022.07.001
2588-9141/

the impact of the pandemic on physical and mental health [12]. The highest psychological distress was reported by Thai respondents, while lowest levels were reported by Vietnamese respondents. The psychological effects of partial lockdown on the general population in Vietnam were lower as compared to the similar studies in China, Iran and Italy [13]. Marital status, employment status, level of education, size of the family, and contact history with COVID patients were the stressors among this population. But the pandemic impacted quality of life and economic wellbeing of Vietnamese population [14]. The family income of near about 66.9 percent of these people was reduced during COVID-19. Presence of physical illness, female gender, and number of family members were the factors affecting quality of life among these people. A cross-country study compared the psychological health of Chinese respondents (encouraging face masks during initial COVID-19 stage) with that of Polish residents (that did not encourage the use of face masks) [10,11]. The results showed that the Polish respondents had higher levels of stress, anxiety and depression, possibly because of larger number of COVID cases in Poland as compared to China.

The implementation of strict policies by some governments to restrict the spread of COVID-19 benefitted the mental health of their population [15]. The findings highlight the need to devise interventions for mental health care of vulnerable population.

Role of yoga and meditation

To cope with the mounting stress imposed by pandemic, people have tried different coping strategies which included exercise, connecting with family & friends, reduced screen time, reading, playing indoor games, healthy diet, smoking, alcohol and drugs [16]. Apart from regular coping strategies, many have tried mind–body practices like yoga and meditation to overcome the stress and improve immunity. The Ministry of AYUSH, Government of India released guidelines for yoga practice and other complementary therapies like Ayurveda as a preventive and add-on therapeutic measures for general public during COVID-19 pandemic [17]. A recent pan India survey involving around 10,000 subjects reported that people who practiced yoga were engaged more with healthy and enduring lifestyle than non-yoga practitioners during COVID-19 pandemic [16]. Earlier studies had also shown increased resilience following yoga/meditation practices [18]. Another recent study also had shown engineering students who practiced yoga during COVID-19 differed in behaviors (healthy) compared to students who did not practice yoga (Beddoes and Danowitz, 2021). These findings suggest that people who are engaged with complementary mind–body practices like yoga, meditation, etc. find comfort and solace during times of distress and uncertainty like the COVID-19 pandemic. Previous studies had shown reduction in perceived stress, anxiety and depression with yoga/meditation practices both in healthy and clinical population [19].

Raja yoga meditation and its role in coping with distress

Raja yoga meditation is a behavioral intervention that aims to empower the mind and thought system of the practitioners [20]. The purpose of this meditation is to encourage the positive flow of thoughts and experience peace through the knowledge of self and the Supreme. Various research studies have proved the physiological, psychological and neural effects of this meditation on regular practitioners. Even short-term Raja yoga meditation intervention may result in decreased stress and anxiety symptoms. A group of patients suffering from anxiety and depression indicated considerable improvement following six weeks of intervention [21]. Another study was conducted observe the effect of Raja yoga meditation on stress, anxiety and depression in women with premenstrual syndrome [22]. Raja yoga was found to be useful in alleviating depression in PMS-affected women. In patients having major heart surgery, the practice of Raja yoga meditation helped to reduce anxiety and cortisol levels [23]. Raja yoga meditation also affected the psychosomatic components of hypertension patients [24]. This meditation intervention helped in lowering hypertension, and also improved general health by reducing psychosomatic symptoms of disease and medication dosages. The EEG recordings of experienced Raj yoga meditators showed that this meditation resulted in a decrease in delta activity and an increase in low alpha activity [25]. The brain areas that demonstrated altered activations relate to attention and cognitive abilities.

The Brahma Kumaris World Spiritual University teaches Raj Yoga meditation, which differs from other meditation approaches in its ideas and practice. It is a globally recognized non-governmental organization (NGO) associated with the United Nations Department of Public Relations [26]. It is the largest spiritual organization led by women. It uses Raja yoga meditation to enable individuals of all religions and cultural backgrounds recognize and feel their inner self and bring positive transformation to their life. The teachings here are accessible to all for free of cost.

With this background, we hypothesized that 1) people practicing regular meditation will have reduced stress/anxiety/depression and also reduced impact of stress & related events during COVID-19 pandemic compared to non-meditators. 2) Status of meditation practice (meditation practitioner or non-meditation practitioner) and COVID infection history will predict the levels of stress/anxiety/depression and the impact of stress and related events during COVID-19 pandemic.

Methodology

Setting & subjects

The study was conducted as an online cross-sectional survey using google forms between Jan 2021 to April 2021. It was a collaborative study between CSIO-CSIR, Chandigarh, India and SpARC wing of Brahma Kumaris, Mount Abu, India. The study was approved by the institutional ethical committee of CSIO-CSIR, Chandigarh (Ref: IEC/CSIO/2020 Project No. 27 dated 22nd Sep 2020). All the subjects had given their informed consent electronically and only consenting subjects were recruited based on their voluntary participation.

The Brahma Kumaris is a global network of organisations with 8,500 established centers in over 130 countries and 900,000 regular students that provides free of cost life time meditation training and programs. The availability of large number of meditation practitioners, low-cost sampling strategy and accessibility during COVID-19 lockdown were the reasons for choosing this particular group for sampling.

The study subjects included both meditators and non-meditators. Subjects with meditation experience were recruited through the SpARC wing of Brahma Kumaris through its nationwide contacts. Inclusion criteria for meditators were a) practicing Brahma Kumaris Raja yoga meditation regularly (at least 3 days a week, 45–60 mins a day) for at least 1-year b) aged between 18 and 60 years c) either sex d) ability to read and understand English/Hindi. Non-meditators were recruited by researchers at CSIO-CSIR, Chandigarh through their acquaintances. The inclusion criteria for non-meditators were same as that of meditators except for the meditation criteria. In both the groups, subjects with diagnosed mental illness were excluded. Subjects who practiced any form of yoga/meditation were excluded from non-meditators group.

Study procedure

All the participants were invited to participate via email or social-media invitation. Assessment scales for stress, anxiety and depression and impact of stressful events were circulated through google form for the willing and consenting subjects in English. The form was sent for language editing and verification for translation and back translation. Firstly, two language experts translated the scale into Hindi, Navneet Anand, language officer, CSIR-CSIO, Chandigarh and Shally Dhawan, language officer, BSNL, Chandigarh. As a consequence, the scale's versions 1 and 2 were created. Each item of these versions was discussed with the subject expert, Dr. Imran Noorani, clinical psychologist resulting in version 3 of the bilingual form. This version was then back translated into English by Dr. Kamna Singh, faculty, Department of English, S.D. College, Chandigarh resulting in version 4 of the scale. After that, this version was compared to the original scale, and any discrepancies were reviewed with the subject expert again. This led to fifth version of the scale. This scale was applied to 40 Rajyoga meditators in Chandigarh to determine how simple it was to comprehend. They were encouraged to indicate the difficulties they were facing in comprehending the items of the scale. Depending on the feedback from the participants, the issues were again discussed with the language and subject expert and efforts were made to keep the language understandable. This final version of the scale has been provided in Appendix A. The survey form was open for all.

All the data including socio-demographic details of the participants were pooled in an excel sheet.

Assessments

Socio-demographic details

Socio-demographic details were collected through structured questionnaire which included age, sex, marital status, employment status and locality. Details about the symptoms of COVID-19 infection, contacts with COVID-19 patients and travel history were also collected from both meditators and non-meditators. Years of experience in Brahma Kumaris Raja yoga meditation was also obtained from meditators.

Mental health assessments

Stress, anxiety and depression was assessed by DASS-21 [27]. It is a self-report scale assessing the emotional states of stress, anxiety and depression with 7 items for each of them. Scores are given on a Likert scale of 0–3 (0- least and 3-most). Dysphoria, despair, devaluation of life, self-deprecation, lack of interest, anhedonia, and lethargy are all assessed on the depression scale. Autonomic arousal, skeletal muscle effects, situational anxiety, and subjective sensation of anxious affect are all measured on the anxiety scale. The stress scale is sensitive to non-specific arousal levels that have been present for a long time. It evaluates restlessness, anxious arousal, and being easily disturbed / agitated, irritable / over-reactive, and impatient. Summing the scores for the relevant elements yields depression, anxiety, and stress scores.

Impact of distress caused by stressful events (like COVID-19) was assessed by Impact of Event Scale-revised (IES-R) [28]. It is a 22 item self-report scale assessing subjective stress following stressful life events. The amount of subjective distress caused by events are scored on a 5-point Likert scale (0-4, 0- not at all affected; 4- extremely affected). The three subscales of IES-R are: 1) Intrusion: 8 items measuring intrusive symptoms such as invasive thoughts, nightmares, intrusive feelings and visions, 2) Avoidance: 8 items measuring avoidance symptoms such as avoidance of feelings, circumstances, and thoughts, as well as numbing of receptivity and 3) Hyperarousal: 6 items measuring hyperarousal symptoms such as anger, impatience, hypervigilance, trouble in concentrating and intensified startle. The IES-R includes questions to assess a patient's level of distress in reaction to trauma. For example, question number 6 assessing intrusion reads as "I thought about it when I didn't mean to", question number 11 measuring avoidance symptoms reads as "I tried not to think about it", and question number 18 attempting to assess hyperarousal symptoms reads as "I had trouble concentrating". Each of the three DASS-21 scales contains 7 items, divided into subscales with similar content. The depression scale assesses dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest / involvement, anhedonia and inertia. The anxiety scale assesses autonomic arousal, skeletal muscle effects, situational anxiety, and subjective experience of anxious affect. The stress scale is sensitive to levels of chronic non-specific arousal. It assesses difficulty relaxing, nervous arousal, and being easily upset / agitated, irritable / over-reactive and impatient. Scores for depression, anxiety and stress are calculated by summing the scores for the relevant items.

Validation of DASS-21 and IES-R during COVID-19

The psychological impact of COVID-19 was assessed in general population of China using IES-R and the mental health states were assessed using DASS-21 [29]. It was found that more than 50 percent of the participants took the impact of the outbreak as moderate to severe, and about 28 percent of the participants had suffered moderate to severe anxiety symptoms. Physical symptoms, female gender and students suffered higher levels of distress. Staying updated and following COVID norms led to decrease in the levels of psychological turbulence. The mental health parameters of Chinese and Spanish respondents were also compared using DASS-21 and IES-R scales [30]. Chinese respondents exhibited higher levels of psychological impact, while Chinese respondents exhibited higher levels of stress, depression and anxiety. Spanish participants suffered COVID symptoms more and utilized medical services. A similar study compared the psychological health of general population of United States and China using IES-R and DASS-21 [31]. The respondents from America suffered more stress and depression, whereas the respondents from China suffered more PTSD symptoms. The same scales IES-R and DASS were used to compare the psychological states of the residents of Iran and China [32]. The residents of Iran reported higher levels of anxiety and depression, probably due to variations in government responses to the epidemic and access to healthcare services. Both the scales were validated in the study that examined the psychological health of general population in Philippines [33]. Near about one-sixth of respondents experienced moderate-to-severe depression and psychological damage, while one-fourth expressed moderate-to-severe anxiety. Female gender, low level of education, single, and young children were more impacted. Another cross sectional study examined the psychological impact of the pandemic among Vietnamese people using IES-R [13]. During the initial COVID-19 nationwide lockdown, there were comparatively high rates of participants experiencing PTSS. A higher level of psychological discomfort was positively correlated with being female, older than 44, or having more children in the household. Hindi version of IES-R has been validated in Rajyoga meditators in a previous study [34]. Scores on the IES-R and the existence of COVID symptoms were shown to be significantly positively correlated. Consequently, the scale seems to be a reliable indicator of post-trauma occurrences in clinical and research situations.

Data extraction and analysis

Data collected via google form were pooled in an excel sheet. Incomplete responses were removed and the subjects' personal identity were deidentified and the group status were coded by SM. Coded data were analyzed by RG using Jamovi version 2.0 [35].

Meditators and non-meditators were compared for the DASS-21 scores and IES-R scores using *t* test for group differences. Categorical variables were analyzed using chi square test. Multiple linear hierarchical regression was performed with meditation status, VOCID infection history, travel history and other socio-demographic variables as predictors and DASS-21 scores and IES-R scores as dependent variable.

Results and discussion

Response rate

Google forms were circulated to around 2000 subjects through SpARC wing of Brahma Kumaris and acquaintances of researchers. From 2000 contacts, 1162 (58.1%) responses were obtained. Data obtained was screened for completeness and 1159 responses were available for analysis.

Socio-demographic characteristics

Out of 1159 respondents, 802 (69.2%) were meditators (Brahma Kumaris Raja yoga practitioners) and 357 (30.8%) were non-meditators. In the table given below, RY stands for the Raja yoga practitioners, which simply means the subjects that practice the Raja yoga meditation regularly and are having the minimum meditation experience of one year. NRY stands for non-Raja yoga practitioners, meaning the subjects having no prior Raja yoga meditation experience. Raja yoga meditation is a mental exercise that can be practiced anywhere at any time with open eyes. Thus, the frequency of this versatile practice cannot be measured. But group meditation and spiritual lessons are conducted every day by the meditation centers and a record is maintained by the respective centers that include attendance and demographics of the practitioners. Other characteristics of meditators and non-meditators like age (category), sex, marital status, employment status, and COVID infection history/contact history/travel history are given in Table 1. Chi square test of association between meditation status and many other COVID related variables and socio-demographic variables were significant as shown in Table 1.

Table 1
Socio-demographic characteristics of subjects.

S. No	Variables	Number (percent)	Chi square/Fisher's exact statistic
1	**Meditation Status**		
	RY	802(69.2%)	171***
	NRY	357 (30.8%)	
2	**COVID Infection History**		
	RY		
	Yes	122(10.5%)	
	No	680(58.6%)	0.04
	NRY		
	Yes	56(4.8%)	
	No	301(25.9%)	
3	**COVID Contact History**		
	RY		
	Yes	175(15.1%)	
	No	466(40.2%)	
	Not Sure	161(13.9%)	3.14
	NRY		
	Yes	62(5.3%)	
	No	216(18.6%)	
	Not Sure	79(6.8%)	
4	**Travel history**		
	RY		
	Yes	14(1.2%)	
	No	788(67.9%)	0.006
	NRY		
	Yes	6(0.5%)	
	No	351(30.2%)	
5	**Sex**		
	RY		
	Male	323(27.8%)	
	Female	479(41.3%)	11.5***
	NRY		
	Male	182(15.7%)	
	Female	175(15.1%)	
6	**Age Category**		
	RY		
	18–30 years		
	30–50 years	114(9.8%)	
	>50 years	381(32.8%)	136***
	NRY	307(26.4%)	
	18–30 years	144(12.4%)	
	30–50 years	173(14.9%)	
	>50 years	40(3.4%)	
7	**Employment Status**		
	RY		
	Employed	296(25.5%)	
	Self employed	210(18.1%)	
	Un employed	296(25.5%)	44.7***
	NRY		
	Employed	200(17.2%)	
	Self employed	44(3.7%)	
	Un employed	113(9.7%)	
8	**Marital Status**		
	RY		
	Married	491(42.3%)	
	Unmarried		
	Widow/Widower	232(20%)	
	Divorced	55(4.7%)	
	Separated	12(1%)	
	NRY	12(1%)	N/A***
	Married	144(12.4%)	
	Unmarried	205(17.6%)	
	Widow/Widower	3(0.2%)	
	Divorced	4(0.3%)	
	Separated	1(0.08%)	

Psychometric properties of DASS-21 & IES-R

Internal consistency
The IES-R used in the survey form demonstrated excellent internal consistency. The scale resulted in Cronbach's alpha value of 0.91. The three subscales also showed good consistency (intrusion 0.83, hyperarousal 0.81, and avoidance 0.81). The DASS scale used in the survey form also showed excellent consistency (Cronbach's alpha value 0.968).

Correlations
Table 2 shows the Pearson correlation analysis between the subscales of IES-R and DASS-21. All the correlations are statistically significant. All the parameters showed correlated well with each other.

DASS 21 & IES-R scores among meditators and non-meditators:

Data for DASS-21 & IES-R for meditators and non-meditators were tested for group differences irrespective of COVID infection status. Data was tested for normality and found to be non-normal. Median and Interquartile range for DASS-21 are 2 and 7 for meditators and 8 and 25 for non-meditators respectively. For IES-R it was 6 and 13 for meditators and 11 and 31 for non-meditators respectively. Mann Whitney *U* test showed a significant difference in DASS-21 scores (Mann Whitney U = 98764, $P < 0.001$) and IES-R scores (Mann Whitney U = 117511, $P < 0.001$) between meditators and non-meditators (refer Table 3).

Similarly, group differences for DASS-21 & IES-R between subjects with and without COVID infection history irrespective of

Table 2
Correlation between the subscales of IES-R and DASS-R.

Pearson's Correlation	Stress	Anxiety	Depression	Avoidance	Intrusion	Hyperarousal
Stress	1	0.882*	0.882*	0.672*	0.873*	0.874*
Anxiety	0.882*	1	0.863*	0.665*	0.825*	0.839*
Depression	0.882*	0.863*	1	0.656*	0.823*	0.830*
Avoidance	0.673*	0.665*	0.656*	1	0.766*	0.778*
Intrusion	0.842*	0.825*	0.823*	0.766*	1	0.929*
Hyperarousal	0.844*	0.839*	0.830*	0.778*	0.929*	1

* Correlation is significant at 0.01level (two-tailed).

Table 3
Comparison of DASS-21 & IES-R Scores-Mann Whitney U Test.

S.No.	Variables	Category	Median	IQR	Test statistic
1	DASS-21	COVID +	8.0	14.0	59394***
		COVID -	3.0	9.0	
2	IES-R	COVID +	12.0	18.0	65427***
		COVID -	6.0	16.0	
3	DASS-21	RY	2	7	98764***
		NRY	8	25	
4	IES-R	RY	6	13	117511***
		NRY	11	31	

meditation status was also tested with Mann Whitney *U* test. Median and Interquartile range for DASS-21 are 8 and 14 for subjects with COVID infection history and 3 and 9 for subjects without COVID infection history respectively. For IES-R it was 12 and 18 for subjects with COVID infection history and it was 6 and 16 for subjects without COVID infection history respectively. Mann Whitney *U* test revealed a significant difference in DASS-21 scores (Mann Whitney U = 59394, P < 0.001) and IES-R scores (Mann Whitney U = 65427, P < 0.001) between subjects with and without COVID infection history irrespective of status of meditation (refer Table 3).

We have also done a subgroup analysis only in either meditators or non-meditators, testing for differences in DASS 21 and IES-R scores between those with and without COVID infection history using Mann Whitney *U* test. Amongst meditators, the DASS 21 (Mann Whitney U = 27143, P < 0.001) and IES-R scores (Mann Whitney U = 29867, P < 0.001) differed significantly. Amongst non-meditators also, the DASS 21 (Mann Whitney U = 5931, P < 0.001) and IES-R scores (Mann Whitney U = 6580, P < 0.009) differed significantly.

Multiple linear regression analysis:

We performed multiple hierarchical linear regression study the link between stress & related events and its impact with meditation status, COVID related variables and other sociodemographic characteristics. Hierarchical linear regression analysis is a special form of multiple linear regression, in which one or more predictor variables are added to the model in separate steps called as "blocks". It enables one to see whether adding variable(s) at each block improves a model stability to predict the response variable.

In this study, hierarchical multiple linear regression was performed with meditation status (meditator or non-meditator), COVID related variables (infection history, contact history and travel history) and other socio-demographic variables (age category, sex, marital status and employment status) as predictors. Dependent variable was either DASS-21 or IES-R scores.

We tested for eight models sequentially as follows,

Model 1: DASS 21 = a + b (Meditation status)

Model 2: DASS 21 = a + b1 (Meditation status) + b2 (COVID infection history)

Model 3: DASS 21 = a + b1 (Meditation status) + b2 (COVID infection history) + b3 (Age)

Model 4: DASS 21 = a + b1 (Meditation status) + b2 (COVID infection history) + b3 (Age) + b4 (COVID contact history

Model 5: DASS 21 = a + b1 (Meditation status) + b2 (COVID infection history) + b3 (Age) + b4 (COVID contact history + b5 (Travel history)

Model 6: DASS 21 = a + b1 (Meditation status) + b2 (COVID infection history) + b3 (Age) + b4 (COVID contact history + b5 (Travel history) + b6 (Gender)

Model 7: DASS 21 = a + b1 (Meditation status) + b2 (COVID infection history) + b3 (Age) + b4 (COVID contact history + b5 (Travel history) + b6 (Gender) + b7 (Marital status)

Model 8: DASS 21 = a + b1 (Meditation status) + b2 (COVID infection history) + b3 (Age) + b4 (COVID contact history + b5 (Travel history) + b6 (Gender) + b7 (Marital status) + b8 (employment status)

Similarly, eight models were tested for IES-R scores as dependent variable (with the same predictor variables as used for predicting DASS 21) as well.

The change in R^2 was compared for each model and the best model was chosen based on model fitness, estimate of the slope and change in amount of variance explained at each model. Out of the eight models, model 3 with meditation status, COVID infection history and age category predicted the model better than other models with 15% (F = 51.5, P < 0.001) amount of variance for DASS-21 scores and 11.3% (F = 38, P < 0.001) amount of variance for IES-R scores. Meditation status, COVID infection history and Age independently and significantly predicted DASS 21(Meditation status: Beta = -0.63, P < 0.001, reference is non-meditators; COVID infection history: Beta = 0.42, P < 0.001 & reference is no COVID infection history; Age category: Beta = -0.27 for 30–50 years of age & −0.36 for above 50 years of age, P < 0.001 for both categories & reference is 18–30 years of age) and IES-R (Meditation status: Beta = -0.51, P < 0.00, reference is non-meditators; COVID infection history: Beta = 0.341, P < 0.001 & reference is no COVID infection history; Age category: Beta = -0.31 for 30–50 years of age & −0.39 for above 50 years of age, P < 0.001 for both categories & reference is 18–30 years of age).

We arrived at the final model (model 3 with meditation status, COVID infection history and age as predictors for both DASS 21 as well as IES-R as dependent variable) of best fit based on the change in adjusted R square which was significant at each block of predictor entry. Details of each model including standardized estimate of slope, adjusted R^2, change in adjusted R^2 and model fitness measures are given in Tables 4–6 (for DASS-21 as dependent variable) and Tables 7–9 (for IES-R as dependent variable).

Comparison analysis of psychological and mental health of meditators and non-meditators

The IES-R and DASS scores of non-meditators were high as compared to that of Rajyoga meditators. Figs. 1–3 show the comparison of scores between them. As shown in the figures, the psychological health of the meditators was sound as compared to the general population.

Discussion and future recommendations

The study results show that the presence of COVID infection increases the level of stress scores assessed by DASS 21 and also a higher score on IES-R scale scores. This is in line with the results of previous findings [36–41]. The findings imply that the lockdown brought on by COVID-19 may have led to lower brain hemodynam-

Table 4
Model Fit Measures-DASS-21.

				Overall Model Test			
Model	R	R^2	Adjusted R^2	F	df1	df2	p
1	**0.335**	**0.112**	**0.111**	**146.1**	**1**	**1157**	**< 0.001**
2	**0.369**	**0.136**	**0.134**	**90.9**	**2**	**1156**	**< 0.001**
3	**0.389**	**0.152**	**0.149**	**51.5**	**4**	**1154**	**< 0.001**
4	0.392	0.154	0.150	35.0	6	1152	< 0.001
5	0.394	0.155	0.150	30.2	7	1151	< 0.001
6	0.398	0.158	0.152	27.0	8	1150	< 0.001
7	0.402	0.161	0.152	18.4	12	1146	< 0.001
8	0.404	0.163	0.153	15.9	14	1144	< 0.001

Table 5
Model comparisons-DASS-21.

Comparison							
Model		Model	ΔR^2	F	df1	p	df2
1	**–**	**2**	**0.02384**	**31.89**	**1**	**1156**	**< 0.001**
2	**–**	**3**	**0.01563**	**10.63**	**2**	**1154**	**< 0.001**
3	–	4	0.00244	1.66	2	1152	0.190
4	–	5	9.61e-4	1.31	1	1151	0.253
5	–	6	0.00318	4.35	1	1150	0.037
6	–	7	0.00305	1.04	4	1146	0.384
7	–	8	0.00202	1.38	2	1144	0.252

Table 6
Model coefficients – DASS-21.

						95% Confidence Interval	
Predictor	Estimate	SE	t	p	Stand. Estimate	Lower	Upper
Intercept	16.04	0.822	19.52	< 0.001			
Category:							
RY – NRY	−7.98	0.795	−10.05	< 0.001	−0.628	−0.750	−0.505
COVID Infection:							
Present – Absent	5.46	0.958	5.70	< 0.001	0.429	0.282	0.577
Age:							
30–50 – 18–30	−3.40	0.907	−3.76	< 0.001	−0.268	−0.408	−0.128
Above 50 – 18–30	−4.59	1.027	−4.47	< 0.001	−0.361	−0.519	−0.202

Reference levels are "NRY' for Meditation status, "COVID infection absent" for COVID infection history & "18–30 years" for age category. DASS-21-Depression Anxiety & Stress

Table 7
Model Fit Measures-IES-R.

				Overall Model Test			
Model	R	R^2	Adjusted R^2	F	df1	df2	p
1	0.287	0.0822	0.0814	103.6	1	1157	< 0.001
2	0.312	0.0970	0.0955	62.1	2	1156	< 0.001
3	0.341	0.1163	0.1133	38.0	4	1154	< 0.001
4	0.345	0.1190	0.1144	25.9	6	1152	< 0.001
5	0.346	0.1198	0.1145	22.4	7	1151	< 0.001
6	0.350	0.1227	0.1166	20.1	8	1150	< 0.001
7	0.354	0.1250	0.1158	13.6	12	1146	< 0.001
8	0.358	0.1282	0.1175	12.0	14	1144	< 0.001

Table 8
Model comparisons-IES-R.

Comparison							
Model		Model	ΔR^2	F	df1	df2	p
1	**–**	**2**	**0.01487**	**19.033**	**1**	**1156**	**< 0.001**
2	**–**	**3**	**0.01928**	**12.587**	**2**	**1154**	**< 0.001**
3	–	4	0.00270	1.764	2	1152	0.172
4	–	5	8.03e-4	1.050	1	1151	0.306
5	–	6	0.00291	3.810	1	1150	0.051
6	–	7	0.00223	0.731	4	1146	0.571
7	–	8	0.00321	2.109	2	1144	0.122

Table 9
Model coefficients – IES-R.

Predictor	Estimate	SE	t	p	Stand. Estimate	95% Confidence Interval	
						Lower	Upper
Intercept	22.83	1.13	20.14	< 0.001			
Category:							
RY – NRY	−8.86	1.10	−8.08	< 0.001	−0.515	−0.641	−0.390
COVID Infection:							
Present – Absent	5.87	1.32	4.44	< 0.001	0.341	0.190	0.492
Age:							
30–50 – 18–30	−5.33	1.25	−4.26	< 0.001	−0.310	−0.453	−0.167
Above 50 – 18–30	−6.77	1.42	−4.78	< 0.001	−0.394	−0.555	−0.232

Reference levels are "NRY' for Meditation status, "COVID infection absent" for COVID infection history & "18–30 years" for age category; IES-R-Impact of Events Scale-Revised; RY-Raja yoga; NRY-Non-Raja yoga.

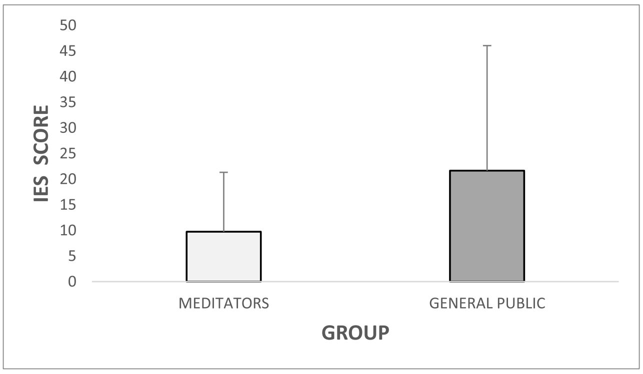


Fig. 1. Comparison of IES-R scores among meditators and non-meditators.

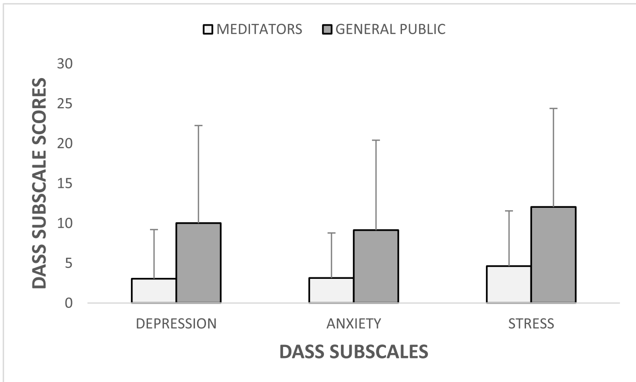


Fig. 3. Comparison of DASS subscale scores among meditators and non-meditators.

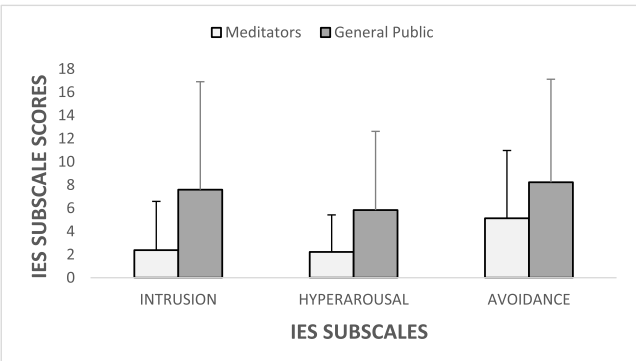


Fig. 2. Comparison of IES-R subscale scores among meditators and non-meditators.

ics, which are further linked to an increased risk of mental health issues including depression or a reduction in cognitive function in mental processes [42]. Urban Green scenery can help to counteract the damaging neuropsychological effects of the pandemic. The study emphasizes the possibility of higher psychological stress following COVID-19 when exposed to typical busy urban street views and the opposite significance of exposure to green urban spaces, which may mitigate the risk negatively impacted by that stress, while simultaneously having additional positive effects on the brain. Viewing greenery images and practicing relaxation are the well-known interventions to enhance mental well-being. Some research studies have examined the effects of viewing pictures of greenery on functional imaging. A study compared the brain activity during arithmetic tasks before and after the intervention in order to discover the functional brain alterations underlying seeing pictures of greenery and a brief relaxing technique [43]. Short relaxation exercises dramatically increased the amount of oxygenated hemoglobin during mathematical activities in important regions of the prefrontal cortex.

The interesting findings of the present study are 1) people practicing Raja yoga meditation are likely to have lesser scores on DASS 21 which assesses stress, anxiety and depression and lesser impact of stressful events assessed by IES-R scale than non-meditators. 2) People aged 18–30 years are likely to have more DASS 21 scores and IES-R scores compared to people aged 30 years and above. This could be because, majority of the working population are youngsters who have the apprehension of getting infected with COVID as they move around, hence possibility of greater stress and its consequences.

Though the study findings are interesting, it needs to be interpreted in the context of the study design. Considering the cross-sectional survey design, no conclusive causal relation can be interpreted between meditation status and stress or related events and their impact with other variables. Moreover, the amount of variance explained by meditation status, COVID infection history and age category in predicting DASS 21(15%) and IES-R scores (11%) is lesser due to greater amount of variability in the data amongst meditators as well as non-meditators, though the three predictors (meditation status, COVID infection history and age category) provided a significant model fit with independently significant slope for both DASS 21 and IES-R scores.

Other possible reason for a smaller amount of variance explained by the predictors could be the significant association between meditation status and many of the socio-demographic variables. As it was a survey design with snow ball sampling strategy, we could not do proper matching of the meditators and non-meditators in socio-demographic variables. As shown in Table 1 many of the socio-demographic variables differed significantly between meditators and non-meditators group. Apart from the differences in socio-demographic characteristics, sample size of non-meditators was only around 50% of the meditators sample size, though the overall sample size was adequate. Perhaps, we faced real challenge in getting response from non-meditators compared to meditators.

Future research can be planned to study if Brahma Kumaris Raja yoga meditation intervention could actually reduce stress and the impact of stress & related events with randomized controlled trials during pandemic conditions like COVID-19. Earlier studies on Brahma Kumaris Raja yoga meditation have shown reduction of stress and related health consequences like tension headache and coronary artery disease [44] and reduction of anxiety and cortisol levels in patients undergoing coronary bypass surgery(U. [23]. In healthy population raja yoga meditators were found to have greater positivity and happiness than matched controls [45]. A recent study has also shown grey matter volume changes in happiness related areas in raja yoga meditators [46]. However, if the same will hold true (Brahma Kumaris Raja yoga meditation as a preventive tool) in the context of uncertainties like the COVID 19 pandemic needs to be further studied in controlled trials. Near infrared technology to measure brain function during Yoga can be used to establish the proven connection between meditation and the neural activations.

Notwithstanding the limitations, the study results highlight the significance of natural subjective comfort provided by mind–body practices like meditation during highly stressful and uncertain conditions like COVID 19 pandemic. It is evident from the greater amount of variance explained by the meditation status in predicting the stress/anxiety/depression scores assessed by DASS 21 and impact of stressful events assessed by IES-.

R scale than the other two significant predictors- COVID infection history and age category. This is corroborated by the findings of another recent large-scale survey on similar lines [16]. Raja yoga meditation which focuses on one's innate inner powers, loveful connection with a supreme being and a greater goodness at a larger context even in adverse situations might facilitate better mental health and this could substantiate our study findings.

Considering the uncertainties and ambiguity in rendering medical care posed by of COVID 19 pandemic, role of mind–body practices like yoga, meditation, physical exercise, etc. needs to be emphasized for its preventive and add-on therapeutic utility through its positive impact on reducing distress. Digital mental health programs which have greater role to play during pandemic like COVID-19 can easily incorporate mind–body interventions like meditation for the betterment of the society at large [47].

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors would like to express their gratitude to all the meditators who took part in this research. The authors also thank the language experts and the subject experts for their contribution. The authors would also like to thank editors and anonymous reviewers for reviewing the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Informed consent

Before the study, all of the participants signed a consent form.

Data and material availability

Upon request, the corresponding author will make the data supporting the results of this study accessible.

Authors' contribution

Shobhika Madhu: Design of study, acquisition of data, analysis and interpretation of data, manuscript drafting and editing. Ramajayam Govindaraj: Design of study, analysis and interpretation of data, manuscript drafting and editing. Prashant Kumar: supervision, analysis and interpretation of data, manuscript reviewing and editing. Sushil Chandra: supervision, analysis and interpretation of data, manuscript reviewing. The final manuscript has been read and accepted by all the authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ceh.2022.07.001.

References

[1]. Lancet T. India under {COVID}-19 lockdown. *The Lancet*. 2020;395 (10233):1315.
[2]. Garfin DR, Silver RC, Holman EA. The novel coronavirus ({COVID}-2019) outbreak: Amplification of public health consequences by media exposure. *Health Psychol*. 2020;39(5):355.
[3]. Orso D, Federici N, Copetti R, Vetrugno L, Bove T. Infodemic and the spread of fake news in the {COVID}-19-era. *European Journal of Emergency Medicine*. 2020.
[4]. Farooqui M, Quadri SA, Suriya SS, et al. Posttraumatic stress disorder: a serious post-earthquake complication. *Trends in Psychiatry and Psychotherapy*. 2017;39:135–143.
[5]. Restauri N, Sheridan AD. Burnout and posttraumatic stress disorder in the coronavirus disease 2019 ({COVID}-19) pandemic: intersection, impact, and

interventions. *Journal of the American College of Radiology*. 2020;17(7):921–926.
[6]. Varma P, Junge M, Meaklim H, Jackson ML. Younger people are more vulnerable to stress, anxiety and depression during {COVID}-19 pandemic: A global cross-sectional survey. *Prog Neuro-Psychopharmacol Biol Psychiatry*. 2021;109 110236.
[7]. Ceban F, Nogo D, Carvalho IP, et al. Association between Mood Disorders and Risk of COVID-19 Infection, Hospitalization, and Death: A Systematic Review and Meta-analysis. *JAMA Psychiatry*. 2021;78(10):1079–1091. https://doi.org/10.1001/jamapsychiatry.2021.1818.
[8]. Renaud-charest, O., Lui, L. M. W., Eskander, S., & Ceban, F. (2020). *Onset and frequency of depression in post-COVID-19 syndrome. January*.
[9]. Xiong J, Lipsitz O, Nasri F, et al. Impact of COVID-19 pandemic on mental health in the general population: A systematic review. *J Affect Disord*. 2020;277(August):55–64. https://doi.org/10.1016/j.jad.2020.08.001.
[10]. Wang C, Chudzicka-Czupała A, Grabowski D, et al. The Association Between Physical and Mental Health and Face Mask Use During the COVID-19 Pandemic: A Comparison of Two Countries With Different Views and Practices. *Front Psychiatry*. 2020;11(September):1–13. https://doi.org/10.3389/fpsyt.2020.569981.
[11]. Wang C, Chudzicka-Czupała A, Tee ML, et al. A chain mediation model on COVID-19 symptoms and mental health outcomes in Americans. *Asians and Europeans. Scientific Reports*. 2021;11(1):1–13. https://doi.org/10.1038/s41598-021-85943-7.
[12]. Wang, C., Tee, M., Roy, A. E., Fardin, M. A., Srichokchatchawan, W., Habib, H. A., Tran, B. X., Hussain, S., Hoang, M. T., Le, X. T., Ma, W., Pham, H. Q., Shirazi, M., Taneepanichskul, N., Tan, Y., Tee, C., Xu, L., Xu, Z., Vu, G. T., . . . Kuruchittham, V. (2021). The impact of COVID-19 pandemic on physical and mental health of Asians: A study of seven middle-income countries in Asia. *PLoS ONE*, *16*(2 Febuary). https://doi.org/10.1371/journal.pone.0246824.
[13]. Le XTT, Dang AK, Toweh J, et al. Evaluating the Psychological Impacts Related to COVID-19 of Vietnamese People Under the First Nationwide Partial Lockdown in Vietnam. *Front Psychiatry*. 2020;11(September):1–8. https://doi.org/10.3389/fpsyt.2020.00824.
[14]. Tran BX, Nguyen HT, Le HT, et al. Impact of COVID-19 on Economic Well-Being and Quality of Life of the Vietnamese During the National Social Distancing. *Front Psychol*. 2020;11(September):1–9. https://doi.org/10.3389/fpsyg.2020.565153.
[15]. Lee, Y., Lui, L. M. W., Chen-li, D., Liao, Y., & Mansur, R. B. (2020). *Government response moderates the mental health impact of COVID-19 : A systematic review and meta-analysis of depression outcomes across countries. January*.
[16]. Raghuram N, Anand A, Rain M, et al. Yoga practise is beneficial for maintaining healthy lifestyle and endurance under restrictions and stress imposed by lockdown during {COVID}-19 pandemic. *Front Psychiatry*. 2021;12:878.
[17]. AYUSH. (2020). *{AYUSH} Guidelines-{COVID} 19*. https://www.ayush.gov.in/ayush-guidelines.html.
[18]. Kwak S, Lee TY, Jung WH, et al. The immediate and sustained positive effects of meditation on resilience are mediated by changes in the resting brain. *Front Hum Neurosci*. 2019;13(March):1–10. https://doi.org/10.3389/fnhum.2019.00101.
[19]. Bushell W, Castle R, Williams MA, et al. Meditation and Yoga Practices as Potential Adjunctive Treatment of SARS-CoV-2 Infection and COVID-19: A Brief Overview of Key Subjects. *J Altern Complement Med*. 2020;26(7):547–556. https://doi.org/10.1089/acm.2020.0177.
[20]. Sahu A. Rajyoga Meditation and Effects : A Comprehensive. *Review.*. 2015;3(4).
[21]. Kiran CH, Arora AK, Girgila KK. *Original Article Effect of Short Term Rajyoga Meditation on Anxiety and Depression.*. 2014;10:18–20.
[22]. Syamala E, Roy P, Sailesh KS, Jabir PK, Madhusudhan U, Mukkadan J. Effectiveness of Raja Yoga Meditation on Depression, Anxiety and Stress in Females with Premenstrual Syndrome. *International Journal of Physiology*. 2019;7(1):90. https://doi.org/10.5958/2320-608x.2019.00020.9.
[23]. Kiran U, Ladha S, Makhija N, et al. The role of Rajyoga meditation for modulation of anxiety and serum cortisol in patients undergoing coronary artery bypass surgery: A prospective randomized control study. *Annals of Cardiac Anaesthesia*. 2017;20(2):158–162. https://doi.org/10.4103/aca.ACA_32_17.
[24]. Shanker S, Sadhana S, Lal B, Agarwal G, Bute J. *Aspects of Hypertensive Patients.*. 2018;06(11):462–468.
[25]. Sharma K, Achermann P, Panwar B, et al. Brain-electric activity during eyes open Brahma Kumaris Rajayoga meditation. *MindrXiv*. 2020;1–15.
[26]. *https://www.brahmakumaris.com/about-us/*. (n.d.).
[27]. Lovibond SH, Lovibond PF. Manual for the Depression, Anxiety and Stress Scales (DASS). *In Sydney Psychology Foundation*. 1995;2.
[28]. Christianson S, Marren J. The impact of event scale–revised ({IES}-R). *Am J Nurs*. 2012;21(5):321–323.
[29]. Wang C, Pan R, Wan X, et al. Immediate psychological responses and associated factors during the initial stage of the 2019 coronavirus disease (COVID-19) epidemic among the general population in China. *Int J Environ Res Public Health*. 2020;17(5). https://doi.org/10.3390/ijerph17051729.
[30]. Wang C, López-Núñez MI, Pan R, et al. The impact of the COVID-19 pandemic on physical and mental health in China and Spain: Cross-sectional study. *JMIR Formative Research*. 2021;5(5):1–10. https://doi.org/10.2196/27818.
[31]. Wang C, Tripp C, Sears SF, et al. The impact of the COVID-19 pandemic on physical and mental health in the two largest economies in the world: a comparison between the United States and China. *J Behav Med*. 2021;44(6):741–759. https://doi.org/10.1007/s10865-021-00237-7.
[32]. Wang C, Fardin MA, Shirazi M, et al. Mental Health of the General Population during the 2019 Coronavirus Disease (COVID-19) Pandemic: A Tale of Two Developing Countries. *Psychiatry International*. 2021;2(1):71–84. https://doi.org/10.3390/psychiatryint2010006.
[33]. Tee, M. L., Tee, C. A., Anlacan, J. P., Aligam, K. J. G., Wincy, P., Reyes, C., Kuruchittham, V., & Ho, R. C. (2020). *Psychological impact of COVID-19 pandemic in the Philippines. Journal of Affective Disorders [revista en Internet] 2020 [acceso 4 de junio de 2018]; 277: 379-391. January*.
[34]. Madhu S, Kumar P, Chandra S. Reliability and factor analysis of Hindi version of IES-R scale: Effect of Rajyoga meditation on perceiving the impact of COVID-19. *Dialogues in Health*. 2022;1 https://doi.org/10.1016/j.dialog.2022.100024 100024.
[35]. Jamovi. (2021). *The Jamovi Project*.
[36]. Brooks SK, Webster RK, Smith LE, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *The Lancet*. 2020;395(10227):912–920.
[37]. Guo WP, Min Q, Gu WW, et al. Prevalence of mental health problems in frontline healthcare workers after the first outbreak of COVID-19 in China: a cross-sectional study. *Health and Quality of Life Outcomes*. 2021;19(1):1–10. https://doi.org/10.1186/s12955-021-01743-7.
[38]. Huang Y, Zhao N. Generalized anxiety disorder, depressive symptoms and sleep quality during COVID-19 outbreak in China: a web-based cross-sectional survey. *Psychiatry Res*. 2020;288. https://doi.org/10.1016/j.psychres.2020.112954.
[39]. Hwang T-J, Rabheru K, Peisah C, Reichman W, Ikeda M. Loneliness and social isolation during the {COVID}-19 pandemic. *Int Psychogeriatr*. 2020;32(10):1217–1220.
[40]. Rubin GJ, Wessely S. The psychological effects of quarantining a city. *The BMJ*, Vol. 368. BMJ Publishing Group; 2020. https://doi.org/10.1136/bmj.m313.
[41]. Varshney M, Parel JT, Raizada N, Sarin SK. Initial psychological impact of COVID-19 and its correlates in Indian Community: An online (FEEL-COVID) survey. *PLoS ONE*. 2020;15(5):1–10. https://doi.org/10.1371/journal.pone.0233874.
[42]. Olszewska-Guizzo A, Mukoyama A, Naganawa S, et al. Hemodynamic response to three types of urban spaces before and after lockdown during the covid-19 pandemic. *Int J Environ Res Public Health*. 2021;18(11). https://doi.org/10.3390/ijerph18116118.
[43]. Zhang Z, Olszewska-Guizzo A, Husain SF, et al. Brief relaxation practice induces significantly more prefrontal cortex activation during arithmetic tasks comparing to viewing greenery images as revealed by functional near-infrared spectroscopy (Fnirs). *Int J Environ Res Public Health*. 2020;17(22):1–10. https://doi.org/10.3390/ijerph17228366.
[44]. Gupta SK, Sawhney RC, Rai L, et al. Regression of coronary atherosclerosis through healthy lifestyle in coronary artery disease patients–Mount Abu Open Heart Trial. *Indian Heart J*. 2011;63(5):461–469.
[45]. Ramesh MG, Sathian B, Sinu E, Rai KS. Efficacy of Rajayoga Meditation on Positive Thinking : An Index for Self-Satisfaction and Happiness in Life. *Journal of Clinical and Diagnostic Research*. 2013;2265–2267. https://doi.org/10.7860/JCDR/2013/5889.3488.
[46]. Babu MGR, Kadavigere R, Koteshwara P, Sathian B, Rai KS. Rajyoga meditation induces grey matter volume changes in regions that process reward and happiness. *Sci Rep*. 2020;10(1):1–11.
[47]. Figueroa CA, Aguilera A. The Need for a Mental Health Technology Revolution in the COVID-19 Pandemic. *Front Psychiatry*. 2020;11. https://doi.org/10.3389/fpsyt.2020.00523.

Shobhika Madhu M.E., is a research scholar at AcSIR-CSIO, Chandigarh, India. She is an active member of SpARC wing of Brahma Kumaris, India.

Dr. Ramajayam Govindaraj MBBS, PhD is Scientist-C in Centre for Consciousness Studies (Dept of Neurophysiology), National Institute of Mental Health and Neurosciences (NIMHANS). His expertise includes positive psychiatry, Yoga, mental health and conciouslecc studies. He has published several research articles and books in international journals/ international publishers of repute.

Dr. Prashant Kumar PhD is a Senior Scientist in Central Scientific Instruments Organisation, Chandigarh which is a national laboratory under Council of Scientific and Industrial Research (CSIR), Govt. of India. He has been an Honorary Assistant Professor at Academy of Scientific & Innovative Research (an institute of national importance and a meta university under CSIR) Chandigarh. His research interests are mainly in the application of soft computing techniques in various fields. He has published several research articles and books in international journals/ international publishers of repute.

Dr. Sushil Chandra is a Scientist G in INMAS-DRDO, India. He is an expert in the field of Cognitive neuroscience, Psychophysiological Tools and methods, Technological and Traditional intervention. He has published several research articles and books in international journals/ international publishers of repute.

Dialogues in Health 1 (2022) 100024

Contents lists available at ScienceDirect

Dialogues in Health

journal homepage: www.elsevier.com/locate/dialog

Reliability and factor analysis of Hindi version of IES-R scale: Effect of Rajyoga meditation on perceiving the impact of COVID-19

Shobhika Madhu [a], Prashant Kumar [a,b,*], Sushil Chandra [c]

[a] Academy of Scientific & Innovative Research (AcSIR), Ghaziabad 201002, India
[b] CSIR-Central Scientific Instruments Organisation, Chandigarh 160030, India
[c] Institute of Nuclear Medicine & Allied Sciences-DRDO, Delhi 110054, India

ARTICLE INFO

Keywords:
Impact of Event-Revised scale
Rajyoga meditators
Psychological impact
Coronavirus
Reliability
Validity

ABSTRACT

The purpose of this study is to present the Hindi translation and validation of the Impact of Event Scale-Revised and to evaluate psychometric qualities of this scale in a sample of regular Rajyoga meditators to examine the psychological impact of Coronavirus on them. The convenience sampling method was used to collect the data from 801 Rajyoga meditators through online survey. Data were analysed using SPSS 26.0. The Hindi version of IES-R demonstrated good internal consistency with the value of alpha coefficient being 0.91 for the scale and ranging between 0.81 to 0.83 for the subscales. The correlations between the subscales varied between 0.55 and 0.66. Principal components analysis using Varimax rotation was run with three-factor solution based on eigen value greater than one. This solution explained 54 percent of the total variance. It generated mainly two factors, an intrusion hyperarousal factor and an avoidance factor and third factor with one item only. Only 4.7 percent of the meditators rated the outbreak's psychological impact as moderate or severe. The mean score of IES-R was 10.01 (with an S.D. of 11.107). Significant positive correlations were found among IES-R scores and the presence of COVID symptoms. Thus, in clinical and research contexts, the scale appears to be a valid measure of post-trauma occurrences. The present study was conducted to generate a validated Hindi version of the IES-R that is easier and more compatible for use in the Indian population.

1. Introduction

The coronavirus crisis is currently being faced by the whole of the world. There is a need to address this psychological crisis through easily accessible and affordable interventions designed to lower the impact of the ongoing situations on mental health of all the individuals.

1.1. Effects of COVID-19 on mental health

A systematic review has been discussed with respect to the impact of COVID-19 on psychological outcomes in the general population and has also identified factors associated with this distress in the literature [1]. In most of the investigations, there was significant prevalence of psychiatric problems. High rates of stress, depression, anxiety and post-traumatic stress disorder were reported in the general population among distinct nations. Those who were at higher risk were the females, young population, psychiatric patients, unemployed, students and the people more exposed to social media. More than half of the respondents (53.8%) reported moderate-to-severe psychological effects when the Coronavirus outbreak in China was in its early beginnings, and almost a third (28.8%) experienced moderate-to-severe anxiety, 16.5 percent of people said their depression was moderate to severe, while 8.1 percent said their stress levels were moderate to severe [2]. Among the general population of Saudi Arabia, approximately one-fourth of those polled (23.6%) suffered moderate to severe psychological distress [3]. The Spanish population labelled the COVID-19 health situation as "quite severe", and about 36% of the sampled population reported the psychological impact as moderate to severe. The economic crisis had worst hit the well-being of the Spanish [4]. In India also, during the first wave, the online survey study concluded that approximately one-third of the subjects had experienced substantial psychological distress [5]. Nearly 18.2 percent of all respondents had moderate to severe psychological distress. In another cross-sectional study, 4612 participants from eight different nations were recruited using chain mediation model [6]. Data on physical symptoms, psychological health (using IES-R and DASS scales) and the need for health-related information was collected from these participants. According to the findings, Poland and the Philippines had the greatest levels of stress, depression, and anxiety, while Vietnam had the lowest average scores. The three nations with the highest IES-R scores were China (mean score 32.54 with standard deviation of 0.52), Iran (mean score 31.61 with standard deviation of 0.82), and Poland (mean score 31.18, with standard deviation of 31.18), while the IES-R score (mean score17.82 with standard deviation of 1.31) in Vietnam was the

* Corresponding author at: Technology Block, CSIO, Chandigarh 160030, India.
E-mail address: prashantkumar@csio.res.in (P. Kumar).

http://dx.doi.org/10.1016/j.dialog.2022.100024
Received 22 December 2021; Received in revised form 15 June 2022; Accepted 20 June 2022
Available online 22 June 2022

lowest [6]. The urge for health-related information and the perceived effect of meditation were shown to be mediator between COVID-19 related physical symptoms and subsequent mental health symptoms. A similar study compared the psychological health of general population in Seven Asian middle-income countries during COVID-19 using IES-R and DASS-21 [7]. The mean scores of depression, stress and anxiety were the highest in Thailand, whereas Vietnam had the lowest scores. Thailand (mean score 42.35 with standard deviation of 13.39), China (mean score 32.98 with standard deviation of 15.42), and Iran were the top three nations with the highest IES-R scores (mean score 30.42 with standard deviation of 15.82), while the IES-R scores of general populations in Vietnam were the lowest (mean score 17.39 with standard deviation of 13.72) [7].

The measures taken by the governments to stop COVID-19 from spreading benefited the mental health of the general population, besides improvements in their physical health. Data taken from participants recruited across 33 countries revealed that in nations where strict restrictions were enacted quickly, the prevalence of clinically severe depression symptoms was much lower [8].

1.2. Impact of Event-Revised (IES-R) scale and its validation

The Impact of Event Scale is an assessment questionnaire designed to assess the stress caused by distressing experiences [9]. But this scale did not include the factors of arousal subscale. As a result, a new version of the scale was formulated that included new items about arousal[10]. It includes 22 items organised into three symptom groups that have been identified as indications of PTSD. (PTSD). These three subscales are Intrusion, and Hyperarousal, and Avoidance. The participants are expected to rate their level of distress on a five-point Linkert scale. Translation and validation of the IES-R scale has been done into several languages like Spanish [11], French [12], Japanese [13], Arabic [14], Indonesian [15], Chinese [16], Swedish [17], and Dutch [18]. The IES-R was also validated in many countries during the COVID-19 pandemic. Psychological impact of COVID-19 was assessed in China using IES-R [19]. The first- and second-survey respondents' mean IES-R scores were higher than the cut-off values (> 24) for PTSD symptoms. High psychological impact was also realized by the Egyptian population. The mean of the Impact Event scale came out to be 34.3 (S.D. of 15). Out of the total respondents, 41.4% reported the impact as severe. About 34% of respondents said they were more stressed at work, about 55% said they were more stressed financially, and 62.7 percent said they were more stressed at home [20]. More than 50 percent of them felt horrified and helpless. High mean IES-R scores (>24 points) were also reported by both the Chinese and the Spanish respondents. The mean IES-R score for the Chinese participants was 30.69 with SD of 16.21, while Spanish participants reported the mean IES-R score of 27.62 with SD of 18.67 [21]. A comparison study of physical and mental health of general population of U.S. and China associated mental health characteristics with physical symptoms, COVID-19 knowledge and preventive health practises [22]. Stress and depression symptoms were more common in Americans, whereas acute-traumatic stress symptoms were more common among Chinese. Face mask use and demands for COVID-19-related health information were shown to differ, with differing mental health effects. Physical symptoms that might be linked to COVID-19 were linked to poor mental health [22]. The psychological impact of the pandemic was compared between Chinese (encouraging face masks) and Poles (discouraging face masks) using IES-R and DASS-21 scales [19]. Stress, anxiety and depression levels were higher in Polish participants than Chinese participants. The IES-R scores were higher in Chinese respondents (mean score 32.98 with standard deviation of 15.42) than in Polish respondents (mean score 31.14 with standard deviation of 13.59) [6]. Nonetheless, both nations' mean IES-R scores were over 24, suggesting the existence of PTSD symptoms in respondents of both the nations. The IES-R scale was also validated in general population of Philippines during the pandemic [23]. The IES-R mean score was found to be 19.57 with standard deviation of 13.12. The psychological impact of the epidemic was considered moderate to severe by 16.3 percent of responders. The psychological impact of the pandemic was measured in Vietnamese population also using IES-R [24]. The IES-R mean score was 17.5 with standard deviation of 11.5. This instrument was used in this study to assess post-traumatic stress symptoms (PTSS) of the respondents. 16.4 percent of the respondents had a low degree of PTSS, 5.3 percent had a moderate level of PTSS, and 5.4 percent had severe PTSS.

1.3. Rajyoga meditation

Rajyoga meditation is taught by Brahma Kumaris Spiritual Global University [25]. This spiritual institution is an international non-governmental organization (NGO) in General Consultative Status with the ECOSOC and UNICEF. It is a global network of organisations with 8,500 established centers in over 137 countries and 900,000 regular students that provides free of cost life time meditation training and programs The institution offers philanthropic services to all irrespective of nationality, religion, caste, creed, gender, etc. Raja Yoga meditation is open to people from all walks of life. This type of meditation doesn't require any rituals or chants, and it can be done anywhere, at any time. Raja Yoga meditation is done with 'open eyes,' making it a diverse, uncomplicated, and easy to perform style of meditation. There are numerous research studies published by Spiritual Application Research Centre (SpARC) wing of Brahma Kumaris spiritual organization that have pointed towards the psychological, physiological and neural benefits of Rajyoga meditation (*Https://Bksparc.In/*, n.d.).

1.4. Significance of Rajyoga meditation during and after COVID-19

Meditation and mindfulness can be used a strategy to fears and lessen anxieties [26]. Regular practice of Raja Yoga meditation results in physiological and psychological wellbeing among the practitioners. Short term and long-term Raja Yoga meditators showed significant improvements in heart rate, respiratory rate, systolic blood pressure and diastolic blood pressure after the practice of meditation after every fifteen minutes. The long-term meditators also got rid of addictions and negative attributes. This meditation has shown the reduction in diastolic BP among patients with hypertension [27]. Rajyoga meditation provides relaxation and harmonises mental and physical energy. Thus, it results in better cardiorespiratory endurance of an individual. For determining the aerobic and physical fitness of an individual, the maximum rate of oxygen consumption during exercise (VO2 max) is one of the parameters. An increase in VO2 max was observed in Rajyoga meditators [28]. The regular practice of Rajyoga meditation helps in regulating anxiety and cortisol level in heart patients going through coronary artery bypass surgery (U. [29]). Meditation is considered to be useful to relieve stress and enhance cardio-respiratory health. Even a short term Rajyoga meditation intervention reduced anxiety and depression among the patients suffering from anxiety and depression following six weeks of intervention (C. H. [30]). Not only physiological and psychological, but there are also neural evidences of benefits of meditation interventions. In a study observing neural correlates of Rajyoga meditators, they showed high-band strength in the alpha and theta range [31]. Thus, meditation had significant positive effect on frontal and parietal areas of brain responsible for emotion and cognitive processing. The activation differences between meditative and resting states of experienced Rajyoga meditators were also established with the help of multichannel EEG recordings. After meditation, the activations in low alpha frequencies were increased and those in delta frequencies were reduced. The networks associated with the altered activations were the central executive network, the mirroring network and the task-positive and the task-negative network.

The objectives of this study are (1) to propose the translated and validated Hindi version of IES-R that is easier and more compatible for use in the Indian population (2) to test the suggested IES-R scale's validity and reliability in Rajyoga meditators by testing the factorial structure and internal consistency of this scale (3) to assess the psychological health of Rajyoga meditators amid this pandemic to bring forward the role of meditation interventions in increasing the resilience against the psychological crisis.

2. Methods

2.1. Design

The form was circulated through convenience sampling to the Rajyoga meditators through the SpARC (Spirituality and Research) wing of the Brahma Kumaris Spiritual Global University. The organization has large number of regular students coming to learn and practice meditation throughout all the centres globally. The reasons for choosing Rajyoga meditators as subjects were the availability of large sample group, that too during the pandemic and inexpensive convenience sampling procedure.

2.2. Inclusion and exclusion criteria

The Rajyoga meditators with at least one year of meditation experience and bearing no psychological disorders were selected for the analysis.

2.3. Ethical clearance and informed consent

Ethical consent was taken from the Institutional Ethical Committee, CSIO-CSIR, Chandigarh. A presentation was organized to inform the participants about the objectives of the study and to provide instructions to fill the survey form. The informed consent was taken from all the respondents. We did not collect any personal data from the participants to maintain anonymity. At any stage during the survey, participants could opt out.

2.4. Development and dissemination of the online survey form

An online survey form was prepared using Google forms consisting of questions in both English and Hindi languages. The form was sent for language editing and verification for translation and back translation. The translated form was then verified by the subject experts and then circulated through convenience sampling to the Rajyoga meditators through the SpARC (Spirituality and Research) wing of the Brahma Kumaris Spiritual Global University. The survey form was open from Jan 2021 to March 2021.

2.5. Recruitment process and survey administration

The survey form was open for everyone who visited the link. The link of the survey form was sent to the meditators through mail ids and What's app numbers saved in the databases of their respective meditation centres. The survey was announced in the online mode. Google forms was used to create the survey form and the data was stored in the respective Google drive. The survey was voluntary and there were not offered any incentives to participate. The survey form was open from Jan 2021 to March 2021. The respondents were able to review and change their answers through Review option before submitting. The response rates were not calculated. The duplicate database entries having the same user ID were eliminated before analysis and the most recent entries were taken. Only completed questionnaires were analysed. There was not any timeframe given to complete the survey.

2.6. Respondents

A total of 801 Rajyoga meditators participated in the study. Out of these meditators, 478 were women (59.7% of the sampled population), 490 were married (61.2% of the sampled population), 296 were employed (37% of the sampled population). The maximum of them (47.6%) were aged between 30 to 50 years. Most of the meditators (31%) were in the intermediate group (5 to 10 years of meditation experience). Table 1 shows the frequency and population distribution of demographic data of the respondents.

Table 1
Demographics

Variables	N (%)
Gender	
Male	321(40.1%)
Female	478(59.7%)
Others	2(0.2%)
Marital Status	
Married	490(61.2%)
Unmarried	232(29%)
Widow/widower	55(6.9%)
Divorced	12(1.5%)
Separated	12(1.5%)
Employment	
Employed	296(37%)
Self Employed	210(26.2%)
Not Employed	295(36.8%)
Suffered Covid Symptoms	
Yes	121(15.1%)
No	680(84.9%)
Contact with Covid person	
Yes	173(21.6%)
No	466(58.2%)
Not Sure	162(20.2%)
Travel History	
Yes	14(1.7%)
No	787(98.3%)
Age	
18-30 years	115(14.2%)
30-50years	381(47.6%)
>50 years	305(38.1%)
Experience of Meditation	
1-4 years	184(23%)
5-10 years	248(31.0%)
11-20 years	158(19.7%)
21-30 years	76(9.5%)
>30 years	42(5.2%)
Not given	93(11.6%)

2.7. Analysis

To find out the internal consistency, Cronbach Alpha was calculated for the Hindi version of the IES-R scale and the corresponding subscales. Cronbach's alpha was evaluated using the following criteria: Excellent (0.9), Good (0.8), and Acceptable (0.7) according to the previously established studies [32]. Pearson's coefficients were used to assess the correlation between the subscales. A principal component analysis was run to find out the three-factor solution of the model of the IES-R scale.

3. Results

3.1. IES-R scores

The analysis resulted in an Impact of Event-revised scale sample mean score of 10.01 (with an S.D. of 11.107). The majority of the meditators (90.3%) rated minimal psychological impact as minimal, about 5.1% of them reported mild psychological impact, and only 4.6% of the sampled meditators suffered moderate or severe psychological impact. Table 2 shows the IES-R scores for Rajyoga meditators. As seen in the Table 2, most of the meditators felt normal during the crisis.

Table 2
Hindi IES-R scores for Rajyoga meditators

Level	Frequency	Percentage
Minimal	723	90.3
Mild	41	5.1
Moderate	9	1.1
Severe	28	3.5
Total	801	100.0

3.2. Internal consistency

The Hindi IES-R resulted in excellent internal consistency. The Cronbach's alpha value was 0.91. Cronbach's alpha values for intrusion subscale = 0.83, hyperarousal subscale = 0.81, and avoidance subscale = 0.81 showed good consistency across all three subscales.

3.3. Correlations

Table 3 shows correlation values between the three subscales. Within the three subscales of the IES-R, Pearson correlations were performed to analyse the connections. At the 0.01 level, all of the correlations are significant (2-tailed). As observed in Table 3, there was a high level of measured correlation between every pair of subscales (range 0.56 – 0.81). There were significant correlations of the age of the meditators, experience of meditation, and presence of illness and covid symptoms with IES-R scale scores. Though the overall percentage of meditators suffering severe or extreme severe impact is very less, but out of them, the meditators who were in the age group of 18 to 30 years, who were suffering from COVID symptoms and the beginners (having meditation experience of fewer than 4 years) suffered the highest impact. Table 4 shows the correlation of IES scores with the sociodemographic variables.

3.4. Construct validity

Principal component analysis evaluated the construct validity of the Hindi IES-R. There were three components with eigenvalues greater than one. This matched with the theoretical structure of IES-R scale [10]. The scree plot consisted of one large factor with an eigenvalue of 8.536 followed by two smaller factors with eigenvalue of 2.296 and 1.061 respectively.

None of the correlation coefficients in the SAQ were particularly large, and all of the items correlated pretty well. The KMO statistic value was 0.934, which is superb and the factor analysis was appropriate because Bartlett's measure was extremely significant ($p < 0.001$). Factor loadings > 0.5 were considered significant. The analysis explained 54.06% of the total variance. As shown in Table 5, the three-factor solution based on eigen value greater than one generated an intrusion hyperarousal component with all the items from intrusion and hyperarousal subscales (except items 16 and 21), an avoidance component with all the items from avoidance sub scale (except items 12 and 13), and third component with item 16 only. Item 13 had insignificant factor loading and thus removed. The analysis was done again without this item giving the total variance of 55.36%. The results were still the same after removing this item.

The previous studies have also explained the lack of correlation of item 13 with other items. It has been pointed out that item 13 should be carefully investigated and may need deletion in future studies [15]. This is because the word "numb" in this statement is confusing and misinterpreted. Item 21 has fallen on avoidance subscale in this analysis while this item taps into intrusion sub scale in theoretical model. This is in similarity with the previous research on factor analysis of IES-R scale [15]. Item 12 should have merged into the avoidance factor according to the theoretical model, but instead loaded on the intrusion- hyperarousal factor. This can be because the first part of the statement about feelings taps into intrusion symptoms, while the second part about dealing with the feelings taps into avoidance symptoms. Item 16 has been originally in the intrusion subscale in the theoretical model, but here it has fallen on the third component. This is because the "feelings" term seems to be confusing and everyone may have different perceptions about the word "feelings".

Table 3
Correlations between the subscales

	Intrusion	Hyperarousal	Avoidance
Intrusion	-	0.81*	0.56*
Hyperarousal	0.81*	-	0.61*
Avoidance	0.56*	0.61*	-

*Correlation is significant at the 0.01 level (2-tailed)

Table 4
Correlation of Hindi IES-R scores with socio-demographic variables

Variables	Severe/ Extreme severe impact Count (%)
Age	
18-30 years	6 (5.22%)
31-50 years	15(3.95%)
>50 years	7 (2.29%)
Presence of COVID symptoms	
Yes	10 (8.20%)
No	18 (2.65%)
Meditation experience (in years)	
0-4	15 (5.42%)
5-10	9 (3.63%)
11-20	4 (2.50%)
21-30	0 (0.0%)
>30	0 (0.0%)

Correlations are significant at the 0.01 level (2-tailed).

Table 5
Principal Component Analysis with three-factor solutions (varimax rotation).

Original factors, items	Content	Three- factor		
Hyper arousal		Intrusion Hyperarousal	Avoidance	Strong Feeling
4	Felt irritable and angry.	.746		
10	Jumpy and easily startled.	.777		
15	Trouble falling asleep.	.763		
18	Trouble concentrating.	.691		
19	Reminders caused physical reactions	.659		
21	Felt watchful and on guard.		.637	
Intrusion				
1	Reminders brought back feelings	.685		
2	Trouble staying asleep	.716		
3	Other things making think about it	.724		
6	Thought about it when didn't mean to	.756		
9	Pictures in head	.658		
14	Acting or feeling like back at that time.	.727		
16	Waves of strong feelings			.864
20	Had dreams	.695		
Avoidance				
5	Avoided getting upset		.636	
7	Felt as if it hadn't happened		.522	
8	Stayed away from reminders		.706	
11	Tried not to think about it.		.725	
12	Aware of feelings but didn't deal.	.667		
13	Numb feelings		.462	
17	Tried to remove it from memory.		.605	
22	Tried not to talk about it.		.745	
Eigen Value		8.536	2.296	1.061
% Variance		38.849	49.229	54.060

Loadings of <0.40 have been deleted.

3.5. Comparison with previous studies in general population during COVID-19

Previous studies have shown large impact and greater score of stress, anxiety and depression among general population of different countries as described in the introduction section.

Figure 1 shows the comparison of percentage of population with minimal, mild and moderate to severe scores of IES-R, along with mean of

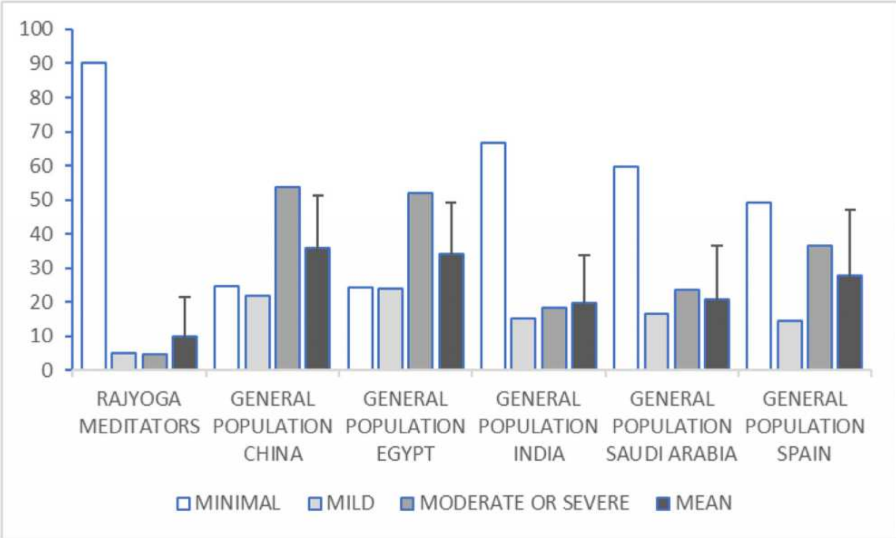


Fig. 1. Comparison of IES-R scores of Rajyoga meditators with those of general population

IES-R scores in Rajyoga meditators with those of general population attained in previous studies.

Thus, it is seen that the Rajyoga meditation helped the practitioners in building resilience against the stress caused by the virus. While most of the meditators were married and employed as per the survey, it also reflects their life chores and responsibility es are same as that of general population, yet they are less prone to stress and anxieties. It has also been shown in young adults of U.S. that greater levels of resilience are capable of attenuating the negative effect of their stress levels [33]. Even the online mindfulness session helped the participants decrease momentary anxiety, stress and COVID-19 concern [34]. Taken together, our study finds out that that when it comes to dealing with pressures, resilience is crucial and meditation interventions help achieve that resilience levels.

4. Discussion

The present study evaluated the internal consistency, correlations, and construct validity of the Hindi translation of IES-R scale in a population of Rajyoga meditators in the initial days of the second wave of COVID-19. The internal consistency of the Hindi IES-R is good, with alpha values ranging from 0.80 to 0.93. We have also suggested a three-factor structure of Hindi IES-R. The three-factor solution explained 54 percent of the total variance with one component merged as intrusion-hyperarousal component, second component as the avoidance component and the third component having only one value of having strong feeling about the disease.

Previously, many studies have analysed the factorial structures of IES-R. This scale was evaluated in research of survivors of life-threatening cardiac episodes, with a focus on the hyperarousal subscale [35]. Whereas the intrusion and avoidance subscale showed high reliability, weaker reliability was shown by the hyperarousal subscale. The study concluded that the hyperarousal subscale's criterion validity required further investigations. Another study looking into the analysis of IES-R in Vietnam veterans found high internal consistency of the scale and high correlations between the subscales [36]. Maximum likelihood estimate was used to conduct a confirmatory factor analysis. But it did not validate the three-component solution related to the three subscales. The exploratory factor analysis was then carried out and single component, two-component, and three-component solutions were provided. Like in our study, the two-component solution (intrusion/hyperarousal and avoidance) fitted the best. The psychometric features of an Arabic-translated version of the IES-R were also investigated for a population of Middle Eastern refugees [37]. Its factor analysis supported a three-component solution that explained 53.8% of the variance. Similarly, the Persian version of IES in a sample of people from Bam after the 2003 earthquake had good internal consistency [38]. Its factor analysis also concluded a three-factor solution which explained 41.6% of the variance. PCA analysis was also performed in the Arabic translation of the IES-R in a population of medical students undergone quarantine during the COVID-19 pandemic [14]. The three-component solution explained 50.5% of the variance.

The prevalence of COVID-19's psychological impact among meditators was also investigated in this study. As hypothesized, most of the Rajyoga meditators (90.1% of the total sampled population) were resilient towards the psychological impact of the Coronavirus and reported the impact as minimal. In the previous research on the psychological impact of Coronavirus among the general public, the lowest percentage of the sampled participants reporting the impact as moderate to severe was 18.2%. While among the Rajyoga meditators in this study, only 4.7 percent of the meditators have shown the impact as moderate to severe. Meditation experience and IES-R score had a negative connection. As the experience increased, the score (or the impact) diminished. So, meditation played a major role in minimizing the perceived impact of the epidemic.

Though the current study is limited by convenience sampling method and absence of test-retest analysis, it depicts the need of developing and delivering possible therapeutic approaches during, and after the pandemic. Therapeutic approaches are the deliberate interventions provided to manage mental illnesses. Health authorities are worried about the biological and physical repercussions of the outbreak, but the psychological consequences are being ignored. There is an urgent need to deliver validated psychological interventions to different sections of society. The guidelines on emergency psychological crisis intervention were also issued by National Health Commission in China on 27 January 2020 for giving mental health support services to patients and health care workers by trained professionals [39]. This type of public health crisis demands a digital mental health revolution for access of free mental health services to people across various platforms [40]. There can be two possible approaches to assist people suffering from psychological issues: psychotherapy and biomedical therapy. Psychotherapy uses psychological treatments or interventions whereas biomedical therapy involves medication and/or medical treatments to treat psychological disorders. Both the therapies are used in tandem for the treatment of psychological illnesses. Psychotherapies can be provided depending on the individuals and the symptoms experienced by them. The common types of psychotherapies include behavioural therapies, cognitive therapies, humanistic therapies or alternative therapies such as meditation and yoga. Yoga and meditation have acquired popularity as therapeutic programmes for psychological discomfort in the last 25 years. Psychotherapy is useful for a variety of illnesses, according to large-scale worldwide assessments of scientific studies. Specific therapies have been tested for use with specific disorders. Both the UK and the US regulatory bodies have provided recommendations of these therapies for certain disorders.

The results were compelling but the results did not generalize beyond Rajyoga meditators. Future studies may prospectively follow up the meditation practitioners in general, and the inclusion of test-retest analysis will further validate the results.

5. Conclusion

The Hindi translation of the IES-R scale is a viable tool for quantifying the psychological impact of Coronavirus pandemic in a population of Rajyoga meditators. This scale appears to be a reliable diagnostic and research tool. The translation of IES-R in Hindi and subsequent validation had filled the gap in its ability to analyze the impact of the pandemic among Hindi speaking population. Further researchers are welcome to use this version for assessing the impact of events on the lives of Indians. Moreover, focussing on the benefits of meditation in reducing the traumas caused by the epidemic will lead to the creation of useful complementary strategies and therapeutic approaches.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Informed consent

Before the study, all of the participants signed a consent form.

Data and material availability

Upon request, the corresponding author will make the data supporting the results of this study accessible.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

Appendix A

Question	English version IES-R	Hindi translation IES-R
1	Any reminder brought back feelings about it.	कोई भी अनुस्मारक मुझे इसकी याद दिलाता था।
2	I had trouble staying asleep.	मुझे सोते रहने में परेशानी होती थी ।
3	Other things kept making me think about it.	अन्य परिस्थितियों में भी इसके बारे में सोचा करता था।
4	I felt irritable and angry.	मैं चिड़चिड़ा और क्रोधित रहता था।
5	I avoided letting myself get upset when I thought about it or was reminded of it.	मैंने इसके बारे में सोचकर परेशान न होने की कोशिश की।
6	I thought about it when I didn't mean to.	मैंने ना चाहते हुए भी इसके बारे में सोचा।
7	I felt as if it hadn't happened or wasn't real.	मुझे लगता था कि ऐसा नहीं हुआ या यह वास्तविक नहीं है।
8	I stayed away from reminders about it.	मैं इसके बारे में याद दिलाने वाली हर चीज़ से दूर रहा।
9	Pictures about it popped into my mind.	इससे सम्बंधित चित्र मेरे दिमाग पर छाए रहते थे।
10	I was jumpy and easily startled.	मैं बेचैन और चौंकित रहता था।
11	I tried not to think about it.	इसके बारे में न सोचने की मैंने कोशिश की।
12	I was aware that I still had a lot of feelings about it, but I didn't deal with them.	मैं इससे सम्बंधित अपनी भावनाओं को समझता था लेकिन मैं उनसे उभर नहीं पाया।
13	My feelings about it were kind of numb.	इसके बारे मैं असंवेदनशील था।
14	I found myself acting or feeling as though I was back at that time.	मैंने खुद को ऐसा अभिनय करते या महसूस करते पाया कि मैं ठीक हूँ।
15	I had trouble falling asleep.	मुझे नींद आने में परेशानी होती थी।
16	I had waves of strong feelings about it.	मैं इसके बारे में भावनात्मक हो गया था।
17	I tried to remove it from my memory.	मैंने इसे अपनी स्मृति से हटाने की कोशिश की।
18	I had trouble concentrating.	मुझे ध्यान केंद्रित करने में परेशानी हुई।
19	Reminders of it caused me to have physical reactions, such as sweating, trouble breathing, nausea or a pounding heart.	इसके अनुस्मारकों ने मुझे शारीरिक प्रतिक्रियाएँ दीं, जैसे कि पसीना आना, सांस लेने में तकलीफ़ होना, जी मचिलाना या तेज़ धड़कन।
20	I had dreams about it.	मुझे इसके सपने आते थे।
21	I felt watchful or on-guard.	मैंने खुद को चौकन्ना महसूस किया।
22	I tried not to talk about it.	मैंने कोशिश की कि मैं इसके बारे में बात न करूँ।

References

[1] Xiong J, Lipsitz O, Nasri F, Lui LMW, Gill H, Phan L, et al. Impact of COVID-19 pandemic on mental health in the general population: A systematic review. J Affect Disord. 2020; 277(August):55–64. https://doi.org/10.1016/j.jad.2020.08.001.

[2] Wang C, Pan R, Wan X, Tan Y, Xu L, Ho CS, et al. Immediate psychological responses and associated factors during the initial stage of the 2019 coronavirus disease (COVID-19) epidemic among the general population in China. Int J Environ Res Public Health. 2020;17(5). https://doi.org/10.3390/ijerph17051729.

[3] Alkhamees AA, Alrashed SA, Alzunaydi AA, Almohimeed AS, Aljohani MS. The psychological impact of COVID-19 pandemic on the general population of Saudi Arabia. Compr Psychiatry. 2020;102:152192. https://doi.org/10.1016/j.comppsych.2020.152192.

[4] Rodríguez-Rey R, Garrido-Hernansaiz H, Collado S. Psychological Impact and Associated Factors During the Initial Stage of the Coronavirus (COVID-19) Pandemic Among the General Population in Spain. Front Psychol. 2020;11(June). https://doi.org/10.3389/fpsyg.2020.01540.

[5] Varshney M, Parel JT, Raizada N, Sarin SK. Initial psychological impact of COVID-19 and its correlates in Indian Community: An online (FEEL-COVID) survey. PLoS One. 2020;15(5):1–10. https://doi.org/10.1371/journal.pone.0233874.

[6] Wang C, Chudzicka-Czupała A, Tee ML, Núñez MIL, Tripp C, Fardin MA, et al. A chain mediation model on COVID-19 symptoms and mental health outcomes in Americans Asians and Europeans. Sci Rep. 2021;11(1):1–13. https://doi.org/10.1038/s41598-021-85943-7.

[7] Wang C, Tee M, Roy AE, Fardin MA, Srichokchatchawan W, Habib HA, et al. The impact of COVID-19 pandemic on physical and mental health of Asians: A study of seven middle-income countries in Asia. PLoS One. 2021;*16*(2 Febuary). https://doi.org/10.1371/journal.pone.0246824.

[8] Lee Y, Lui LMW, Chen-li D, Liao Y, Mansur RB. Government response moderates the mental health impact of COVID-19 : A systematic review and meta-analysis of depression outcomes across countries; 2020. January.

[9] Kolokotroni F. In: Michalos AC, editor. Impact of Event Scale BT - Encyclopedia of Quality of Life and Well-Being Research. Netherlands: Springer; 2014. p. 3102–5. https://doi.org/10.1007/978-94-007-0753-5_1377.

[10] Weiss DS, Marmar CR. The impact of event scale—revised assessing psychological trauma and PTSD. In: Wilson JP, Keane TM, editors. The Guilford Press. The Guilford Press; 1997. p. 399–411.

[11] Baguena Puigcerver MJ, Villarroya E, Beleña A, Díaz A, Roldán C, Reig R. Psychometric properties of the Spanish version of the impact of event scale revised (EIE-R). Análisis y Modificación de Conducta. 2001;27(114):581–604.

[12] Brunet A, St-Hilaire A, Jehel L, King S. Validation of a french version of the impact of event scale-revised. Can J Psychiatr. 2003;48(1):56–61. https://doi.org/10.1177/070674370304800111.

[13] Asukai N, Kato H, Kawamura N, Kim Y, Yamamoto K, Kishimoto J, et al. Reliability and validity of the Japanese-language version of the Impact of Event Scale-Revised (IES-R-J): Four studies of different traumatic events. J Nerv Ment Dis. 2002.;190(3) https://journals.lww.com/jonmd/Fulltext/2002/03000/RELIABILIGY_AND_VALIDITY_OF_THE_JAPANESE_LANGUAGE.6.aspx.

[14] Alharbi HY, Alzahrani AS. Reliability and Validity of Arabic Translation of Pandemic, 24; 2020; 105.

[15] Warsini S, Buettner P, Mills J, West C, Usher K. Psychometric evaluation of the Indonesian version of the Impact of Event Scale-Revised. J Psychiatr Ment Health Nurs. 2015; 22(4):251–9. https://doi.org/10.1111/jpm.12194.

[16] Wu KK, Chan SK. Psychometric properties of the Chinese version of the impact of event scale-revised. Hong Kong J Psychiatry. 2004;14(4):2–8.

[17] Sveen J, Lowaili A, Dyster-Aas J, Ekselius L, Willebrand M, Gerdin B. Validation of a Swedish version of the Impact of Event Scale-Revised (IES-R) in patients with burns. J Anxiety Disord. 2010;24(6):618–22. https://doi.org/10.1016/j.janxdis.2010.03.021.

[18] Olde E, Kleber RJ, van der Hart O, Pop VJM. Childbirth and posttraumatic stress responses: a validation study of the Dutch Impact of Event Scale-Revised. Eur J Psychol Assess. 2006;22(4):259–67. https://doi.org/10.1027/1015-5759.22.4.259.

[19] Wang C, Chudzicka-Czupała A, Grabowski D, Pan R, Adamus K, Wan X, et al. The Association Between Physical and Mental Health and Face Mask Use During the COVID-19

Pandemic: A Comparison of Two Countries With Different Views and Practices. Front Psychiatry. 2020;11(September):1–13. https://doi.org/10.3389/fpsyt.2020.569981.
[20] El-Zoghby SM, Soltan EM, Salama HM. Impact of the COVID-19 pandemic on mental health and social support among adult Egyptians. J Community Health. 2020;45(4): 689–95. https://doi.org/10.1007/s10900-020-00853-5.
[21] Wang C, López-Núñez MI, Pan R, Wan X, Tan Y, Xu L, et al. The impact of the COVID-19 pandemic on physical and mental health in China and Spain: Cross-sectional study. JMIR Format Res. 2021;5(5):1–10. https://doi.org/10.2196/27818.
[22] Wang C, Tripp C, Sears SF, Xu L, Tan Y, Zhou D, et al. The impact of the COVID-19 pandemic on physical and mental health in the two largest economies in the world: a comparison between the United States and China. J Behav Med. 2021;44(6):741–59. https://doi.org/10.1007/s10865-021-00237-7.
[23] Tee ML, Tee CA, Anlacan JP, Aligam KJG, Wincy P, Reyes C, et al. Psychological impact of COVID-19 pandemic in the Philippines. J Affect Dis [revista en Internet]. 2020;277: 379–91. [acceso 4 de junio de 2018]. January.
[24] Le XTT, Dang AK, Toweh J, Nguyen QN, Le HT, Do TTT, et al. Evaluating the Psychological Impacts Related to COVID-19 of Vietnamese People Under the First Nationwide Partial Lockdown in Vietnam. Front Psychiatry. 2020;11(September):1–8. https://doi.org/10.3389/fpsyt.2020.00824.
[25] Movements NR. The Brahma Kumaris World Spiritual University; 2008. June.
[26] Behan C. The benefits of meditation and mindfulness practices during times of crisis such as COVID-19. Ir J Psychol Med. 2020;37(4):256–8. https://doi.org/10.1017/ipm.2020.38.
[27] Sukhsohale ND, Phatak Mrunal S, Sukhsohale Sachin D, Agrawal Sanjay B. Does Raja Yoga meditation bring out physiological and psychological general well being among practitioners of it? Int J Collaborat Res Int Med Public Health. 2012;4(12):2000–12.
[28] Meshram K, Meshram A, Biswas D. Modulation of VO2 max by Rajyoga meditation in young adult males. Nat J Physiol Pharm Pharmacol. 2017;8(1):1. https://doi.org/10.5455/njppp.2018.8.0723431072017.
[29] Kiran U, Ladha S, Makhija N, Kapoor PM, Choudhury M, Das S, et al. The role of Rajyoga meditation for modulation of anxiety and serum cortisol in patients undergoing coronary artery bypass surgery: a prospective randomized control study. Ann Card Anaesth. 2017;20(2):158–62. https://doi.org/10.4103/aca.ACA_32_17.
[30] Kiran CH, Arora AK, Girgila KK. Original article effect of short term rajyoga meditation on anxiety and depression, 10; 2014; 18–20.
[31] Sharma K, Achermann P, Panwar B, Sahoo S, Ganesan A, Pascual-marqui RD, et al. Brain-electric activity during eyes open Brahma Kumaris Rajayoga meditation. MindrXiv. 2020:1–15.
[32] Gliem J, Gliem RR. Calculating, interpreting, and reporting Cronbac_s alpha reliability coefficient for Likert-Type Scales; 2003. https://bksparc.in/. (n.d.).
[33] Polizzi C, Lynn SJ, Perry A. Stress and coping in the time of COVID-19: Pathways to resilience and recovery. Clin Neuropsychiatry. 2020;17(2):59–62. https://doi.org/10.36131/CN20200204.
[34] Farris SR, Grazzi L, Holley M, Dorsett A, Xing K, Pierce CR, et al. Online mindfulness may target psychological distress and mental health during COVID-19. Global Adv Health Med. 2021;10. https://doi.org/10.1177/21649561211002461.
[35] Baumert J, Simon H, Gündel H, Schmitt C, Ladwig KH. The Impact of Event Scale - Revised: Evaluation of the subscales and correlations to psychophysiological startle response patterns in survivors of a life-threatening cardiac event: An analysis of 129 patients with an implanted cardioverter defibrillator. J Affect Disord. 2004;82(1): 29–41. https://doi.org/10.1016/j.jad.2003.09.006.
[36] Creamer M, Bell R, Failla S. Psychometric properties of the Impact of Event Scale - Revised. Behav Res Ther. 2003;41(12):1489–96. https://doi.org/10.1016/j.brat.2003.07.010.
[37] Davey C, Heard R, Lennings C. Development of the Arabic versions of the Impact of Events Scale-Revised and the Posttraumatic Growth Inventory to assess trauma and growth in Middle Eastern refugees in Australia. Clin Psychol. 2015;19(3):131–9. https://doi.org/10.1111/cp.12043.
[38] Panaghi L, Shooshtari M Hakim, Mogadam J Atari. Persian version validation in impact of event scale revised. Tehran Univ Med J. 2006;64(3):52–60.
[39] Li W, Yang Y, Liu ZH, Zhao YJ, Zhang Q, Zhang L, et al. Progression of mental health services during the COVID-19 outbreak in China. Int J Biol Sci. 2020;16(10):1732–8. https://doi.org/10.7150/ijbs.45120.
[40] Figueroa CA, Aguilera A. The need for a mental health technology revolution in the COVID-19 pandemic. Front Psychiatry. 2020;11(June):1–5. https://doi.org/10.3389/fpsyt.2020.00523.

Brain-electric activity during eyes open Brahma Kumaris Rajayoga meditation.

Kanishka Sharma[a], Peter Achermann[b], Bhawna Panwar[c], Shrikant Sahoo[c], Ramakrishnan Angarai Ganesan[a], Roberto D. Pascual-Marqui[b], Pascal L. Faber[b,*]

[a] Medical Intelligence and Language Engineering (MILE) Lab, Electrical Engineering Department, Indian Institute of Science, Bengaluru, India

[b] The KEY Institute for Brain-Mind Research, Department of Psychiatry, Psychotherapy and Psychosomatics, University Hospital of Psychiatry, Zurich, Switzerland

[c] Spiritual Applications Research Centre (SpARC Wing) of Rajyoga Education and Research Foundation (RERF) BrahmaKumaris, Mount Abu, India

[*] Corresponding author at:
The KEY Institute for Brain-Mind Research, University Hospital of Psychiatry, Lenggstr. 31, CH-8032 Zurich, Switzerland.
E-mail address: pfaber@key.uzh.ch (P.L. Faber) / scholar.google.com/citations?user=pascalfaber

Acknowledgements

The authors would like to acknowledge the team members who supported in experimental recording.

Abstract

Brahma Kumaris Rajayoga's open eyed 'seed stage meditation' was studied in 52 meditators. Meditation stages: concentration on peace, realization of being a soul and communion with the Supreme Soul. Frequency domain brain electric source localization was used on multichannel EEG recordings to establish activation differences between meditation and open eyed, task-free resting. Additional exploratory analyses probed for effects of passing time from initial rest through meditation to final rest. Meditation showed reduced activity in delta and increased activity in low alpha frequencies. Affected brain areas comprised the following networks: central executive network, mirroring network, task-positive and task-negative network. These altered activations reflect the main cognitive-affective and behavioral specifics of seed stage meditation: attention modulation, self-related processing, experiencing the soul as a point of light between the eyes, endowing the soul with the properties (peacefulness) of the Supreme Soul. Future studies need to differentiate between the stages of the meditation.

Keywords

Rajayoga, meditation, EEG, source localization, eLORETA

1. Introduction

Brahma Kumaris (BK) Rajayoga is a modern revival of the Indian Rajayoga (RY) system. Unlike most other RY systems, BK Rajayoga is not based on the Patanjalayoga system and has little to do with it (Birch, 2013). Rajayoga as taught by the Prajapita Brahmakumaris World Spiritual University and is popularized as a way for self-realization and the realization of the supreme almighty. It does not rely on rituals or mantras and can be practiced by anyone anywhere at any time. The most common meditation practice within this tradition is ‘seed stage meditation’. Practitioners believe that through this practice they seek the intellectual and loving communion of the soul with the Supreme Soul (Brahmakumaris, 1986). This meditation follows several steps and moves through different stages (Ramesh, Sathian, Sinu, & Kiranmai, 2013; Telles & Desiraju, 1993). Sitting with eyes open, in a comfortable posture, for example in an armchair, the practitioner gazes at a meaningful symbol, such as a picture depicting the Supreme Soul as a radiating point of light or just imagines the emergence of soul in between the two eye brows facing a neutral wall. The meditation itself goes through the following stages using appropriate autosuggestions to keep the mind focused on task during the process, thus avoiding the mind from wandering. Practice begins with sitting quietly and relaxed, followed by the stage of concentration, when the practitioner uses auto-suggestions to settle into a feeling of peace. This meditation can also be done using feelings of purity, love, joy, power or wisdom. In the present study, only the feeling of peace was used. The practitioner may either try to produce the feeling of peacefulness in the moment or bring forth this feeling through recalling it from an autobiographical memory. This feeling of peace is the foundation for the next stage, namely soul consciousness. The practitioner reminds him-/herself that he/she is a soul, a sparkling light between his/her eyes. The last stage is described by the practitioners as the connection (a conversation) of the soul with the Supreme Soul, a bodyless light source with perfect qualities of peace. The practitioner imagines receiving these qualities from the Supreme Soul and letting them permeate the soul. When successful, this culminates in absorption. The practitioner’s mind is totally calm, and there is little to no active guiding of the intellect; only calmness and absorption. Soul consciousness is a progression away from everyday concerns, away from the body, towards the realization of being a soul and the connection of this soul with the Supreme Soul and ultimately the absorption within it.

On a side note, seed stage meditation is practiced with open eyes for two reasons (Ramsay, Manderson, & Smith, 2010): First, the practitioners thus exercise their faculty to meditate anywhere irrespective of what is going on around them. Second, it is believed to enable direct communication between souls through ‘drishti’ (‘vision’) such as exchanging positive feelings.

Several attempts have been put forth in the literature to categorize meditation practices. The most common classification systems distinguish between focused attention (FA), open monitoring (OM) and automatic self-transcendence practices (Lutz, Slagter, Dunne, & Davidson, 2008; Raffone & Srinivasan, 2010; Travis & Shear, 2010). Josipovic (2010) proposed to include nondual awareness as a defining characteristic of some practices. Nash and Newberg (2013) categorize practices as belonging to a cognitive, affective and null domain. The respective practices foster an enhanced cognitive, affective, or non-cognitive/non-affective state. In order to allow for a better understanding of how the different practices might foster well-being, Dahl et al. (2015) proposed a classification distinguishing between attentional, constructive, and deconstructive families of practices, i.e. practices that cultivate meta-awareness, enhance cognitive and affective patterns which increase well-being or focus on self-inquiry respectively.

How does BK Rajayoga meditation (BKRYM) fit into these schemes? Rajayoga meditation has strong elements of an FA meditation as it needs concentration to guide the mind through the different stages, focusing on the soul (i.e. a point of light between the eyebrows) and the qualities of the Supreme Soul. This process of observing soul as a different entity from body but residing in itself can be categorized as self-monitoring. Following the classification of Nash & Newberg (2013), this would be the cognitive domain. As it also has a strong affective component with the practitioner seeking the feeling of peacefulness, the affective domain is also strongly present. Within the classification of Dahl et al. (2015) , BKRYM most strongly fits into the constructive family of practices, as it targets a change in perspective, a cognitive reappraisal of oneself as a soul that is pure in its qualities as are the souls of all human beings (see also Nair, Sasidharan, John, Mehrotra, & Kutty, 2017).

In general, regular meditation practice has many potential benefits (for a review, see Keng, Smoski, & Robins, 2011), such as increased subjective well-being, reduced psychological symptoms and emotional reactivity, and improved behavioral regulation. For a review on the benefits of yoga meditation in particular (including RY), see Rajoria and Singh (2017). Among the reported benefits of the practice of BK Rajayoga specifically are the following: improved basic cardio-respiratory functions (Sukhsohale & Phatak, 2012); reduced anxiety and depression scores (Kiran, Chalana, Arora, & Girgila, 2014); higher self-satisfaction and happiness in life compared to a non-meditator group (Ramesh et al., 2013); less neurotic symptoms and higher scores on hope and happiness (Misra, Gupta, Alreja, & Prakash, 2013); improved general well-being as measured with a quality of life questionnaire (WHO-QOL) after one year of practice (Meshram & Meshram, 2016) and significant increase of IQ in a group of 42 ADHD children after 3 months of practice (Naik, Patel, Biswas, & Verma, 2016). BK Rajayoga as other spiritual paths is thought to help generate resilience through the cultivation of meaning and self-transformation based on the respective spiritual guidelines (Ramsay & Manderson, 2011).

Not much is known about the brain electric mechanisms sub-serving the different states of the meditation practice of BK Rajayoga. A popular one-minute meditation in contrast with resting was explored in long-term BK Rajayoga practitioners, short term practitioners and meditation naïve subjects. This study reported increased theta and alpha band-power in the EEG for long-term and short-term practitioners respectively during meditation compared to resting (Nair et al., 2017), also long-term meditators reliably shifted between resting and meditation states, short-term meditators less reliably and controls were unable to do so. Another study exploring a 10-minute practice of meditation found changes in theta and lower alpha band and higher alpha-asymmetry in meditators during meditation compared to controls during resting (Sharma, Chandra, & Dubey, 2018). The activity of the default mode network (DMN) during BKRYM and resting compared to resting in control subjects was studied in a study using simultaneous EEG-fMRI recordings (Panda et al., 2016). Increased duration and occurrence of the EEG microstates corresponding to DMN activation was reported as well as an increase in EEG spectral power in the alpha, theta and beta bands (Panda et al., 2016).

In order to prepare the ground for future investigations about how physiological and psychological health benefits might be associated with the brain electric specifics of the BKRYM practice, we investigated the brain electrical underpinnings of this meditation practice compared to task free resting within a large group of experienced practitioners. We used frequency domain source localization to detect intracortical electrical activity changes occurring during meditation. Based on the description above of the cognitive and affective particulars of this practice, we expected brain areas involved in attention modulation as well as emotion and memory processing to show alterations in electrical activity. Consequently, we expected the central executive network (CEN) and the task-positive network to show increased activation and the default mode network to show decreased activation.

2. Materials & methods

2.1. Participants

Fifty-two meditators (age: 42.0 ± 10.1 years, range: 25-59; meditation experience: 17.5 ± 10.8 years, range: 4 -43; 14 females) were recruited and recorded during winter season when followers from across the world visit the headquarters of Brahma Kumaris.

2.2. EEG recordings

The EEG recordings took place at the International Centre for Higher Learning, Academy for a Better World, Brahma Kumaris, Gyan Sarovar, Mount Abu, India (1722 m above sea level). The recordings were performed in a small normally lit room with the participants sitting upright and either cross-legged on a couch or on the couch border with their feet on the ground. They were facing a neutral, coffee-colored tapestry on the wall. The experimenter controlled the recording from a small adjacent room containing the recording computer and allowing easy view of the participant through a clear glass window. Based on the 10-10 electrode placement system (Nuwer et al., 1998), 61 EEG channels were recorded at the following locations: Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, POz, O1, O2, AF7, AF3, AF4, AF8, F5, F1, F2, F6, FC3, FCz, FC4, C5, C1, C2, C6, CP3, CP4, P5, P1, P2, P6, PO5, PO3, PO4, PO6, FT7, FT8, TP7, TP8, PO7, PO8, Oz. All the channels were referenced to CPz, and AFz was used as ground. Horizontal left EOG was also recorded. The recordings were performed using a 64 channel ANT neuro mylab© system. EEG was recorded at 500 Hz. Impedance for all EEG and EOG channel was lower than 10 K Ohms to ensure data quality. The EEG amplifier along with the acquisition system (laptop) were running on battery and were not connected to the mains during data recording. Band pass filter was applied from 0.3 to 75 Hz in the recording software as was a 50 Hz notch filter.

2.3. Recording conditions

The recordings adhered to the following protocol:

- Initial rest: 3 min with eyes open (instruction: 'sit quietly without meditating')
- Initial rest: 3 min with eyes closed (instruction: 'close your eyes and sit quietly without meditating')
- 30 min of Rajayoga seed stage meditation with eyes open (shifting the awareness from the visible world to 'the soul and its peaceful nature' and then connecting to the 'Supreme Soul')
- Final rest: 3 min with eyes open (instruction: 'sit quietly without meditating')
- Final rest: 3 min with eyes closed resting (instruction: 'close your eyes and sit quietly without meditating')

During the 30 min of meditation the participants were prompted 4 to 5 times at random intervals via an acoustic tone to mentally note what was going through their minds. The whole protocol was timed using digital stopwatch to ensure proper length of data segments.

For the present report, mainly initial rest with eyes open was compared to meditation. Additional analyses were done to test for effects of passing time: the meditation data was cut into thirds to test for changes over time during meditation and meditation as well as initial rest (eyes open) were also compared to final rest (eyes open).

2.4. Data conditioning

The preprocessing of the EEG data first consisted of down-sampling the data to 128 Hz using spline interpolation. Then, 1 min of EEG was removed after each tonal prompt to avoid the inclusion of non-meditation epochs. First, eye movement artifacts were corrected using independent component analysis where necessary and then, the remaining eye, muscle, sweat and technical artifacts were marked through visual inspection. The EEG was segmented into 2-s epochs and all artifact-free epochs were exported for further analysis. The data was preprocessed using BrainVision Analyzer version 2.1.2 (www.brainproducts.com). The meditation session was cut into thirds to be able to check for time effects. To account for the difference in the recording duration between meditation and rest, a random selection of 50 artifact free epochs were collected for initial and final rest as well as for each third of the meditation (resulting in a total of 150 epochs for the complete meditation session).

2.5. Data analysis

The 50 preprocessed, artifact-free 2-s epochs per condition (150 for combined meditation thirds) were subjected to source localization analyses using exact low resolution brain electromagnetic tomography (eLORETA, Pascual-Marqui, 2007), freely available at http://www.uzh.ch/keyinst/loreta.htm. eLORETA is a genuine inverse solution that shows exact, zero error localization even in the presence of measurement and structured biological noise (Pascual-Marqui, 2007). The analysis procedure follows the LORETA functional tomography analysis approach (Pascual-Marqui et al., 1999; Pascual-Marqui, Michel, & Lehmann, 1994). Applying the procedure delineated in Frei et al. (2001), cross-spectra (128 discrete frequencies, from 0.5-64.0 Hz, at 0.5 Hz frequency resolution) were computed for all available epochs and averaged per condition and participant and then transformed into eLORETA images (with 6239 cortical voxels at a spatial resolution of 5 mm^3). For all comparisons between and within conditions, paired t-statistics were computed on the log-transformed current density values at each voxel. Corrections for multiple testing (over all 6239 voxels and 128 frequencies) using nonparametric randomization (Nichols & Holmes, 2002) were applied. Significant LORETA voxels were attributed to their corresponding Brodmann areas (BAs) based on their coordinates in MNI space (Evans & Collins, 1993).

3. Results

3.1. Meditation vs initial rest

Frequencies showing significant differences between meditation and initial rest in at least 15 voxels were found in two frequency ranges: the delta range between 0.5 and 4.0 Hz and the range between 7.0 and 9.5 Hz, which we consider as ‘low alpha’ (Klimesch, Doppelmayr, Schwaiger, Auinger, & Winkler, 1999). The cluster of significant voxels was largest at 1.5 Hz for delta and at 9.0 Hz for low alpha activity.

Meditation showed decreased delta activity compared to initial rest in a large cluster encompassing bilateral prefrontal (BAs 9, 10, 46), orbitofrontal (left BAs 11, 47) and dorsolateral areas (BA 46), the anterior insula (BA 13), the frontal eye fields (BA 8), Broca’s area (BAs 45, 44) and extending to the premotor cortex (BA 6) and in the primary motor cortex (BA 4), the somatosensory cortex (BAs 1, 2, 3 and adjacent BA 43), the precuneus (BA 7) and parietal areas (left BAs 5, 40) as well as temporal areas (BAs 20, 21, 22, 41, 42).

Meditation revealed increased activity compared to initial rest in low alpha frequencies. These increases were found bilaterally in the cingulate cortex (BAs 23, 24, 29, 30, 31), the parahippocampal and fusiform gyrus (BAs 27, 28, 36, 37), the superior and inferior temporal gyrus (BAs 22, 20), Wernicke’s area (BAs 39, 40) and the auditory cortex (BAs 41, 42 right), the insula (BA 13), the associative and secondary visual cortices (BA 18, 19) and precuneus (BA 7).

Figure 1 illustrates these findings with cortical slices through difference maxima between conditions per frequency. The number of voxels significantly differing between conditions in the delta and low alpha range are listed in Table 1 (left) per Brodmann area and in Table 2 per anatomical structure.

No significant differences between meditation and initial rest were present in other frequency ranges, i.e. the theta, upper alpha, beta, and gamma frequencies.

Sharma, Achermann, Panwar, Sahoo, Angarai Ganesan, Pascual-Marqui, Faber: Brain-electric activity during eyes open Brahma Kumaris Rajayoga meditation. Date: 2020-12-17

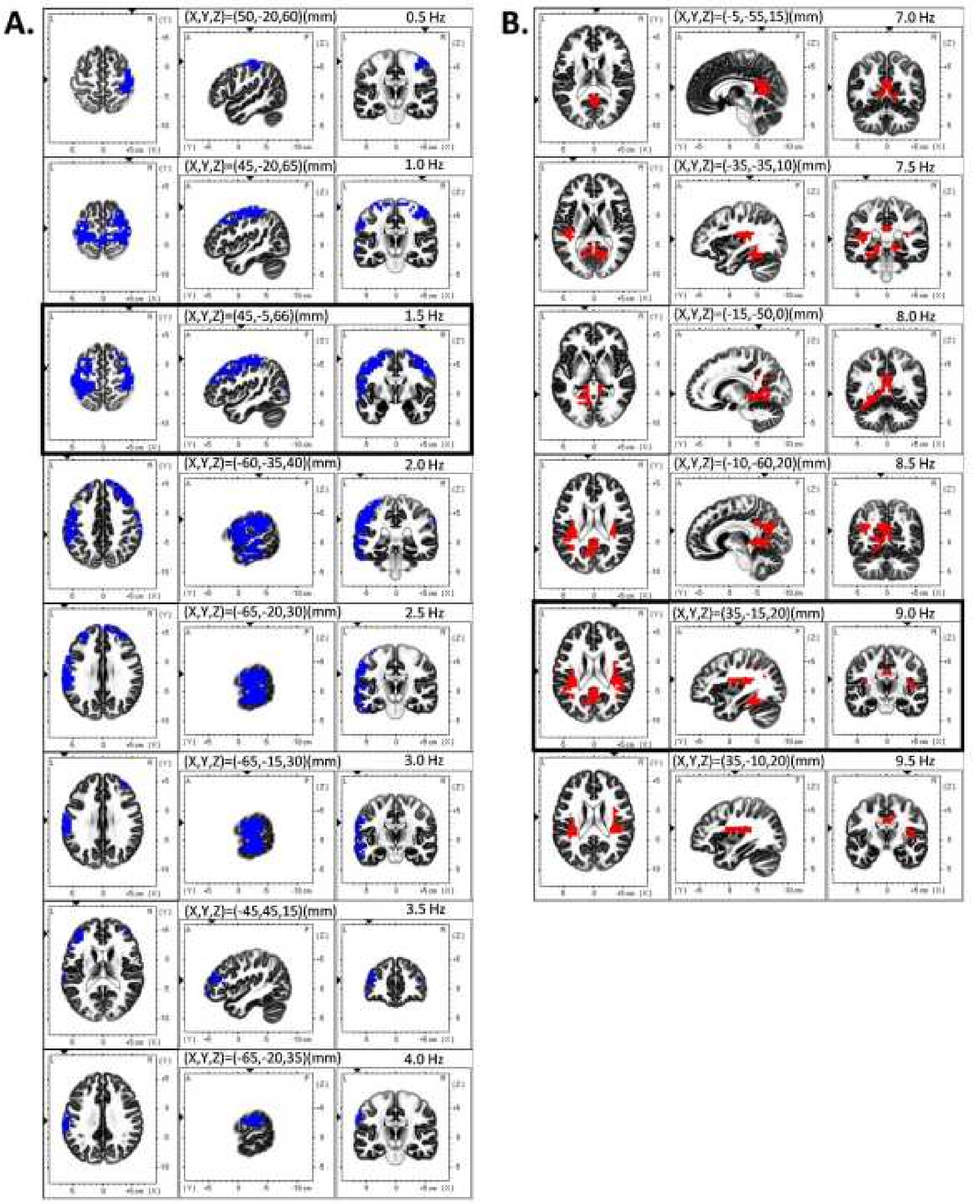


Fig. 1. Frequencies showing significant differences between meditation and initial rest. Decreases (blue) during meditation were seen in delta frequencies (A.) Increases (red) during meditation were seen in low alpha frequencies (B.). Shown are slices (transverse, sagittal and coronal from left to right) through the voxel of maximal difference (indicated by black triangles) between meditation and initial rest per frequency. The MNI coordinates of the voxel of maximal difference are indicated on top of each sagittal slice, and the frequency on top of the coronal slice. Slices with bold borders indicate the frequency in each frequency range with the highest number of significant voxels.

Table 1. Number of voxels per Brodmann area significantly differing between meditation and initial and final rest for specific frequency / frequency ranges showing at least 15 significant voxels in each associated frequency.

	meditation vs initial rest						**final rest vs meditation**						**final rest vs initial rest**					
	0.5 – 4.0 Hz			**7.0 – 9.5 Hz**			**1.5 – 7.0 Hz**			**11.0 – 14.5 Hz**			**1.5 – 7.0 Hz**			**26 Hz**		
	decreases in meditation			*increases* in meditation			decreases in final rest			decreases in final rest			decreases in final rest			decreases in final rest		
BA	**LH**	**M**	**RH**	**LH**	**M**	**RH**	**LH**	**M**	**RH**	**LH**	**M**	**RH**	**LH**	**M**	**RH**	**LH**	**M**	**RH**
1	9	-	9	-	-	-	7	-	9	4	-	2	9	-	8	1	-	-
2	40	-	27	-	-	*3*	42	-	46	18	-	13	43	-	42	6	-	-
3	66	-	41	-	-	-	67	-	56	49	-	31	72	-	54	17	-	-
4	63	1	56	-	-	-	59	1	66	40	1	42	69	1	70	8	-	-
5	20	1	8	-	-	-	40	9	41	40	9	41	40	9	41	14	-	9
6	173	1	153	-	-	*2*	185	12	122	163	13	150	261	13	275	15	-	-
7	9	-	-	*13*	*4*	*2*	186	25	189	98	10	85	186	25	198	15	-	78
8	9	-	63	-	-	-	23	8	36	10	7	9	74	9	91	-	-	-
9	34	-	93	-	-	-	38	3	9	-	-	2	124	9	134	-	-	-
10	30	-	46	-	-	-	-	-	-	-	-	-	56	-	51	-	-	-
11	4	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-
13	11	-	2	*30*	-	*66*	12	-	4	-	-	-	37	-	36	-	-	-
17	-	-	-	-	-	-	36	2	21	-	-	-	36	2	36	-	-	-
18	-	-	-	*8*	-	*9*	145	28	80	-	-	-	141	28	142	-	-	-
19	-	-	1	*41*	-	*26*	180	2	78	-	-	-	179	2	170	-	-	-
20	31	-	-	*8*	-	*11*	-	-	-	-	-	-	11	-	74	-	-	-
21	63	-	-	-	-	-	-	-	-	-	-	-	12	-	101	-	-	-
22	60	-	10	*3*	-	*8*	6	-	4	-	-	-	37	-	85	-	-	-
23	-	-	-	*12*	*1*	*19*	15	15	22	10	8	11	3	-	3	-	-	-
24	-	-	-	*4*	*5*	*15*	39	13	46	44	13	58	43	9	37	-	-	-
27	-	-	-	*7*	-	*9*	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	*3*	-	*1*	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	*5*	-	*4*	5	-	4	-	-	-	-	-	-	-	-	-
30	-	-	-	*30*	*3*	*35*	32	3	19	-	-	-	13	-	13	-	-	-
31	-	-	-	*56*	*1*	*53*	80	29	59	42	19	37	49	10	35	-	-	-
32	-	-	-	-	-	-	17	4	26	22	4	28	39	5	39	-	-	-
35	-	-	-	*5*	-	*1*	-	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	*10*	-	*10*	-	-	-	-	-	-	1	-	15	-	-	-
37	2	-	-	*28*	-	*15*	23	-	-	-	-	-	83	-	88	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-
39	3	-	8	*18*	-	*3*	70	-	29	-	-	-	77	-	60	-	-	-
40	164	-	101	*3*	-	*8*	174	-	147	59	-	43	189	-	180	4	-	6
41	11	-	-	*17*	-	*21*	-	-	-	-	-	-	13	-	27	-	-	-
42	19	-	4	-	-	*1*	2	-	2	-	-	-	11	-	20	-	-	-
43	10	-	1	-	-	-	-	-	-	-	-	-	12	-	11	-	-	-
44	22	-	8	-	-	-	-	-	-	-	-	-	22	-	15	-	-	-
45	25	-	15	-	-	-	-	-	-	-	-	-	14	-	27	-	-	-
46	20	-	21	-	-	-	-	-	6	-	-	-	18	-	26	-	-	-
47	14	-	1	-	-	-	-	-	-	-	-	-	1	-	28	-	-	-

LH: left hemisphere, RH: right hemisphere, M: midline voxels. Numbers in italics indicate activity increases in the respective frequency / frequency range and condition, normal font numbers indicate activity decreases.

Table 2: Number of voxels per anatomical structure significantly differing between meditation and initial rest in 2 frequency ranges (0.5-4.0 Hz; decreases in meditation and 7.0-9.5 Hz; increases in meditation).

	meditation vs initial rest					
	0.5 – 4.0 Hz			7.0 – 9.5 Hz		
	decreases in meditation			*increases* in meditation		
anatomical structure	**LH**	**M**	**RH**	**LH**	**M**	**RH**
Inferior Frontal Gyrus	76	-	40	-	-	-
Medial Frontal Gyrus	9	-	20	-	-	-
Middle Frontal Gyrus	108	-	164	-	-	-
Superior Frontal Gyrus	50	-	107	-	-	-
Precentral Gyrus	149	-	115	-	-	*2*
Postcentral Gyrus	160	-	103	-	-	*5*
Paracentral Lobule	6	3	8	-	-	-
Anterior Cingulate	-	-	-	*6*	*6*	*22*
Posterior Cingulate	-	-	-	*241*	*116*	*236*
Parahippocampal Gyrus	-	-	-	*204*	-	*93*
Transverse Temporal Gyrus	12	-	-	*20*	-	*10*
Inferior Temporal Gyrus	27	-	-	*1*	-	-
Middle Temporal Gyrus	64	-	6	*8*	-	*2*
Superior Temporal Gyrus	77	-	18	*58*	-	*40*
Insula	8	-	1	*125*	-	*129*
Fusiform Gyrus	9	-	-	*80*	-	*22*
Lingual Gyrus	-	-	-	*70*	-	*37*
Precuneus	1	-	-	*92*	*30*	*38*
Cuneus	-	-	-	*19*	-	*14*
Inferior Parietal Lobule	146	-	86	*2*	-	*8*
Superior Parietal Lobule	10	-	-	*7*	-	-

LH: left hemisphere, RH: right hemisphere, M: midline voxels. Numbers in italics indicate activity increases in the respective frequency range and condition, normal font numbers indicate activity decreases.

3.2. Temporal evolution during meditation

Successive thirds of meditation did not differ, i.e. the beginning from the middle part and the middle from the final part. However, from the beginning to the final part of the meditation a decrease in low frequencies (1.5-4.5 Hz) in the motor (BAs 4, 6) and somatosensory (BAs 1, 2, 3, 5) cortices as well as parietal areas (BA 40) were observed (table 3). Some decreases occurred also at 26 Hz, mainly in the left cingulate cortex (BAs 23, 24, 31; Table 3).

Table 3. Number of voxels per Brodmann area significantly differing between first and last third of meditation for frequencies / frequency ranges showing at least 15 significant voxels in each associated frequency.

	meditation third part vs first part					
	1.5 – 4.5 Hz			**26 Hz**		
	decreases in third part			*increases* in third part		
BA	**LH**	**M**	**RH**	**LH**	**M**	**RH**
1	6	-	-	-	-	-
2	24	-	6	-	-	-
3	17	-	5	*1*	-	-
4	11	-	7	*1*	-	-
5	-	-	6	-	-	-
6	2	-	1	*7*	-	-
7	-	-	1	-	-	-
23	-	-	-	*5*	-	-
24	-	-	-	*18*	-	-
31	-	-	-	*13*	-	-
40	25	-	18	-	-	-

LH: left hemisphere, RH: right hemisphere, M: midline voxels. Numbers in italics indicate activity increases in the respective frequency / frequency range and condition, normal font numbers indicate activity decreases.

3.4. Final rest compared to meditation and initial rest

Final rest showed decreases compared to meditation in large areas of two frequency ranges (1.5-7 Hz and 13.5-14.5 Hz), and also decreases compared to initial rest in the frequency ranges of 1.0-7 Hz and 13.5-14.5 Hz (Table 1, right).

4. Discussion

The main goal of the present study was to look at changes in EEG sources (i.e. activity in specific brain areas) during BKRYM meditation compared to rest. Arguably, initial rest before meditation is closer to everyday resting than final rest immediately following a meditation session. Therefore, our main focus was on the comparison of meditation with initial rest. In a more exploratory analysis, final rest was included to evaluate possible lingering effects of the meditation session. Further, the meditation session data was partitioned into thirds and pairwise compared as a means to find possible indications of arousal differences due to the passing of time. First, we will discuss the results of the main comparison between meditation and initial rest.

4.1. Reduced inhibition

During BKRYM 'seed stage meditation', the inhibitory delta band activity (Niedermeyer & Lopes da Silva, 1993) decreased in a large bilateral frontal and central cluster that extended into left-hemispheric temporal and parietal areas (Figure 1, Table 1 (left) and Table 2). Thus, we see reduced functional inhibition, which likely implies increased activation (processing) in these affected areas during meditation as compared to task-free rest. These areas sub-serve functions such as empathy (bilateral (pre-)frontal: Seitz, Nickel, & Azari, 2006), behavioral inhibition / executive control (dorsolateral prefrontal cortex – DLPFC: Kübler, Dixon, & Garavan, 2006; Van Oort et al., 2017), visuo-spatial cognition and spatial information processing (middle frontal, BAs 9/46: Leung, Gore, & Goldman-Rakic, 2002), somatosensory processing (homunculus) (BAs 3,1,2) and semantic language processing (BAs 20,21,22,44,45,6: Bookheimer, 2002). As hypothesized, at the level of affected brain networks, we see an activation of the central executive network (CEN) (Van Oort et al., 2017) with decreased delta activity in the DLPFC (BAs 9,10 46), the frontal eye fields (FEF; BA 8) and the posterior parietal cortex (PPC; BA 7). Sustaining attention during meditation has been reported to keep the DLPFC as part of the CEN activated (Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012).

Our results fit well the subjective experience involved in seed stage meditation. The increased behavioral inhibition is expected as the meditators sit still and relaxed during meditation. Increased semantic language processing could be the result of the auto-suggestive nature of the meditation process, since the meditators internally verbalize the steps involved in achieving each stage of the meditation. The left-sided activation of language areas (BAs 44/45 and 21/22) possibly reflects the logical reasoning involved in following the sequence of auto-suggestive sentences (Bookheimer, 2002; Caplan & Dapretto, 2001).

We found increased activation in the somatosensory cortex (homunculus, BAs 3,2,1). On one hand, this is a bit surprising, as meditators do not actively pay attention to their body. One explanation for this finding could be that during resting, the practitioners actively were inhibiting (higher delta activity) the somatosensory cortex, as they were instructed to sit quietly and not move. During meditation, there was no longer any special focus on relaxation or on not moving and the activity in the somatosensory cortex went back to more normal levels, i.e. resulting in reduced delta activity as compared to resting. On the other hand, the 20% of voxels showing the highest t-values for reduced delta activity were located in a small cluster with average MNI coordinates (44, 1, 51 mm) in the right hemisphere and (-60, -28, 32 mm) in the left hemisphere, corresponding to the face areas on the homunculus (Roux, Djidjeli, & Durand, 2018). This might be the result of focusing the attention between the eyes as an important stage during the meditation. The increased visuo-spatial cognition and spatial information storage might result from having the eyes opened during the meditation. This allows the meditator to keep an image of himself/herself in relation to the tapestry on the wall that he/she gazes at. It is even conceivable that the nature of the meditation itself fosters spatial processing. Indeed, the meditator attempts to become aware of himself/herself as a soul, a point of light between the eyes that becomes increasingly distanced to the material world. Also, the Supreme Soul is envisioned as separate from the soul before letting the perfect qualities of the Supreme Soul permeate the soul, which implies a direction. This latter part of sensing the perfect qualities of the Supreme Soul and attempting to let them permeate the self, might explain the apparently enhanced emphatic processing during meditation.

4.2. Increased facilitation

Power in the low alpha frequencies (7.0 to 9.5 Hz) increased during meditation in a cluster of voxels with the cluster being largest at 9.0 Hz (Figure 1). While upper alpha frequencies have been considered inhibitory (Bazanova & Vernon, 2014; Klimesch, Doppelmayr, Russegger, Pachinger, & Schwaiger, 1998; Klimesch et al., 1999), we consider lower alpha frequencies as facilitatory and therefore as activation. This cluster encompassed the bilateral posterior (and to a lesser degree the right anterior) cingulate, extended bilaterally to the parahippocampal gyrus and the superior temporal gyrus, the bilateral insula, the fusiform gyrus, the inferior parietal lobule, bilateral lingual gyrus, and occipitally and bilaterally to the cuneus and precuneus. How does an activation of these brain areas relate to soul-conscious meditation?

The left BA 37 and BA 19 bilaterally have been implicated in mental imagery (D'Esposito et al., 1997), as were BAs 40 and 7 (Knauff, Kassubek, Mulack, & Greenlee, 2000) and 18 (De Volder et al., 2001). Soul-conscious meditation has a strong focus on mental imagery as the practitioner imagines himself/herself as a point of light between the eyes, as distant from his/her body and the world and witnessing the light of the Supreme Soul.

The involvement of the insula (BA 13) might result from imagining the feeling of peacefulness as the insula processes states of feeling cortically (Damasio, Damasio, & Tranel, 2012). The perirhinal cortex (BA 36) processes semantic memory (Davies, Graham, Xuereb, Williams, & Hodges, 2004) as do other parts of the temporal lobe (BAs 20, 21 and 22) (Bookheimer, 2002) and their activation could reflect the meditators' focus on the concept of peacefulness and related memories. One of these areas was activated by decreased delta (BA 21), one by increased low alpha (BA 36) and some by both frequency ranges (BAs 13, 20, 22). Considering both frequency ranges as activations, what activation patterns appear across frequency ranges?

4.3. Combined activations

Across delta and low alpha, several networks were activated. The mirroring or experience sharing network (for a meta-analysis see Molenberghs, Cunnington, & Mattingley, 2012) was activated in its classical regions (ventral premotor cortex, inferior frontal gyrus, inferior parietal lobule) and also in regions associated especially with mirroring emotional expression (insula and cingulate cortex) (Molenberghs et al., 2012). An important part of BKRYM seed stage meditation is for the practitioner trying to mirror the feeling of peacefulness perceived in the Supreme Soul and let it permeate his/her own soul. This could explain the activation of this network.

Thirty-five % of all significant voxels across delta and low alpha belonged to the task-positive network (BAs 6, 19, 37, 40, 46) and twenty-two % to the task-negative network (BAs 8, 10, 20, 21, 30, 31, 39) (Fox et al., 2005). While the activation of the task-positive network confirms our hypothesis, the activation of the task-negative network was unexpected. These two networks are typically anti-correlated (Fox et al., 2005; Fukunaga et al., 2006) , except for states of non-dual awareness during deep meditation as proposed by Josipovic (2014). The task-negative network (or default mode network - DMN, Raichle et al., 2001) has been related to mind wandering (Mason et al., 2007), episodic memory processing (Buckner, Andrews-Hanna, & Schacter, 2008; Greicius, Srivastava, Reiss, & Menon, 2004) and conceptual processing (Binder et al., 1999). Interestingly, these processes are all important for maintaining the sense of self (Gusnard, Akbudak, Shulman, & Raichle, 2001; Lou et al., 2004). Many meditation practices tend to weaken the sense of self and are accompanied by a deactivation of the DMN (e.g. Brewer et al., 2011; Garrison, Zeffiro, Scheinost, Constable, & Brewer, 2015). Soul consciousness though has a strong focus on the self, as it relates the self to the everyday world, the own body, the point between the eyes and the Supreme Soul during its different stages. Self-related processing is known to activate the DMN (Buckner et al., 2008; Raichle et al., 2001).

The areas belonging to the task-positive network have been associated with different aspects of attention (Corbetta, Patel, & Shulman, 2008; Posner & Petersen, 1990). Shifting the attention back to the focus of the meditation after noticing mind wandering as well as sustaining the attention on the focus of meditation has been associated with activation in the task-positive network (Hasenkamp et al., 2012).

It is interesting that the two networks are both activated during BKRYM seed stage meditation. There is no subjective evidence for a state of non-dual awareness during the different stages of the meditation, except maybe for the very last stage. So, they should rather be anti-correlated. It is conceivable that these simultaneous activations are due to the averaging over the different stages of the meditation. Possibly, at different times during the meditation, there is an anti-correlation of the networks. This needs to be disentangled in future studies by differentiating between the different stages of meditation. Across all states, BKRYM seed stage meditation seems to involve the task-negative network with its strong focus on self-referential processing and the task-positive network with its need to shift attention to and sustain it on the task of going through the different stages of the meditation.

It is unclear why certain brain areas were activated by reduced delta activity and others by increased low alpha activity. A few regions showed activations in both frequency ranges (Table 1). Possibly, studying separately the different states of BKRYM seed stage meditation could shed some light on this issue.

How could the present findings relate to the reported benefits of meditation in general and BKRYM in particular? It has been proposed that associative learning processes through imagination help promote change and well-being (Reddan, Wager, & Schiller, 2018). It is conceivable that the mechanism leading to change and enhanced well-being through the continued practice of soul-conscious meditation lies in imagining oneself as a soul, a light point between the eyes and linking the own soul (oneself) with the Supreme Soul, mirroring its pure attributes (such as peacefulness) and the reported underlying brain-electric activations.

4.4. Probing for time effects

To probe for effects of passing time (e.g. changes in arousal) over the 30-min meditation session, the meditation data was partitioned into three blocks, each covering 10 minutes of the meditation. The middle part did not differ from the first or third part. There were slight changes from the first to the third part of the meditation though. These changes were decreases in delta (1.5 – 4.5 Hz) activity in somatosensory, premotor and motor cortices (BAs 1-6) as well as the inferior parietal lobule (BA 40) and increases at 26 Hz in the cingulate cortex (BAs 23, 24, 31), and the premotor and supplementary motor area (BA 6). All these changes also show up when comparing the complete meditation session to initial rest. These changes thus slightly increase with progression of the 30-min meditation session.

4.5. Comparisons with final rest

Meditation shows different changes compared to final rest than it does to initial rest. Most noteworthy is the decrease of upper alpha (11.0-14.5 Hz) frequencies in final rest, but also the decrease of activity in the delta and theta (1.5-7.0 Hz) frequencies in many areas. Thus, it is apparent that coming out of meditation is different from going into meditation. This has already been described in a study on functional connectivity in meditators from 5 different meditation traditions (Lehmann et al., 2012). On a side note, the differential involvement of low alpha during meditation compared to initial rest and upper alpha during final rest compared to meditation seems to imply that low and upper alpha reflect different processes and caution should be applied when analyzing a single broad alpha band.

At this point, we do not want to over-interpret these findings, because final rest immediately followed meditation without any break, except for the experimenter prompting the participant to stop meditating. It seems reasonable that large parts of the brain show changes during this transition back to a normal state. To study the change from meditation to rest after meditation, future studies should record rest during a longer time period after meditation or during several intervals within a couple of hours after meditation. This would help elucidate how the brain returns to its normal, everyday state of mind after an extended meditation session.

The same holds for the comparisons of final to initial rest. Final rest differs largely from initial rest in almost all brain areas, thus possibly showing a lingering effect of the meditation session combined with a reorganization of brain activity to normal processing. Not knowing when the return to a normal state is complete, looking only at these first 3 minutes seems insufficient to draw any useful conclusions.

4.6. Limitations

We note some limitations of this study. First, our practitioners were all adept Brahma Kumaris meditators. As such, they practice a certain lifestyle that could very well have an influence on their general state of mind, irrespective of the seed stage meditation studied here. This lifestyle includes celibacy, a vegetarian diet and a strict daily routine (e.g. getting up early for morning meditation).

Second, Mount Abu is situated at 1,722 m above sea and the altitude could have influenced the EEG patterns. Also, the recordings were performed during a winter retreat. We note that all participants had 3 to 5 days of acclimatization before the recording. The more intense meditation schedule during the retreat might also have influenced the results. Although, these effects should all be mitigated by our intra-subject comparisons.

Third, the recording protocol did not control for the different stages of meditation. Each meditator used his/her idiosyncratic pacing. To disentangle the brain electric characteristics of the different stages, these should be triggered by the experimenter in a controlled fashion in future studies.

Fourth, to study how the brain activity returns to normal after an extended meditation session, future studies should record rest after meditation over a prolonged period.

4.7. Conclusion

In sum, the BKRYM seed stage meditation with open eyes showed activations in brain areas sub-serving the subjective experience of the practitioners during the different stages of meditation. The modulated areas were part of the CEN, the DMN and the task-positive network. They inhibit movement, foster and modulate attention to stay on the task of moving through the different stages of the meditation and enable self-related processing for experiencing the soul as a point of light between the eyes, distant from the everyday world, and endowing it with the properties (i.e. peacefulness) of the Supreme Soul.

Ethical approval

All the procedures performed in this study were in accordance with the ethical standards of the Institutional ethics committee of Rajayoga Education and Research Foundation (RERF) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or

not-for-profit sectors.

Disclosure

The authors declare that they have no conflict of interest.

References

Bazanova, O., & Vernon, D. (2014). Interpreting EEG alpha activity. *Neuroscience & Biobehavioral Reviews,* 44, 94-110.
Binder, J. R., Frost, J. A., Hammeke, T. A., Bellgowan, P., Rao, S. M., & Cox, R. W. (1999). Conceptual processing during the conscious resting state: a functional MRI study. *Journal of cognitive neuroscience,* 11(1), 80-93.
Birch, J. (2013). Rājayoga: The Reincarnations of the King of All Yogas. *International Journal of Hindu Studies,* 17(3), 399-442.
Bookheimer, S. (2002). Functional MRI of language: new approaches to understanding the cortical organization of semantic processing. *Annual review of neuroscience,* 25(1), 151-188.
Brahmakumaris. (1986). *Positive Health - Rajayoga meditation for stress-free peaceful and healthy life.* Delhi, India: Prajapitha Brahma Kumaris Ishwarya Vishwa Vidyalaya.
Brewer, J. A., Worhunsky, P. D., Gray, J. R., Tang, Y.-Y., Weber, J., & Kober, H. (2011). Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences,* 108(50), 20254-20259.
Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences,* 1124(1), 1-38.
Caplan, R., & Dapretto, M. (2001). Making sense during conversation: an fMRI study. *Neuroreport,* 12(16), 3625-3632.
Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: from environment to theory of mind. *Neuron,* 58(3), 306-324.
D'Esposito, M., Detre, J. A., Aguirre, G. K., Stallcup, M., Alsop, D. C., Tippet, L. J., et al. (1997). A functional MRI study of mental image generation. *Neuropsychologia,* 35(5), 725-730.
Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: cognitive mechanisms in meditation practice. *Trends in cognitive sciences,* 19(9), 515-523.
Damasio, A., Damasio, H., & Tranel, D. (2012). Persistence of feelings and sentience after bilateral damage of the insula. *Cerebral Cortex,* 23(4), 833-846.
Davies, R., Graham, K. S., Xuereb, J. H., Williams, G. B., & Hodges, J. R. (2004). The human perirhinal cortex and semantic memory. *European Journal of Neuroscience,* 20(9), 2441-2446.

De Volder, A. G., Toyama, H., Kimura, Y., Kiyosawa, M., Nakano, H., Vanlierde, A., et al. (2001). Auditory triggered mental imagery of shape involves visual association areas in early blind humans. *Neuroimage,* 14(1), 129-139.
Evans, A., & Collins, D. (1993). *A 305-member MRI-based stereotaxic atlas for CBF activation studies.* Paper presented at the Journal of Nuclear Medicine.
Fox, M. D., Snyder, A. Z., Vincent, J. L., Corbetta, M., Van Essen, D. C., & Raichle, M. E. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences,* 102(27), 9673-9678.
Frei, E., Gamma, A., Pascual-Marqui, R., Lehmann, D., Hell, D., & Vollenweider, F. X. (2001). Localization of MDMA-induced brain activity in healthy volunteers using low resolution brain electromagnetic tomography (LORETA). *Human brain mapping,* 14(3), 152-165.
Fukunaga, M., Horovitz, S. G., van Gelderen, P., de Zwart, J. A., Jansma, J. M., Ikonomidou, V. N., et al. (2006). Large-amplitude, spatially correlated fluctuations in BOLD fMRI signals during extended rest and early sleep stages. *Magnetic resonance imaging,* 24(8), 979-992.
Garrison, K. A., Zeffiro, T. A., Scheinost, D., Constable, R. T., & Brewer, J. A. (2015). Meditation leads to reduced default mode network activity beyond an active task. *Cognitive, Affective, & Behavioral Neuroscience,* 15(3), 712-720.
Greicius, M. D., Srivastava, G., Reiss, A. L., & Menon, V. (2004). Default-mode network activity distinguishes Alzheimer's disease from healthy aging: evidence from functional MRI. *Proceedings of the National Academy of Sciences,* 101(13), 4637-4642.
Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: relation to a default mode of brain function. *Proceedings of the National Academy of Sciences,* 98(7), 4259-4264.
Hasenkamp, W., Wilson-Mendenhall, C. D., Duncan, E., & Barsalou, L. W. (2012). Mind wandering and attention during focused meditation: a fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage,* 59(1), 750-760.
Josipovic, Z. (2010). Duality and nonduality in meditation research. *Consciousness and cognition,* 19(4), 1119-1121.
Josipovic, Z. (2014). Neural correlates of nondual awareness in meditation. *Annals of the New York Academy of Sciences,* 1307(1), 9-18.
Keng, S.-L., Smoski, M. J., & Robins, C. J. (2011). Effects of mindfulness on psychological health: A review of empirical studies. *Clinical psychology review,* 31(6), 1041-1056.
Kiran, Chalana, H., Arora, A. K., & Girgila, K. K. (2014). Effect of short term Rajyoga meditation on anxiety and depression. *Pakistan Journal of Physiology,* 10(1-2), 18-20.
Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience letters,* 244(2), 73-76.
Klimesch, W., Doppelmayr, M., Schwaiger, J., Auinger, P., & Winkler, T. (1999). Paradoxical'alpha synchronization in a memory task. *Cognitive Brain Research,* 7(4), 493-501.
Knauff, M., Kassubek, J., Mulack, T., & Greenlee, M. W. (2000). Cortical activation evoked by visual mental imagery as measured by fMRI. *Neuroreport,* 11(18), 3957-3962.
Kübler, A., Dixon, V., & Garavan, H. (2006). Automaticity and reestablishment of executive control—An fMRI study. *Journal of cognitive neuroscience,* 18(8), 1331-1342.
Lehmann, D., Faber, P. L., Tei, S., Pascual-Marqui, R. D., Milz, P., & Kochi, K. (2012). Reduced functional connectivity between cortical sources in five meditation traditions detected with lagged coherence using EEG tomography. *Neuroimage,* 60(2), 1574-1586.
Leung, H.-C., Gore, J. C., & Goldman-Rakic, P. S. (2002). Sustained mnemonic response in the human middle frontal gyrus during on-line storage of spatial memoranda. *Journal of cognitive neuroscience,* 14(4), 659-671.
Lou, H. C., Luber, B., Crupain, M., Keenan, J. P., Nowak, M., Kjaer, T. W., et al. (2004). Parietal cortex and representation of the mental self. *Proceedings of the National Academy of Sciences,* 101(17), 6827-6832.
Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in cognitive sciences,* 12(4), 163-169.
Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: the default network and stimulus-independent thought. *Science,* 315(5810), 393-395.
Meshram, K., & Meshram, A. (2016). Usefulness of Rajyoga meditation in assessment of general well being of badminton players an experimental study. *Int J Pharm Biol Sci,* 7(1), 161-166.
Misra, N., Gupta, A., Alreja, S., & Prakash, O. (2013). Effect of Raj Yoga meditation on affective & cognitive functions. *International Journal of Heath Sciences and Research,* 3(2), 38-46.
Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: a meta-analysis of 125 human fMRI studies. *Neuroscience & Biobehavioral Reviews,* 36(1), 341-349.

Naik, A., Patel, S., Biswas, D., & Verma, M. (2016). Effect of Rajyoga meditation on intelligence quotient of attention deficit hyperactivity disorder. *J Yoga Phys Ther,* 6(242), 2.

Nair, A. K., Sasidharan, A., John, J. P., Mehrotra, S., & Kutty, B. M. (2017). Just a minute meditation: Rapid voluntary conscious state shifts in long term meditators. *Consciousness and cognition,* 53, 176-184.

Nash, J. D., & Newberg, A. (2013). Toward a unifying taxonomy and definition for meditation. *Frontiers in psychology,* 4, 806.

Nichols, T. E., & Holmes, A. P. (2002). Nonparametric permutation tests for functional neuroimaging: a primer with examples. *Human brain mapping,* 15(1), 1-25.

Niedermeyer, E., & Lopes da Silva, F. (1993). *Electroencephalography: basic principles, clinical applications and related fields.* (3rd ed.). Baltimore, MD: Williams and Wilkins,.

Nuwer, M. R., Comi, G., Emerson, R., Fuglsang-Frederiksen, A., Guérit, J.-M., Hinrichs, H., et al. (1998). IFCN standards for digital recording of clinical EEG. *Electroencephalography and clinical Neurophysiology,* 106(3), 259-261.

Panda, R., Bharath, R. D., Upadhyay, N., Mangalore, S., Chennu, S., & Rao, S. L. (2016). Temporal dynamics of the default mode network characterize meditation-induced alterations in consciousness. *Frontiers in human neuroscience,* 10, 372.

Pascual-Marqui, R. D. (2007). Discrete, 3D distributed, linear imaging methods of electric neuronal activity. Part 1: exact, zero error localization. *arXiv preprint arXiv:0710.3341*.

Pascual-Marqui, R. D., Lehmann, D., Koenig, T., Kochi, K., Merlo, M. C., Hell, D., et al. (1999). Low resolution brain electromagnetic tomography (LORETA) functional imaging in acute, neuroleptic-naive, first-episode, productive schizophrenia. *Psychiatry Research: Neuroimaging,* 90(3), 169-179.

Pascual-Marqui, R. D., Michel, C. M., & Lehmann, D. (1994). Low resolution electromagnetic tomography: a new method for localizing electrical activity in the brain. *International Journal of psychophysiology,* 18(1), 49-65.

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual review of neuroscience,* 13(1), 25-42.

Raffone, A., & Srinivasan, N. (2010). The exploration of meditation in the neuroscience of attention and consciousness. *Cogn Process,* 11, 1-7.

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences,* 98(2), 676-682.

Rajoria, K., & Singh, S. K. (2017). Therapeutic benefits of Raj Yoga–A review. *Indian Journal of Traditional Knowledge,* 16(Suppl), 88-95.

Ramesh, M., Sathian, B., Sinu, E., & Kiranmai, S. R. (2013). Efficacy of rajayoga meditation on positive thinking: An index for self-satisfaction and happiness in life. *Journal of clinical and diagnostic research: JCDR,* 7(10), 2265.

Ramsay, T., & Manderson, L. (2011). Resilience, spirituality and posttraumatic growth: Reshaping the effects of climate change. In *Climate change and human well-being* (pp. 165-184): Springer.

Ramsay, T., Manderson, L., & Smith, W. (2010). Changing a mountain into a mustard seed: Spiritual practices and responses to disaster among New York Brahma Kumaris. *Journal of Contemporary Religion,* 25(1), 89-105.

Reddan, M. C., Wager, T. D., & Schiller, D. (2018). Attenuating neural threat expression with imagination. *Neuron,* 100(4), 994-1005. e1004.

Roux, F. E., Djidjeli, I., & Durand, J. B. (2018). Functional architecture of the somatosensory homunculus detected by electrostimulation. *The Journal of physiology,* 596(5), 941-956.

Seitz, R. J., Nickel, J., & Azari, N. P. (2006). Functional modularity of the medial prefrontal cortex: involvement in human empathy. *Neuropsychology,* 20(6), 743.

Sharma, K., Chandra, S., & Dubey, A. K. (2018). Exploration of lower frequency EEG dynamics and cortical alpha asymmetry in long-term rajyoga meditators. *International journal of yoga,* 11(1), 30.

Sukhsohale, N. D., & Phatak, M. S. (2012). Effect of short-term and long-term Brahmakumaris Raja Yoga meditation on physiological variables. *Indian J Physiol Pharmacol,* 56(4), 388-392.

Telles, S., & Desiraju, T. (1993). Autonomic changes in Brahmakumaris Raja yoga meditation. *International Journal of Psychophysiology,* 15(2), 147-152.

Travis, F., & Shear, J. (2010). Focused attention, open monitoring and automatic self-transcending: categories to organize meditations from Vedic, Buddhist and Chinese traditions. *Consciousness and cognition,* 19(4), 1110-1118.

Van Oort, J., Tendolkar, I., Hermans, E., Mulders, P., Beckmann, C., Schene, A., et al. (2017). How the brain connects in response to acute stress: A review at the human brain systems level. *Neuroscience & Biobehavioral Reviews,* 83, 281-297.

2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC) | 978-1-7281-1179-7/21/$31.00 ©2021 IEEE | DOI: 10.1109/EMBC46164.2021.9629633

Increased Entropy of Gamma Oscillations in the Frontal Region during Meditation

G. Pradeep Kumar, *Member, IEEE*, Kanishka Sharma, A. G. Ramakrishnan, *Senior Member, IEEE* and A. Adarsh

Abstract— **Meditation practices are considered mental training and have increasingly received attention from the scientific community due to their potential psychological and physical health benefits. We compared the EEG data recorded from long-term rajayoga practitioners during different meditative and non-meditative periods. Minimum variance modified fuzzy entropy (MVMFE) is computed for each EEG band for all channels of a given lobe. The means across all the channel entropy values were obtained and compared during meditative and non-meditative states. Meditators showed higher frontal entropy in the lower gamma band (25-45Hz) during the meditative states. Independent component analysis was applied to ensure that muscle or eye artifacts did not contribute to the gamma activity. Our results extend previous findings on the changes in entropy observed in long-term meditators during rajayoga practice. Gamma band in EEG is implicated in cognitive processes requiring high-level processing such as attention, learning, memory control, and retrieval. Gamma activity is also suggested as a potential biomarker for therapeutic progress in patients with clinical depression. Based on our findings, there is an excellent possibility to utilize the practice of meditation as a training tool to strengthen the neural circuits, where age-related degeneration is making its pathological impact.**

I. Introduction

Over the last decade, the volume of scientific publications on studies related to meditation has dramatically increased [1]. Neuroscientists are investigating the changes in emotion regulation and cognition due to mental practices like meditation. Psychotherapists are also interested in improvements in interpersonal relationships, and personal development [2]. The entropic brain hypothesis proposes that the level of conscious states can be indexed with entropy, with increased entropy of brain activity relating to the psychedelic state [3]. High entropy is associated with uncertainty leading to low predictability, which is a result of subjective experiences during meditation, which is beyond the scope of ordinary conscious wakefulness [4], [5]. The hypothesis supports the increase in the entropy during meditation that the long-term practice of meditation is associated with an increased repertoire of experiences which are subjective [6], [7].

Consistent differences were found in the prefrontal cortex and regions involved in body awareness in meditators as compared to controls [8]. Permutation entropy and fractal dimension were used to analyze two types of meditation, and it was found that permutation entropy was advantageous over fractal dimension [9]. Decrease of non-linear dimensional complexity in midline frontal and central regions was observed during Sahaja yoga meditation as compared to rest condition [10]. Neuroimaging study on rajayoga practitioners has shown enhanced white matter integrity in corpus callosum segments as compared to controls [11].

Frequency components around '40 Hz' termed as gamma band are considered to be a vital characteristic of the brain activation during meditation [12]. It has been hypothesized that the role of gamma-band is prominent in the 'binding problem' defined as the binding of independent neural assemblies resulting in the integration of information processing for unified conscious experience [13]. A study of advanced meditators on four different meditations revealed that the source of gamma-band activity was in the anterior regions of the brain during meditation [14]. Another study of advanced practitioners has indicated an increase in the gamma band activity supporting the higher attentional capacities [15].

The objective of this study is to examine whether there exists a consistent difference in entropy in the EEG activity of rajayoga practitioners between meditative and non-meditative states. It has been observed that the increase in entropy during meditation was significant in frontal and centroparietal regions [16]. This analysis is now extended to bandwise computation in the present work.

A. Rajayoga practice and present study

Rajayoga meditation is a practice reported to be based on contemplation on the supreme soul and thus may involve more metaphysical components. The present study investigates entropy changes during the following two types of rajayoga practices: peaceful soul consciousness meditation(PM) and angelic meditation (AM).

II. Experimental Procedure

This work is a continuation of the analysis reported in our previous publication [16].

A. Participants

Fourteen long-term meditators (one female) with mean age and standard deviation of 42 $\pm$ 5 years, with an average experience and standard deviation of 23 $\pm$ 5 years, were recruited for the study. The experiments were carried out at the Brahma Kumaris headquarters, Mount Abu, India.

All the authors are with the MILE Laboratory, Department of Electrical Engineering, Indian Institute of Science, Bangalore 560012, India, pradeepkg@iisc.ac.in, kanishkas@iisc.ac.in, agr@iisc.ac.in, adarsha@iisc.ac.in

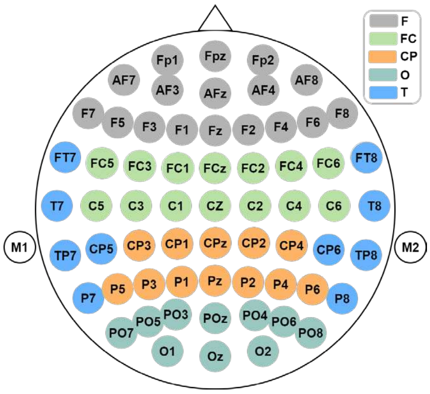


Fig. 1: Grouping of the 64 EEG electrodes recorded according to the 10-10 system into different lobes considered in the study. F: frontal; FC: fronto-central; CP: centro-parietal; O: occipital; and T: temporal.

B. Experimental Design

All the participants were instructed about the protocol, and a written consent form was collected. The experiment consisted of two different rajayoga meditation types for 10 minutes each in the protocol. Initial (BL) before PM, intermediate (IBL) after PM, and final baseline (FBL) segment after AM with a duration of five minutes were recorded [16]. The present study analyzes the changes in entropy in different frequency bands during the various segments of the protocol. The meditation segments AM and PM were not randomized in the protocol of the proposed study.

C. EEG data acquisition and pre-processing

EEG data were recorded using 64 + 8 channels ANTNeuro amplifier system with a 10-10 standard Waveguard head cap. Data were recorded at a sampling frequency of 1024 Hz, and all the electrodes were kept within 20 kΩ impedance. Data were preprocessed with EEGLAB version 13. A highpass filter with a 0.5 Hz cutoff and an order of six was applied to the EEG time series. Independent components due to muscle artifacts, eye movements, and electrode popping were removed using independent component analysis (ICA) and other procedures described in detail in a previous publication [16]. The 64 channels considered for the study were grouped into broader regions of the brain, as illustrated in Fig. 1.

D. Minimum variance modified fuzzy entropy (MVMFE)

EEG time series were filtered using EEGLAB to obtain the canonical frequency bands listed in Table 1.

The fuzzy entropy used in the study is based on the estimated complexity of a time series derived from the concept of membership function defined by De Luca and Termini [17] [18]. In the proposed study, a relative energy function is used as the membership function termed as MVMFE [19] to extract the entropy values from epochs of 0.5 seconds (512 samples) length. Given a time series $X = \{x_1, x_2, ..., x_N\}$,

TABLE I: Frequency bands considered in the study.

Sl. No.	Band name	Frequency range
1	Delta	0.25 - 4 Hz
2	Theta	4 - 8 Hz
3	Alpha	8 - 13 Hz
4	Beta	13 - 25 Hz
5	Gamma	25 - 45 Hz

the key computations are

$$FE = -K\sum_{i=1}^{N}[\mu_i log(\mu_i) + (1-\mu_i)log(1-\mu_i)] \quad (1)$$

where K is a constant $(= 1/N)$ and μ_i is obtained using the relative power membership function given by,

$$\mu_i = \frac{|x_i|^2}{\sum_{i=1}^{N}|x_i|^2} \quad (2)$$

III. Results

Multiple comparisons are shown in Fig 2, with the increase in entropy observed in all brain regions. However, the increase is statistically significant only in the frontal region in the gamma band.

A. Statistical Analysis

Wilcoxon signed-rank test, a non-parametric two-sample test, is applied to assess the difference between two conditions/states of the protocol, and Cohen's d test is used to find the effect size. Results of the Wilcoxon test are graphically represented in Fig. 3. MVMFE of narrow-band EEG signal is computed for each channel of a given lobe, and the means across all the channel entropy values are obtained. The results are significant only for the gamma band (25 - 45 Hz) in the frontal lobe. As shown in Fig. 3, the changes in other frequency bands and lobes are not significant.

The topographic distribution of electrodes of overall MVMFE increase in the gamma band, predominantly in the brain's frontal and temporal regions, is as shown in Fig 4.

IV. Discussion

Our analysis has extended our previous findings by showing how rajayoga practice can increase signal complexity in the brain's frontal region as indexed by MVMFE. Our findings are consistent with increased gamma synchronization during meditative states [15] and increased sample entropy in the alpha and gamma bands during meditation [6]. Increased EEG gamma activity in the parieto-occipital lobe has been observed in other studies during non-rapid eye movement (NREM) sleep in experienced mindfulness meditators [20]. A study on long-term Vipassana meditators reported increased occipital gamma power compared to controls and was hypothesized to be the effect of imagined visualization of body parts during meditation. Vipassana meditation is considered to be of the open-monitoring type, which may

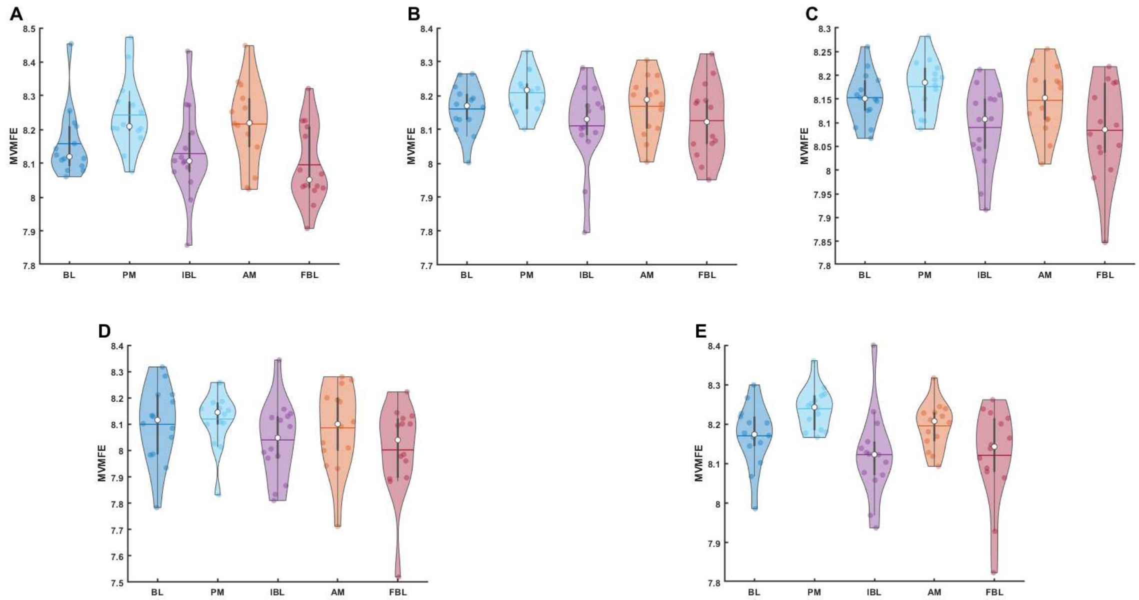


Fig. 2: Effect of meditation on the entropy of gamma oscillations of all the subjects (14 points in each state). The meditative state changes the entropy of gamma oscillations in frontal **(panel A)**, frontocentral **(panel B)**, centroparietal **(panel C)**, occipital **(panel D)** and temporal **(panel E)** lobes. Colored circles represent the number of subjects; white circles, the median values; respective dark color horizontal lines in the violin plots represent the mean values; thick grey color bars denote the interquartile range. (BL: Baseline, PM: Peaceful soul consciousness meditation, IBL: Inter-mediate baseline, AM: Angelic meditation, FBL: Final baseline)

be interpreted as the state of enhanced wakefulness [21]. Cognitive processes such as learning, working memory, and attention are implicated by gamma-band oscillations [22]. Gamma activity observed in the frontal area can be related to the redirection of attention towards the meditation task, which can be a top-down control of attention [1].

A. *Gamma and associated artifacts*

ICA methods are utilized to remove the artifacts from the muscles of the scalp, eye blinks, and movements. Hence, an increase in the gamma entropy values in the brain's frontal region during the meditative states is not due to eye movements.

V. Conclusion

In summary, peaceful soul consciousness and angelic meditations under rajayoga practice result in increased gamma-band entropy of EEG in the frontal brain region. The changes in other regions of the brain and frequency bands vary across subjects. Future research should address whether these reported results are related to the long-term meditation as a trait effect relative to control subjects.

Acknowledgment

The authors thank the kind support given by the SpARC wing of Brahmakumaris Organization for lending their EEG

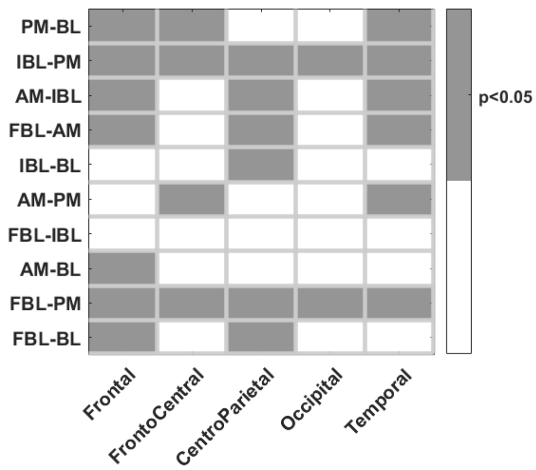


Fig. 3: Statistical significance of entropy changes in gamma band between different meditative and non-meditative states in different brain regions considered in the study. x-axis is the lobe considered, and the y-axis is the combination of states for which the statistical significance was calculated. Grey color denotes significant entropy changes with p-value ≤ 0.05.

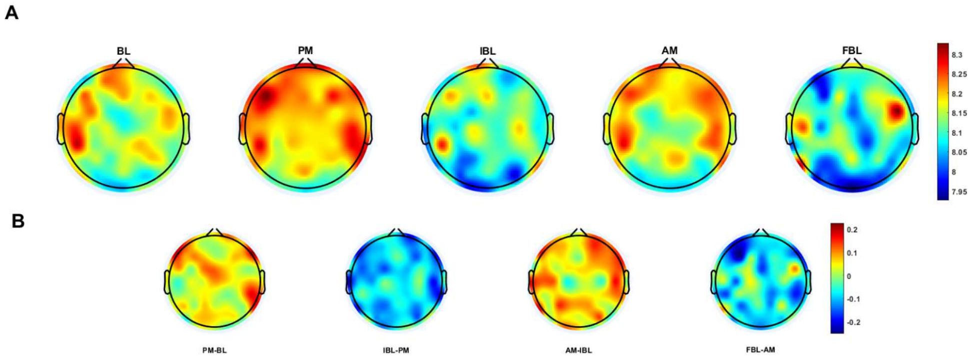


Fig. 4: Localization of entropy changes in gamma band averaged across all the 14 subjects. Topographic distribution of higher MVMFE values in meditative states relative to non-meditative states for the gamma band **(panel A)**: From left to right, BL, PM, IBL, AM, and FBL. **Panel B** is the difference entropy plot with successive states. From left to right, PM-BL, IBL-PM, AM-IBL, and FBL-AM.

system to conduct this research and encouraging the subjects who participated in this study.

References

[1] C. Braboszcz, B. R. Cahn, J. Levy, M. Fernandez, and A. Delorme, "Increased gamma brainwave amplitude compared to control in three different meditation traditions," *PloS one*, vol. 12, no. 1, p. e0170647, 2017.

[2] D. S. Ludwig and J. Kabat-Zinn, "Mindfulness in medicine," *Jama*, vol. 300, no. 11, pp. 1350–1352, 2008.

[3] R. L. Carhart-Harris, "The entropic brain-revisited," *Neuropharmacology*, vol. 142, pp. 167–178.

[4] E. Tagliazucchi, R. Carhart-Harris, R. Leech, D. Nutt, and D. R. Chialvo, "Enhanced repertoire of brain dynamical states during the psychedelic experience," *Human brain mapping*, vol. 35, no. 11, pp. 5442–5456, 2014.

[5] F. Cavanna, M. G. Vilas, M. Palmucci, and E. Tagliazucchi, "Dynamic functional connectivity and brain metastability during altered states of consciousness," *Neuroimage*, vol. 180, pp. 383–395, 2018.

[6] R. M. Vivot, C. Pallavicini, F. Zamberlan, D. Vigo, and E. Tagliazucchi, "Meditation increases the entropy of brain oscillatory activity," *Neuroscience*, vol. 431, pp. 40–51, 2020.

[7] T. Brandmeyer, A. Delorme, and H. Wahbeh, "The neuroscience of meditation: classification, phenomenology, correlates, and mechanisms," *Progress in brain research*, vol. 244, pp. 1–29, 2019.

[8] K. C. Fox, S. Nijeboer, M. L. Dixon, J. L. Floman, M. Ellamil, S. P. Rumak, P. Sedlmeier, and K. Christoff, "Is meditation associated with altered brain structure? a systematic review and meta-analysis of morphometric neuroimaging in meditation practitioners," *Neuroscience & Biobehavioral Reviews*, vol. 43, pp. 48–73, 2014.

[9] O. Vyšata, M. Schätz, J. Kopal, J. Burian, A. Procházka, K. Jiří, J. Hort, M. Vališ *et al.*, "Non-linear EEG measures in meditation," *Journal of biomedical science and engineering*, vol. 7, no. 09, p. 731, 2014.

[10] L. Aftanas and S. Golocheikine, "Non-linear dynamic complexity of the human EEG during meditation," *Neuroscience letters*, vol. 330, no. 2, pp. 143–146, 2002.

[11] K. Sharma, R. Trivedi, S. Chandra, P. Kaur, P. Kumar, K. Singh, A. K. Dubey, and S. Khushu, "Enhanced white matter integrity in corpus callosum of long-term brahmakumaris rajayoga meditators," *Brain connectivity*, vol. 8, no. 1, pp. 49–55, 2018.

[12] J.-P. Banquet, "Spectral analysis of the EEG in meditation," *Electroencephalography and clinical neurophysiology*, vol. 35, no. 2, pp. 143–151, 1973.

[13] K. J. Meador, P. G. Ray, J. R. Echauz, D. W. Loring, and G. J. Vachtsevanos, "Gamma coherence and conscious perception," *Neurology*, vol. 59, no. 6, pp. 847–854, 2002.

[14] D. Lehmann, P. Faber, P. Achermann, D. Jeanmonod, L. R. Gianotti, and D. Pizzagalli, "Brain sources of EEG gamma frequency during volitionally meditation-induced, altered states of consciousness, and experience of the self," *Psychiatry Research: Neuroimaging*, vol. 108, no. 2, pp. 111–121, 2001.

[15] A. Lutz, L. L. Greischar, N. B. Rawlings, M. Ricard, and R. J. Davidson, "Long-term meditators self-induce high-amplitude gamma synchrony during mental practice," *Proceedings of the national Academy of Sciences*, vol. 101, no. 46, pp. 16 369–16 373, 2004.

[16] P. Kumar, A. G. Ramakrishnan, and K. Sharma, "Fuzzy entropy as a measure of EEG complexity during rajayoga practice in long-term meditators," in *2020 IEEE 17th India Council International Conference (INDICON)*. IEEE, 2020, pp. 1–5.

[17] A. De Luca and S. Termini, "A definition of a nonprobabilistic entropy in the setting of fuzzy sets theory," *Information and control*, vol. 20, no. 4, pp. 301–312, 1972.

[18] S. Al-Sharhan, F. Karray, W. Gueaieb, and O. Basir, "Fuzzy entropy: a brief survey," in *10th IEEE International Conference on Fuzzy Systems.(Cat. No. 01CH37297)*, vol. 3. IEEE, 2001, pp. 1135–1139.

[19] S. Raghu, N. Sriraam, G. P. Kumar, and A. S. Hegde, "A novel approach for real-time recognition of epileptic seizures using minimum variance modified fuzzy entropy," *IEEE Transactions on Biomedical Engineering*, vol. 65, no. 11, pp. 2612–2621, 2018.

[20] F. Ferrarelli, R. Smith, D. Dentico, B. A. Riedner, C. Zennig, R. M. Benca, A. Lutz, R. J. Davidson, and G. Tononi, "Experienced mindfulness meditators exhibit higher parietal-occipital EEG gamma activity during nrem sleep," *PloS one*, vol. 8, no. 8, p. e73417, 2013.

[21] B. R. Cahn, A. Delorme, and J. Polich, "Occipital gamma activation during vipassana meditation," *Cognitive processing*, vol. 11, no. 1, pp. 39–56, 2010.

[22] P. Fries, D. Nikolić, and W. Singer, "The gamma cycle," *Trends in neurosciences*, vol. 30, no. 7, pp. 309–316, 2007.

Characterization of Meditation EEG based on Consistency of Covariance Matrices over Time

Ramakrishnan Angarai Ganesan
Department of Electrical Engineering
Indian Institute of Science
Bangalore, India
agr@iisc.ac.in

Pradeep Kumar G
Department of Electrical Engineering
Indian Institute of Science
Bangalore, India
pradeepkg@iisc.ac.in

Kanishka Sharma
Department of Electrical Engineering
Indian Institute of Science
Bangalore, India
kanishkas@iisc.ac.in

2020 IEEE 17th India Council International Conference (INDICON) | 978-1-7281-6916-3/20/$31.00 ©2020 IEEE | DOI: 10.1109/INDICON49873.2020.9342426

***Abstract*— Electroencephalogram (EEG) is investigated for changes in the pattern of brain activity during meditation. Correlation between the neural activity in each region with those of other regions of the brain are studied. EEG recorded from fifteen practitioners of the peace and angelic meditations, being part of the Rajayoga meditation of Prajapita Brahmakumaris World Spiritual University is analyzed for this study. The mean and variance of the Frobenius norms of the difference matrices between the covariance matrices of successive epochs is used to study the meditative and non-meditative states. Analysis has been carried out region wise. The covariance matrices become more uniform during meditation, leading to decreased distance between matrices of successive epochs. The frontal region shows significantly decreased distances between the covariance matrices during meditation.**

Keywords*— *EEG, Rajayoga meditation, peace meditation, angelic meditation, covariance matrices, Frobenius norm.

I. Introduction

Meditation practice is considered to be one of the primary approaches in many mystical traditions to reach transpersonal states denoted by terms like samadhi, transcendental consciousness, and nirvana as reported by Britta et. al [1]. Conventional meditation teaching organizations stress the importance of regular practice, e.g. the yoga sutras of Patanjali (sutra I.14; Vivekananda, 2001 [2]). However, there are no objective indices to characterize the meditation of a long-term practitioner as “deep” compared to a novice.

Meditation can be considered as a family of attentional regulatory and complex emotional training regimes [3]. According to our survey of the existing literature, most of the work reported on the depth of meditation is based on the questionnaires as reported by Gifford-May et. al. [4], Piron et. al [5], Jian et. al. [6] and Tetsuya et. al [7]. A recent study of Sharma et. al [8] on seed stage meditation under Rajayoga practice with open eyes reported activation of many networks across delta and low alpha frequencies. Sharma et.al [9] saw higher band power in alpha and theta frequencies and high frontal and parietal cortical asymmetry in long term Rajayoga meditators. Telles et. al [10] reported increase in heart rate during Rajayoga meditation practice which is a sign of psychophysiological arousal due to cardiosympathetic activation. However, a decrease in heart rate was also reported along with decrease in respiratory rate, systolic and diastolic blood pressure during Rajayoga practice by Sukhsohale et. al. [11]. The study suggested that cardiovascular parameters improved because of sympathetic arousal. Decrease in peak latency of a negative component in the middle latency auditory evoked potentials during Rajayoga meditation was seen in a study by Telles et. al [12]. Neuroimaging study conducted by Sharma et. al [13] on long-term meditators of Rajayoga meditation suggested enhanced white matter integrity in corpus callosum segments as compared to controls. Increased entropy of EEG time series in frontal lobe during Rajayoga practice were observed in the dataset analyzed in the current work [14]. Our work intends to be the starting point in quantifying the depth of meditation and developing an index for the same using the covariance matrices. In this work, we analyse the EEG recorded during Rajayoga meditation, which is practiced with the eyes open, which makes it unique among the different meditation techniques. An attempt is made to analyse the covariance matrix which captures the inter-dependencies of different regions of the brain during the meditative states. Features such as the mean and variance of the distances between the successive covariance matrices have been used to compare the meditative with the non-meditative states.

II. Dataset Description

A. Subject Selection

EEG data collected from fifteen healthy right-handed subjects [15] practicing Rajayoga meditation regularly for a period of more than 10 years (age 30-52 years, mean 43.9 (SD=3.96) years) has been used in this study. With a record of regular practice, these meditators have spent 11-17 years in practicing this technique after learning the same. At the time of recording the EEG data, the total number of hours spent in meditation throughout their life `ranged from 4000 to 7200 hours. The subjects did not have any history of cardiac, pulmonary, and other nervous system dysfunctions. The experimental procedures were explained to the subjects. A written information consent was obtained from each subject. The status of non-consumption of alcohol, cigarette or any therapeutics by the subjects within the last six months was confirmed.

B. Experimental Protocol

EEG data was recorded using 64-channel ANT Neuro amplifier with a 10-10 Waveguard standard 64-channel cap. EEG signals were digitally filtered at 0.5-75 Hz during recording. The subjects were asked to sit on a floor mat, and it was made sure that the ground was not in contact with the body during the entire recording session.

3 minutes Baseline (BL) was recorded, and the subjects were asked to relax with their eyes open before the recording of the meditation session. After BL, the peaceful soul consciousness (PM) state of meditation was practiced and recorded for around 10 minutes. PM is defined to be focusing their attention on the positive thought considering themselves as peaceful souls. PM was followed by an intermediate baseline (IBL) for 3 minutes. Following IBL, subjects were asked to practice another technique, angelic (AM) state of meditation for 10 minutes, where subjects assumed to attain a blissful state. A final baseline (FBL) was recorded for 3

minutes. The complete protocol is presented graphically in Fig 1. The fundamental difference between the two meditation techniques is the self-observing experience in PM and the state of being detached from the physical body, its sensual pleasures, relationships, and material assets in AM [16] More information on different states of meditation is given in Appendix.

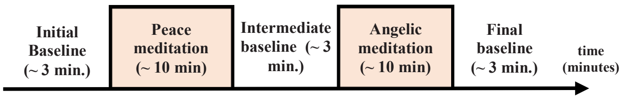


Fig. 1. The protocol followed in EEG recording: Subject practice two types of meditation for 10 min. each. Baseline EEG is recorded for 3 min. at the beginning, in between the two meditative states and at the end.

C. *Preprocesing*

The data was recorded at a sampling frequency of 1024 Hz. Using EEGLAB v 13.4 the pre-processing pipeline was performed. Line noise (50 Hz) removal followed by band-pass filter with cut-off 0.5 Hz to 45 Hz was applied on the EEG time series. The runica independent component analysis algorithm [17] was applied to reject eye movement and muscle activity. Residual components with eye movements, muscle artifacts and electrode popping were removed to make the data artifact-free using a manual procedure. 14 subjects were considered for analysis and one subject was dropped due to excessive artifacts and low SNR channels. Data of each subject is grouped into five broader groups namely Frontal, Frontocentral, Centroparietal, Occipital and Temporal (see Fig. 2). Both Temporal right and left are grouped as Temporal.

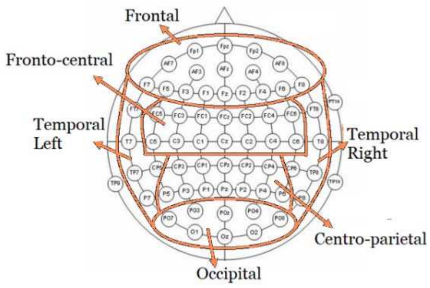


Fig. 2. 64-channel EEG electrode configuration following the 10-10 system. The electrodes from broad regions are grouped for the proposed analysis.

III. Methodology

Covariance matrix characterizes the relationship between various random variables. Covariance matrix obtained from EEG signals of different channels quantifies the pairwise correlation between those channels over a given epoch [18]. The diagonal elements of the covariance matrix give the variances of the different channels being analyzed. The off-diagonal elements capture the inter-channel correlation. In the work reported here, the covariance matrix is computed for a set of channels grouped as a specific region of the brain. In our proposed work, distances between the covariance matrices of successive epochs are used to distinguish between the different meditative and non-meditative (baseline) states. During meditation, the interchannel correlation is expected to increase in certain lobes of the brain, which we expect the sequence of covariance matrices to capture and illustrate. Further, since attention is maintained in a particular way throughout any meditation session, we also expect the correlation pattern to be relatively stable across successive epochs and have minimal changes in time.

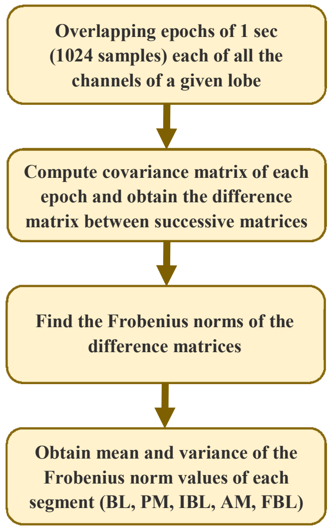


Fig. 3. Graphical abstract of the proposed methodology. Overlapping epochs of 1024 samples each were extracted from all the channels and covariance matrices were calculated across the channels. Distance between successive covariance matrices was calculated using the Frobenius norm of the difference matrix. Mean and variance of the Frobenius norm values were calculated for all the segments.

A. *Covariance matrix of a group of channels*

Figure 3 shows the graphical abstract of the proposed methodology to characterize the meditative states. All the channels of a given lobe are considered for obtaining the covariance matrix for that lobe. The artifact-free multichannel EEG of ith lobe is divided into overlapping epochs of 1 sec each with 50% overlap between the epochs. The data matrix X_i^k for the k-th epoch of the i-th lobe is formed as

$$X_i^k = \begin{bmatrix} x_{1,1} & x_{1,2} & \dots & x_{1,N} \\ x_{2,1} & x_{2,2} & \dots & x_{2,N} \\ \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & & \vdots \\ x_{M_i,1} & x_{M_i,2} & \dots & x_{M_i,N} \end{bmatrix}, \quad \begin{cases} 1 \le i \le 5 \\ 1 \le k \le K_j \end{cases}$$

where, M_i is the number of channels in the i-th lobe, N is the number of samples per epoch, and K_j is the number of epochs for the j-th state of meditation or baseline namely BL, PM, IBL, AM, FBL and $1 \le j \le 5$. The covariance matrix is defined as

$$C_i^k = \frac{1}{N} X_i^k (X_i^k)^T - \mu_i^k (\mu_i^k)^T \quad (1)$$

where μ_i^k is the mean column vector of the k-th epoch. Difference matrices between the covariance matrices corresponding to successive epochs are obtained. The (k-1)th difference matrix D_i^{k-1} is given by,

$$D_i^{k-1} = C_i^k - C_i^{k-1}, \quad \begin{cases} 1 \le i \le 5 \\ 2 \le k \le K_i \end{cases} \quad (2)$$

Frobenius norms of the difference matrices are calculated for all the epochs.

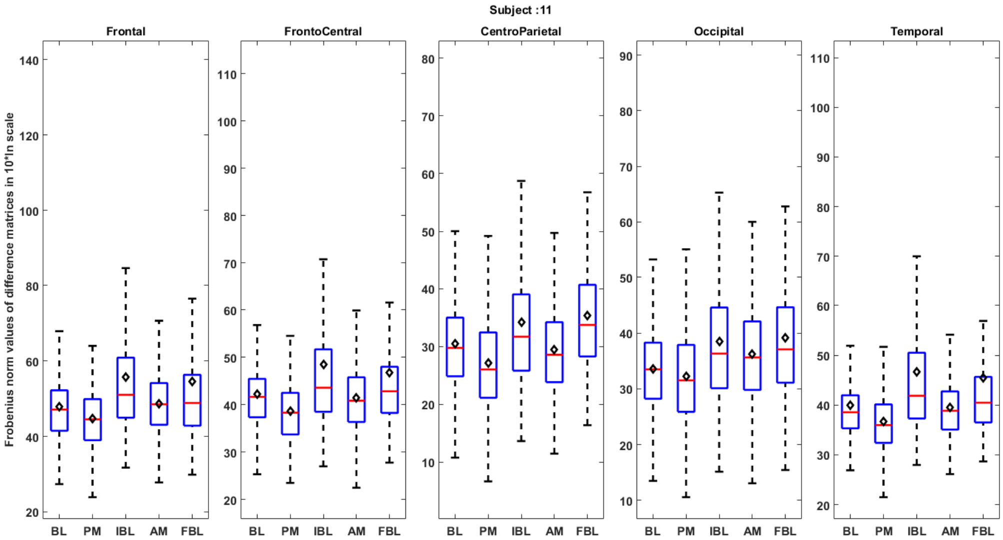


Fig. 4. Box plots of the Frobenius norms of difference matrices between covariance matrices of successive epochs for subject 11 without the outliers. Red lines represent the median and diamonds, the mean. (A) Frontal region, (B) Frontocentral region, (C) Centroparietal region, (D) Occipital region, (E) Temporal region.

The Frobenius norm of the difference matrix D_i^k is obtained as,

$$h_i{}^k = \sqrt{trace[(D_i^k)'\ D_i^k]},\ \begin{cases} 1 \le i \le 5 \\ 1 \le k \le K_j - 1 \end{cases} \quad (3)$$

resulting in a vector of length equal to $K_j - 1$ for the data corresponding to each state (BL, PM, IBL, AM, FBL).

B. Mean and variance of the sequence of Frobenius norm values

After estimating the Frobenius norm values ($h_i{}^k$), the mean and variance for a given lobe and subject are obtained as,

$$H_{mean}^i = mean(h_i{}^k)\ ,\begin{cases} 1 \le i \le 5 \\ 1 \le k \le K_j - 1 \end{cases} \quad (4)$$

$$H_{var}^i = var(h_i{}^k)\ ,\begin{cases} 1 \le i \le 5 \\ 1 \le k \le K_j - 1 \end{cases} \quad (5)$$

IV. Results

The analysis of the covariance matrices for consistency during the different states showed decrease in the mean and variance of the norms of the difference matrices during the meditation states from their values during the non-meditating states. Figure 4 shows the distance values during meditating and non-meditating states in all the regions of the brain for subject 11 considered in the analysis.

Our hypothesis in analyzing the covariance matrices is decreased values and variance of the distances between the covariance matrices in the meditative states as compared to non-meditative states. This is the trend seen in all the lobes with varied statistical significance as given in Fig 6. However, the mean distances during meditating states were also observed as given in Fig 5. Changes in the distance values in the frontal region were more statistically significant than in other regions and hence the statistical significance results of the frontal region only are reported here. A study conducted by Travis et. al [19] has reported increase in frontal EEG coherence and was positively correlated with inner orientation, emotional stability and moral reasoning. The higher statistical significance in frontal lobe as compared to other lobes to be investigated in future.

Given that very few antecedents of scientific papers investigating the covariance matrices and in specific the distance between the covariance matrices during meditation, comparing the results reported in the proposed work is difficult. The meditation types studied here are practiced with open eyes, whereas almost all the other traditions are performed with closed eyes. Also, the neuronal activity during meditation is confounded by many factors and hence the results may not be consistent with other meditation methods. The non-parametric Wilcoxon tests revealed that the proposed Frobenius distance values decreased in the frontal lobe during the meditative states as shown by the z-values given in Table I and p-values in Table II.

TABLE I. z-values of mean distances between covariance matrices of successive epochs from the frontal lobe. Comparison of the meditation and baseline (non-meditating) states.

	PM	IBL	AM	FBL
BL	-2.3541	-1.9147	-0.2825	-2.4797
PM		-2.9191	-2.2286	-1.9147
IBL			-2.103	-1.3497
AM				-2.2286

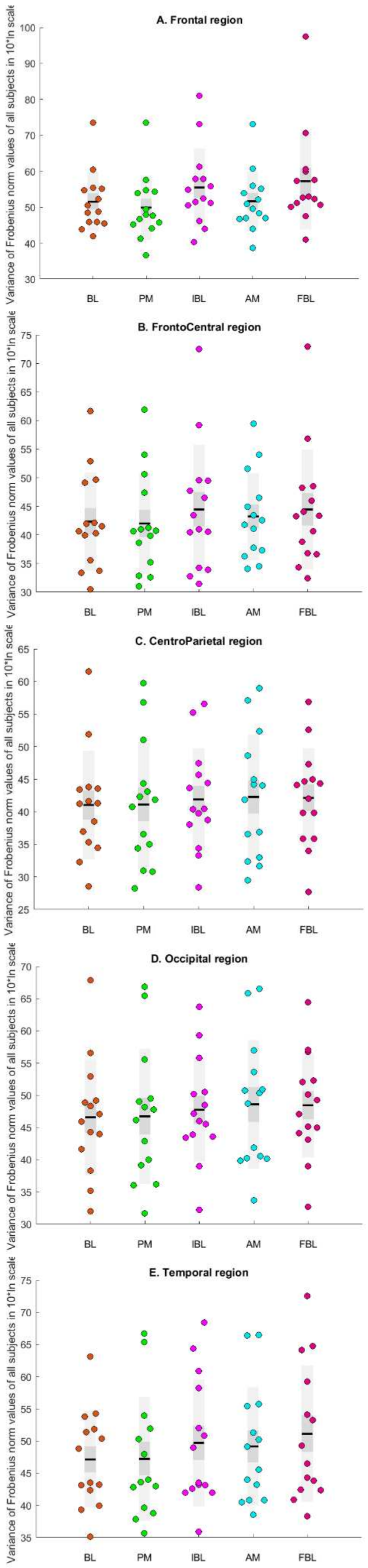


Fig. 5. Univariate scatter plot of the means for all the meditative and non-meditative states of all the 14 subjects. Black horizontal line represents the mean, dark grey box, the SEM and light grey box, the standard deviation. (A) Frontal region, (B) Frontocentral region, (C) Centroparietal region, (D) Occipital region, (E) Temporal region.

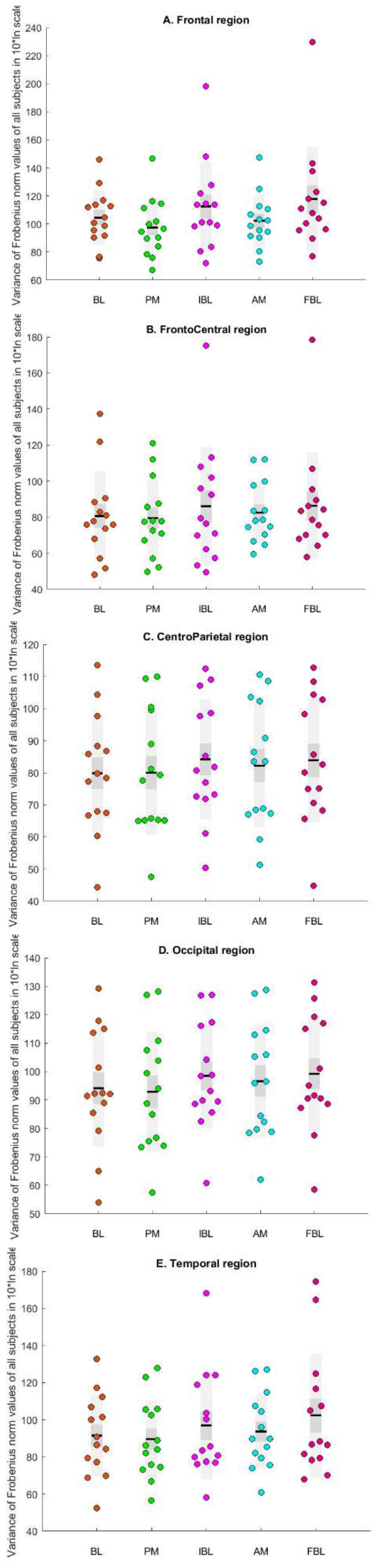


Fig. 6. Univariate scatter plot of the variances for all the meditative and non-meditative states of all the subjects (14 points in each state). Black horizontal line represents the mean, dark grey box, the SEM and light grey box, the standard deviation. (A) Frontal region, (B) Frontocentral region, (C) Centroparietal region, (D) Occipital region, (E) Temporal region.

TABLE II. p-values of mean distances between covariance matrices of successive epochs from the frontal lobe. Comparison of the meditation and baseline (non-meditating) states.

	PM	IBL	AM	FBL
BL	0.0094	0.0281	0.3897	0.0066
PM		0.0018	0.0129	0.0281
IBL			0.0179	0.0885
AM				0.0129

V. CONCLUSION

In summary, peace and angelic meditations, practices under the tradition of Rajayoga meditation, resulted in decreased mean and variance of distance values between covariance matrices of successive epochs of the EEG recorded from the frontal region of the brain. This shows that the interrelationships between the frontal lobe channels are becoming much more uniform during meditation, compared to the baseline. This consistency of EEG covariances can be used to quantify the depth of meditation in addition to the questionnaires resulting in an index for the same.

Our study provides an example of using covariance matrices in characterizing and distinguishing between meditative and non-meditative states. Future research should include the analysis of frequency band-wise covariance matrices and address how these stationary covariance patterns are related to the long-term positive effects that certain meditative traditions can have on mental and physical health. Other important direction should include the quantification of depth of meditation based on EEG.

ACKNOWLEDGMENT

The authors thank the kind support given by SpARC wing of Brahmakumaris Organization by lending their EEG system to conduct this research and encouraging the subjects, who participated in this study.

REFERENCES

[1] Hölzel, B., & Ott, U, “Relationships between meditation depth, absorption, meditation practice, and mindfulness: A latent variable approach”, *Journal of Transpersonal Psychology*, 38(2), 179-199, 2006.

[2] Noble, M. E., Vivekananda, S., & Vedanta, A., “Sister Nivedita. Footfalls of Indian History”, Gipidi Box, Kolkata, 2001.

[3] Xue, S. W., Tang, Y. Y., Tang, R., & Posner, M. I. “Short-term meditation induces changes in brain resting EEG theta networks”, *Brain and cognition*, 87, 1-6, 2014.

[4] Gifford-May, D., & Thompson, N. L."Deep states of meditation: Phenomenological reports of experience”, *Journal of Transpersonal Psychology*, 26, 117-117, 1994.

[5] Piron, H., “The meditation depth index (MEDI) and the meditation depth questionnaire (MEDEQ)”, *Journal for Meditation and Meditation Research*, 1(1), 69-92, 2001.

[6] Lin, J. W., & Mai, L. J. “Impact of mindfulness meditation intervention on academic performance”, *Innovations in Education and Teaching International*, 55(3), 366-375, 2018.

[7] Takahashi, T., Murata, T. & Wada, Y., “Changes in EEG and autonomic nervous activity during meditation and their association with personality traits”, *International Journal of Psychophysiology*, 55(2), 199-207, 2005.

[8] Sharma, K., Achermann, P., Panwar, B., Sahoo, S., AG Ramakrishnan, Pascual-Marqui, R. D., & Faber, P. “Brain-electric activity during eyes open Brahma Kumaris Rajayoga meditation”, *mindrxiv.org,* 2020.

[9] Sharma, K., Chandra, S., & Dubey, A. K. “Exploration of lower frequency EEG dynamics and cortical alpha asymmetry in long-term rajyoga meditators”, *International Journal of Yoga*, *11*(1), 30, 2018.

[10] Telles, S., & Desiraju, T. “Automatic changes in Brahmakumaris Raja yoga meditation”, *International Journal of Psychophysiology*, *15*(2), 147-152, 1993.

[11] Sukhsohale, N. D., & Phatak, M. S. “Effect of short-term and long-term Brahmakumaris Raja Yoga meditation on physiological variables”, *Indian J Physiol Pharmacol*, *56*(4), 388-92, 2012.

[12] Telles, S., & Naveen, K. V. “Changes in middle latency auditory evoked potentials during meditation”, Psychological Reports, 94(2), 398-400, 2004.

[13] Sharma, K., Trivedi, R., Chandra, S., Kaur, P., Kumar, P., Singh, K. & Khushu, S. “Enhanced white matter integrity in corpus callosum of long-term Brahmakumaris Rajayoga meditators”, *Brain connectivity*, *8*(1), 49-55, 2018.

[14] KG Pradeep, AG Ramakrishnan, Sharma K. "Fuzzy entropy as a measure of EEG complexity during Rajyoga practice in long-term meditators", *Proc. IEEE 17th India Council International Conference (INDICON),* Dec. 11-13, 2020, to be published.

[15] Sharma, K., “Attention networks in long term Rajayoga meditators”. Ph D thesis, University of Delhi, 2019.

[16] Dadi Janki, “Attaining angelic attributes By Brahma Kumaris”. Available:https://www.soulveda.com/spiritual-leader/attaining-angelic-attributes/

[17] Makeig, S., “Matlab Toolbox for analysis of electrophysiological data”, 1997.

[18] Prabhu, S. S., & Sinha, N., “Sleep EEG analysis utilizing inter-channel covariance matrices”, *Biocybernetics and Biomedical Engineering*, 40(1), 527-545, 2020.

[19] Travis, F., & Arenander, A. Cross-sectional and longitudinal study of effects of transcendental meditation practice on interhemispheric frontal asymmetry and frontal coherence. *International Journal of Neuroscience*, *116*(12), 1519-1538, 2006.

[20] Brahma Kumaris World Spiritual University. “Rajayoga meditation step-by-step Teachers Guide”, 1994

Appendix

The content of this section is taken from [20]. First step in Brahmakumaris Rajayoga meditation (BKRYM) is to become soul conscious. The question is however, have you really experienced yourself to be a soul and have you been able to sustain this experience? Visualization helps to create and sustain this consciousness. For better visualization, inculcating the thoughts, self-talk may help. Following are some thoughts which helps in visualizing the soul consciousness stage which is the fundamental of all the states such as peaceful soul consciousness state, angelic state etc.

A. Soul consciousness state

"I turn my thoughts inward... I pay no attention to the things around me…. I direct all my thoughts towards the one whom I really am... I ask myself: Who am l?... I am a soul….an eternal, immortal soul.., l, the soul, will always live.,. I am the living being... the spark of living energy in the center of the forehead...I realize that this is the one whom I really am,,. for so long I have thought that I was the body, my form, my role.,. but now I know that I am an eternal soul and that my form is a point of light.

l, the soul, shine like a star... like a bright star in the center of the forehead...I visualize myself... I see myself as this shining star of living light.., my attention is focused on point of light.

B. Peaceful soul consciousness state

For visualization of peaceful soul state, one will undergo the process of contemplating following thoughts.

"What are the original qualities of l, the soul?...my original quality is of pure divine peace...peace is my original nature-.-the closer I get to myself, the deeper I go into my original peace...peace, my original strength. I am no longer distracted by the things around me.. peace and silenced. Peace is such a great power, the power of my true self...the power to best able under all conditions...I allow this feeling of pure peace...the peace of my original nature to flow through me...peace belongs to me...peace is me...and when I am close to my real self, I notice how strong I am... I have strength,.. the power to be myself whenever I want; beyond influences...I am completely inside...very quiet; Very peaceful...at one with myself,. Peace and silence.

In silence I experience a feeling of love., love for who I really am... understanding of myself..-acceptance of myself... respect for my original eternal being... when I see myself in this way, love emerges,., and confidence..,and I ask myself: the world of eternal peace...the world of light.,. of silence.-.the world beyond of stillness and peace...this is my silent, eternal home...this is where I come from... the world of silent peace and light...peace and light." "Where do I come from?... I realize that my original home is far, very tar away from this world of sound and matter... it is

C. Angelic state

Angelic state is an advanced state of BKRYM where the soul consciousness is the primary stage and proceeds with meeting the Shiv Baba; the supreme soul (used many times in the text).

"My ability to help others is often limited by time and distance and can reach only a few people at a time. Subtle help through sending thoughts of virtue, support and good wishes can benefit all souls, even those who are physically many miles away.

God's love and support are eternal gifts that are given to all souls. I can be an instrument to pass this spiritual nourishment on to others. When connected with God I stay peaceful, loving, happy and pure and can refresh many others with the power of good wishes."

"I fly to my home...the world of pure light...the world of peace...here in this peaceful land I sit next to the source of peace, God the Supreme... the unlimited Ocean of Peace.

In front of me I now visualize all other souls...like so many stars...I share all the peace and love I feel within me with these souls...I am filled with this powerful vibration of purity coming from God...passing through me...to all others.

A superb sensation of light grows inside me as I take on my angelic form...I become the form of light...and I am aware of Baba... God, the Supreme...the Ocean of Light.

My sweet Baba ...You are the World Benefactor...and, when I am with You...so too am I a benefactor to others.

I bathe gently in these warm waves of love and peace...which I now pass on these experiences to all my brother souls...and in this light and detached state...I can see the beginning...the middle...and the final scenes of this cycle of world history unfolding before me...I can see the time of transformation...of great beneficial change...coming close.

Here, in this region where only angels can dwell...I am light and free...absolutely no

physical or subtle burden can pull me...I enjoy only the bliss of Your sweet love. I feel your purity. Baba what is left for me but to become an instrument for your mercy...

The old tired world is so far away...and yet close enough that our pure vibrations and thoughts can bring love, solace and mercy to all...my dearest Baba...may all souls come to taste this sweet nectar of contentment!"

Gone with the mind: Thought based meditation and its implications to attention strategies

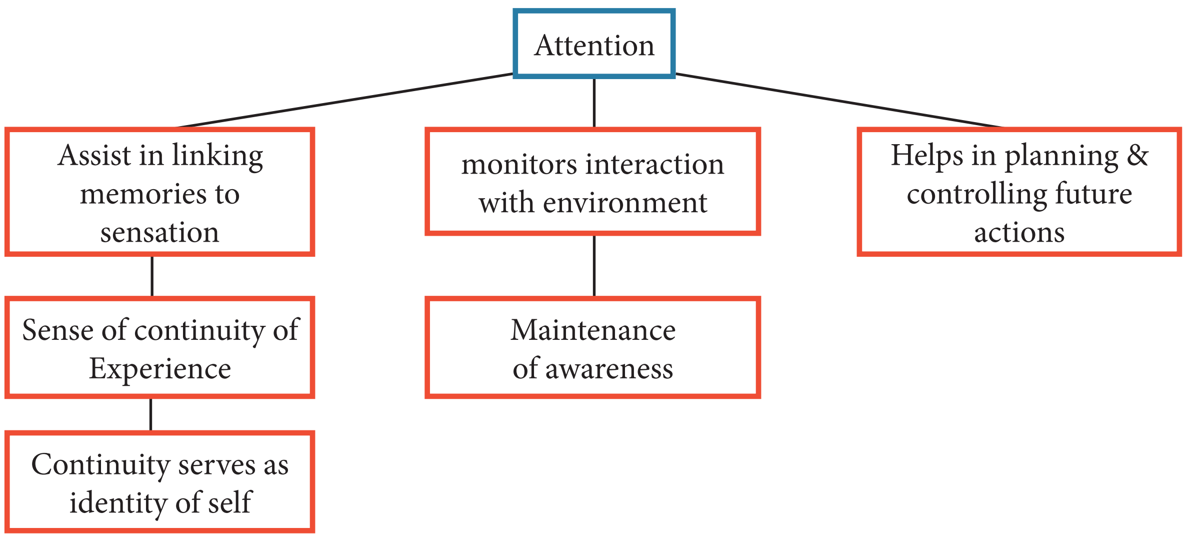
Kanishka Sharma[1], Richa Trivedi1, Sushil Chandra[1], Ashok K Dubey[2]
1. Dept. of Biomedical Engg., INMAS-DRDO, Delhi, 2. Division of Biotechnology, NSIT, Dwarka, Delhi

Abstract

Meditation has been proven to be a boon to medical sciences as well as for gaining powerful self-regulatory mechanisms. In the present review, a model has been hypothesized for a method of meditation (Rajayoga Meditation) based on the generation of thought and its propagation to the utmost level o consciousness. Rajayoga meditation (RM) is being taught worldwide by Brahma Kumaris World Spiritual University. It has many classified strategies, which allow its effects to leave impressions on the conscious mind, unlike defined instructions for mindfulness and concentrative meditation; RM is composed of many modes of thoughts. In the given model, attention correlates of long term meditators are presented and with their experience, it has been approached to provide insights of: how they react to any sensory cue provided, how they orient their attention to other cue and how they became able to monitor conflict; generated due to provided cue having similar properties. Most striking are the changes lied down in their approach of reactions due to the regular practice of meditation. One interesting finding has been documented relating to one's intrinsic awareness with extrinsic attention. As the Rajayoga is based on positive thought incorporation and its iteration, it provides flexibility & modulates the ability to evaluate performance by Meta-cognitive awareness of one's cognitive processes. With previous findings on cognitive control and attention, meditation has been found out to create holistic awareness about environmental cues with reduced arousal (Langer, 1981). But due to reduced arousal focal attention is also reduced on specific cue and habitual responding with many hours of meditation practice also gets reduced. Expert Meditators can reverse the phenomenon of automatization as their involvement in meditation leads to a reduction in habitual cognition. It has been described in the poster with the help of an interactive model.

Introduction

Rajayoga is a regulated exercise in which recollection, contemplation, concentration, and attention are used in a methodical way to achieve a blissful state. While doing a practice of Rajayoga one has to detach from mundane the gross and material. Mind, intellect, and emotions are being used for a special theme in a special way. It may be practiced at progressive levels of knowledge, faith, energy, and consciousness. The technique of self-exploration, leading to the experience of heightened and expanded awareness reaching to supreme and bridging itself to the soul's awareness. It is based on thought generation and propagation of mind to blissful state using the same thought. This practice meditator gets mind transformed into a reservoir accepting positive thoughts and neglecting negative thoughts.



Approach:

Approach of this poster is a depth review of researches done on meditation and its effect on cognitive dimensions of human. Meditation provide a vision over metacognitive process which flexibly control over perception and attention.

State of Meditation

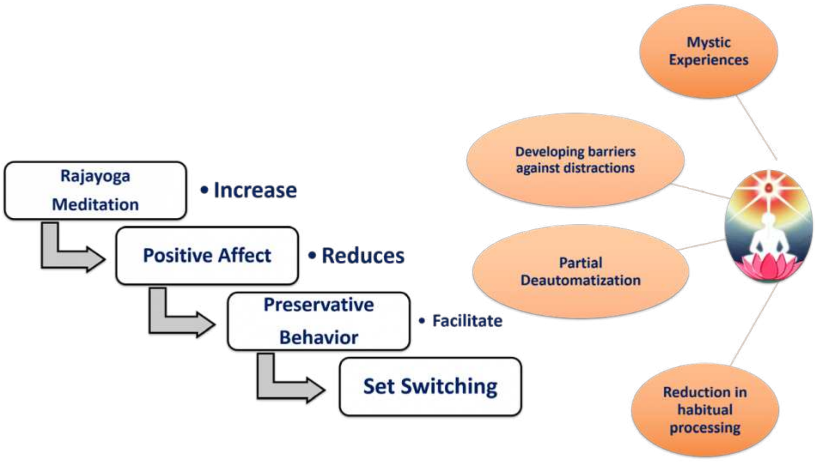
- Mystic Experience
- Positive Affect
- Deautomatized state
- Enhanced awareness
- Intuitive Perceiving
- Silently reflecting

Cognitive Properties

- Attention
- Habitual responding reduced
- Cognitive control
- Conflict monitoring
- Proactive control

Behavioral Outputs

- Reduction in arousal
- Effortless concentration
- True perception of reality
- High absorption
- Reduction in errors
- Strong Decision making
- Blissful State
- Happy and pleasant state of mind



Conclusion:

Meditation has been as the most wonderful phenomenon to achieve performance enhancement. In most meditation types, there is a zeal to achieve an elevated state. This state of elevation extends to relaxed and calm mind or enervated state or thoughtlessness. With the diagrammatic representation of Rajayoga meditation, it has been tried to understand the manner in which it is influencing the state of self-awareness and monitors the performance measures itself while engaging in task-based stress. A person engaged in Rajayoga practice for a long time i.e. years might develop steady changes in strategies to look into situations and deal with them efficiently. The major part of this enhancement is played by the positive affect and thoughts generated and propagated in this type of meditation. There is still a gap with a reduction in arousal hypothesis states. But with widely accepted researches stating performance enhancement with meditation makes it a prominent non-invasive method for attention enhancement.

References:

- Brahmakumaris (1996) Practical Meditaion: Brahmakumaris Ishwariya Vishwa Vidyalaya.
- Dreisbach, G. (2006). How positive affect modulates cognitive: The costs and benefits of reduced maintenance capability. Brain and cognition, 60, 11-19.
- Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perserveration at the cost of increased distractibility. Journal of Experimental Psychology, 30, 343-353.
- James W (1929) The Varieties of Religious experience; New York, Modern Library, 388.
- Sormaz S.W. (2005) Meditation can reduce habitual responding, Alternative therapies.11.2, 42-58.
- Wouwe van N.C., Band PH Guido, Ridderinkhof K.R., (2010) Positive affect modulates flexibility and evaluative control, Journal of Cognitive Neuroscience 23:3, 524-539.

THE SOUL OF RAJYOGA MEDITATION: A BRAIN MAPPING 3D CORTEX/ SCALP/ ELECTRODES, EEG IMAGING USING LORETA (LOW RESOLUTION ELECTROMAGNETIC TOMOGRAPHY)

Kanishka Sharma[1], Rajesh Kumar[1], Ashok K Dubey[2], Sushil Chandra[1] Department of Biomedical Engineering,

1-Institute of Nuclear Medicine and Allied Sciences (INMAS), DRDO, Delhi, India 2-Division of Biotechnology, NSIT, Delhi University

Abstract:

Rajyoga meditation aimed at spiritual energies and attention whose seed already resides within us. It flourish exceptional positive variations in cognitive properties viz. alertness, decision-making and emotion regulation. Following research was designed to assess long-term practice effects of Rajyoga meditation on attention networks in brain, which are for alertness to specific cue, orientation to another cue and conflict resolution. Physiological data of electroencephalography during meditation, and pre post effects were recorded with 14 channel EEG using Emotiv® following 10-20 electrode placement system, and cortical activation was further analyzed with sLORETA software as reference of EEG coherence data (low resolution brain electromagnetic tomography) exposed area of brain activation pre post & during attention network test (ANT) Performed, image comparison was done with prepost, during meditation and during performing attention network test.

Introduction:

Rajyoga Meditation is alertness of the physical self and absorption of one's mind in loveful and purposeful consciousness of God and his divine attributes. The word 'Yoga' means 'to unite'; Yoga is, therefore, the practice or art of uniting or linking the mind with God by focusing attention on him as an incorporeal being-of- light and thinking of nothing but his divine qualities. This takes one into a state of absorption in bliss and peace through positive thinking. It recharges one's self or soul with light and might and fills one with creative energy. Meditation gives us mental relaxation as well as physical relaxation and constant peace and improves the quality of being, also Stress and anxiety reduced (Newsome, Christopher, 2006; linda M. Mascaritolo, 2009). Meditation is currently an important topic in affective and cognitive neuroscience. Many physiological and psychological aspects of meditation practice have been reported applying very different measurement and analysis approaches (e.g. Luders et. al., 2009; Lutz et al., 2009; Van den Hurk et al., 2010). The EEG measure of functional connectivity implemented as coherence between head surface recorded EEG time series has been used to assess brain states during meditation.This result shown the increased EEG coherence during meditation and Improvement of Emotion And Attention Regulation after meditation (Carolina Baptista Menezes et. al., 2013, Gaëlle Desbordes et.al 2012 Aleksander Sobolewski et. al. 2011,), also self compassion as a measures positive and negative (Neff, 2003b). Meditation produces long-term increases in the efficiency of the executive attentional network (anterior cingulate/prefrontal cortex) but no effect on the orientation network (parietal systems), (Davina chan et al., 2007) LORETA (Roberto et. al., 1994) is a simple method to visualize the dipolar sources in a 3D head model from surface EEG. In principle, the LORETA is a linear method of estimation.

Objective:

We have defined following objectives to study brain activation in rajyoga meditation.

- Average ortical activations during meditation, attention task in Long term meditators.
- Utilization of sLORETA to find out brain activation in low resolution EEG data

Methodology:

Participants- N=10, Male, aged 30 to 50 years, Samarpit Rajyoga meditators and having atleast 10 years (2 hrs daily) of regular practice of same. Design-Study was designed in Pre-Practices-Post Evaluation basis (Various psycophysiological Tests with EEG). EEG from each subject was recorded with a low-cost EEG device Emotiv®. EPOC, from 14 Channel locations are: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4. Recording: The EEG data acquired At Headquarters Brahmakumaris, Shantivan, Mount Abu, Rajasthan in the month of September 2014.

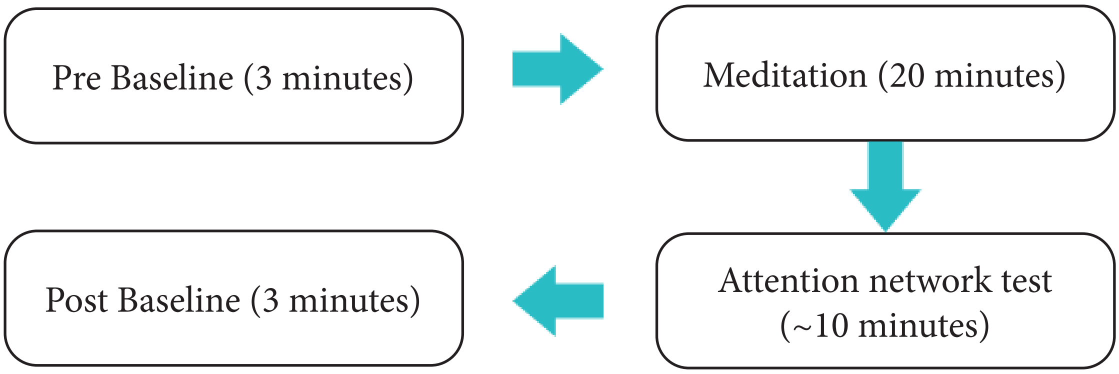


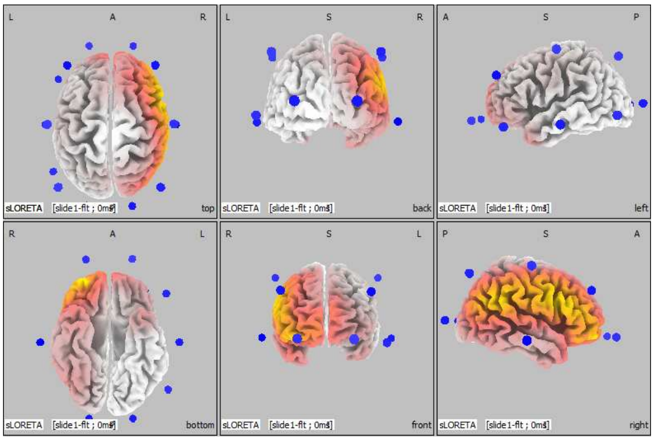
Fig 1:- (a) Emotive Epoc EEG headset, (b) Electrode positions

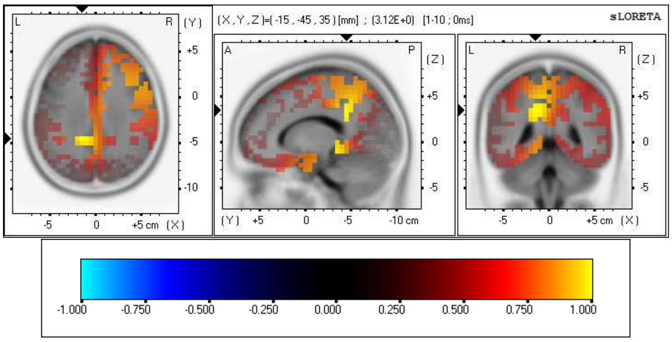
Conclusion & Discussion

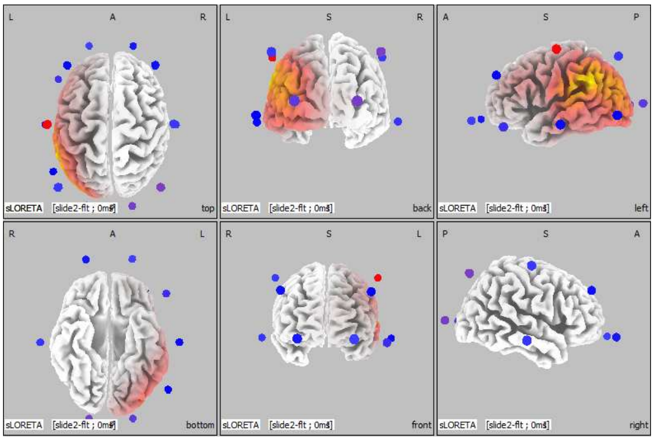
As shown with figure, more activated areas with different conditions were illuminated with yellow tone. During attention task, Superior Frontal Gyrus & cingulate gyrus were activated. As these cortical areas are respectively responsible for Self awareness, coordination with action of the sensory system, emotion formation and processing & during learning & memory as well as executive functions and respiratory control. Anterior cingulate gyrus is responsible for error and conflict detection process. During meditation Superior temporal gyrus and supramarginal gyrus were activated which are responsible for perception of emotion and facial stimuli, processing of sound and important structure for coordination among decision making and affect regulation. Supramarginal gyrus plays important role in empathy towards people as well as quick judgements regulated by SMG. As results were calculated with 14 channel EEG data only major activations were able to determined by sLORETA. As future perspectives high density EEG can provide more depthful spatial locations of brain activations during Rajyoga meditation

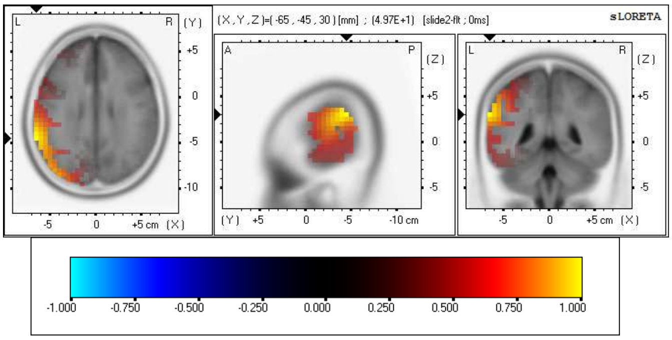
Result:

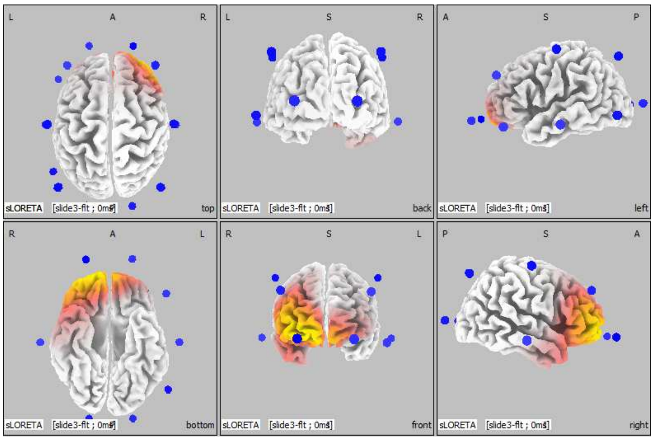
We have investigated average cortical activation of brain regions by processing EEG data with the help of sLORETA. while performing Attention network Test (Fan J, 2002) during meditation and pre-post baseline for 3 minutes eyes open.

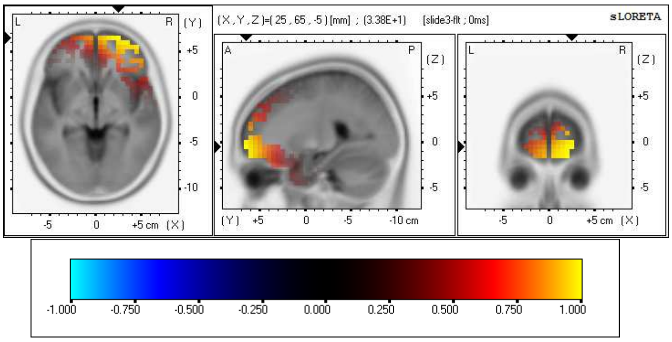


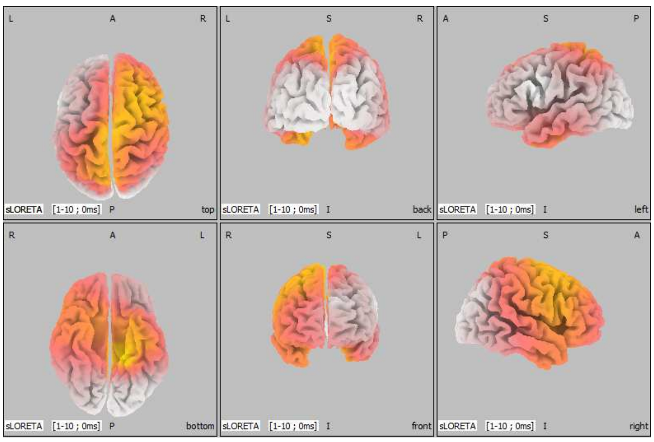


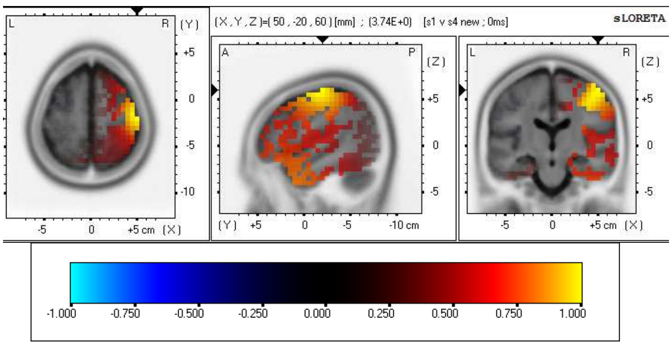












Acknowledgement

Following research was supported/funded by INMAS- Defence Research & Development Organization. Also, we are highly thankful for all the participants and SpARC wing of Brahmakumaris for their invaluable support for the study.

Reference

- Chan, D., Woollacott M., (2007) Effects of Level of Meditation Experience on Attentional Focus:Is the Efficiency of Executive or OrientationNetworks Improved? The journal of alternative and complementary medicine, 13 (6), 651–657

- Gaëlle Desbordes, Lobsang Tenzin Negi, Thaddeus W. W. Pace et al. (2012) Effects of mindful-attention and compassion meditation training on amygdala response to emotional stimuli in an ordinary, non-meditative state, Frontiers in Human Neuroscience, 6, 292, 1-15

- Luders, E., Toga, A. W., Lepore, N., & Gaser, C. (2009). The underlying anatomical correlates of long-term meditation: Larger hippocampal and frontal volumes of gray matter. NeuroImage, 45, 672–678

- Lutz, A., Slagter H.A., Rawlings N.B., Francis A.D. Greischer L.L., Davidson R.J., Mental Training Enhances Attentional Stability: Neural and Behavioral Evidence, 29, 42, 13418-13427

- Newsome, S., Christopher, J. C., Dahlen, P., & Christopher, S. (2006).Teaching counselors self-care through mindfulness practices. Teachers College Record, 108, 1881–1990

- Moscaritolo L. M. (2009). Interventional Strategies to Decrease Nursing Student Anxiety in the Clinical Learning Environment. Journal of Nursing Education, 48, 1, 17-23 • Menezes C.B., de Paula Couto M. Buratto L.G., Erthal F, Pereira M.G., Bizarro L., (2013) The Improvement of Emotion and Attention Regulation after a 6-Week Training of Focused Meditation: A Randomized Controlled Trial. Evidence-Based Complementary and Alternative Medicine, 2013, 1-11

- Neff, K. D. (2003b). The development and validation of a scale to measure self-compassion. Self and Identity,2, 223–250

- Pascual-marqui R.D., Michel, C.M., Lehmann D. (1994) Low resolution electromagnatic tomography: A new method for l;ocalizing electrical activity in the Brain. Int. Journal of Psychopysiology, 18, 49-65

- van den Hurk P. A. M., Giommi F., Gielen S. C., Speckens A. E. M., Barendregt H. P. (2010).Greater efficiency in attentional processing related to mindfulness meditation. Q. J. Exp. Psychol.63, 1168–1180

DOI: 10.7860/JCDR/2013/5889.3488

Original Article

Psychiatry Section

Efficacy of Rajayoga Meditation on Positive Thinking: An Index for Self-Satisfaction and Happiness in Life

RAMESH M.G.[1], SATHIAN B.[2], SINU E.[3], KIRANMAI S. RAI[4]

ABSTRACT

Objectives: Psychological studies have shown that brief period of mindfulness meditation significantly improves critical cognitive skills. But, there are no studies which have assessed the effects of Brahma Kumaris Rajayoga Meditation (BKRM) practice on positive thinking and happiness in life. The present study was designed to test the hypothesis is BKRM enhances positive thinking and that essential to attain higher levels of self-satisfaction and happiness in life.

Material and Methods: This study is a cross sectional comparative study which was done between Rajayoga meditators and non-meditators. This study was conducted at BKRM Centres at Manipal and Udupi in Karnataka, India. Fifty subjects were selected for this study, which included those practising BKRM in their normal routine life (n=25) and non-meditators (n=25) who were aged 42.95+/15.29 years. Self-reported Oxford happiness questionnaire (OHQ) was administered to all subjects and their happiness scores and status were assessed and compared. Items related to self-satisfaction in life were selected from the OHQ and compared between meditators and non-meditators. Participants completed self-reported OHQ, from which data of happiness status and self-satisfaction in relation to meditation duration and frequency were analyzed by descriptive statistics and test of hypothesis.

Results: Mean happiness scores of BKRM were significantly higher ($p<0.001$) in meditators as compared to those in non-meditators. The number of meditators experiencing happiness status were significantly higher ($p<0.05$) in comparison with non-meditators. Additionally, meditators scored significantly higher on self-satisfaction items ($p<0.001$) as compared to non-meditators. There was no correlation between age and years of meditation practice with happiness score and self-satisfaction score.

Conclusion: BKRM helps in significantly increasing self-satisfaction and happiness in life by enhancing positive thinking. Irrespective of age and years of short-term or long-term meditation practice, enhanced positive thinking increases self-satisfaction and happiness in life.

Key words: Brahmakumaris Rajyoga Meditation, Positive thinking, Happiness, Self-satisfaction

INTRODUCTION

"Positive psychology," is a recent method which is being employed in psychological treatment protocols, in an effort to better understanding about happiness, meaning of life, character strengths, and how all these can be developed and enhanced in life to have a better quality of life [1]. Positive emotions promote discovery of novel and creative actions, ideas and social bonds, which in turn, build an individual's personal resources; ranging from physical and intellectual resources, to social and psychological resources [2]. Positive emotions play a crucial role in enhancing resources and coping in the face of negative events [3]. Subjective well-being and satisfaction with life are important domains of life [4]. Brief training on mindfulness meditation or somatic relaxation reduces distress and improves positive mood states [5]. Meditation is an age-old self-regulatory strategy that is gaining more interest in mental health counsel and psychiatry, as it can reduce arousal states and anxiety conditions [6]. Meditation is considered as a type of mind-body complementary medicine. It can give a sense of calmness, peace and balance that benefits both emotional well-being and overall health. Spending even a few minutes in meditation can restore mental calmness and inner peace [7]. Brahma kumaris Rajyoga Meditation (BKRM) gives a clear spiritual understanding of self and helps one to re–discover the use of positive qualities which are already latent within oneself, this enables to develop strengths of character and to create new attitudes and responses to life [8].

The present study was aimed at assessing the efficacy of BKRM on positive thinking, essential for enhancing self-satisfaction and happiness in life. Studies done by psychologists have identified significant improvement in critical cognitive skills following brief period of mindful meditation. But, there are no studies which have related the effect of Brahma Kumaris Rajayoga Meditation (BKRM) practice on positive thinking and happiness in life. The present study was designed to test the hypothesis that meditation enhances positive thinking and that it is essential for increasing self-satisfaction and happiness in life.

MATERIAL AND METHODS

This study was approved by the ethical committee of Annamalai University Distance Education program, Annamalai University, Tamilnadu, India. Fifty participants [age: 42.95±15.29] selected for this study included BKRM practitioners (n=25) and normal healthy non-meditator subjects [not practising any kind of meditation] (n=25). Socio-demographic profile of each participant was collected, as has been shown in [Table/Fig-1]. Regular meditators were selected from BKRM Centres at Manipal and Udupi, India. All the 25 meditators were daily practitioners of Rajayoga meditation at the centres, who undertook similar practices at home as well. The inclusion criteria for selecting these meditators was, a minimum period of 3 months of regular BKRM practice. Non-meditators were healthy subjects who were willing to participate, selected for the study from the general population of Manipal.

Rajayoga Meditation

Rajayoga meditation is one of the training courses of Rajayoga Education and Research Foundation of Brahma Kumaris World Spiritual University (BKWSU), a Non-Governmental Organization [NGO] that has consultative status with UNO, UNICEF and WHO [9].

During Rajayoga Meditation, subjects sit in soul consciousness with their eyes open, and with their gazes fixed on a meaningful symbol (a point of light which is considered as Supreme Soul).The mental connection between the soul and Supreme Soul or the remembrance of the Supreme Soul by the soul is called as Rajayoga. Stability in the Soul-consciousness and God-consciousness will bring peace and bliss to the soul [10] .

This meditation is practised in four stages: [11]

- **Initiation:** Comfortable, quiet, sitting posture with eyes open, relaxing the body and mind.
- **Meditation:** A connected series of pure and positive thoughts that produces the fuel for inner journey of the soul.
- **Concentration:** In this stage, world thoughts cease without difficulty, as the mind becomes fascinated with its own reality and the presence of Supreme Being becomes evident.
- **Realization:** Realization of peace and happiness of mind, experienced as bliss.

Psychological Test Tool

In this study, Oxford Happiness Questionnaire (OHQ) was used to measure the self-reported happiness status. It is being widely used by psychologists and sociologists as a tool for assessing happiness status. OHQ is a uni-dimensional scale with 29-items, designed to measure the happiness status. It is a reliable and valid questionnaire [12]. It employs a 6 point Likert-type format of response, from 'strongly disagree' to 'strongly agree, to measure self-reported happiness score and self-satisfaction score OHQs filled out by all subjects were collected and the mean score for the 29 items was calculated. The lowest possible score was 1 and the highest was 6. Based on the mean score, the 'unhappy to happy state of mind' can be interpreted. In this study, mean scores of 4 or >4 were considered as representing happy state and those <4 were considered as representing unhappy state. Further, the items which represented self-satisfaction [Table/Fig-2] of the subjects were selected and the average score of self-satisfaction was compared between meditators and non-meditators.

STATISTICAL ANALYSIS

Descriptive statistics and testing of hypothesis were used for the analysis by using R v2.15.2. The associations between the different variables were tested using the Chi-square test and strength of the relationship was tested using logistic regression. Student t-test was used for the comparison of the mean happiness scores and self-satisfaction scores.

RESULT

In the present study, no significant difference was found in socio-economic status between meditators and non-meditators, as has been shown in [Table/Fig-1]. The mean happiness scores and happiness status were compared between meditators and non-meditators, as has been shown in [Table/Fig-2]. Mean happiness scores of meditators were significantly higher (t=5.88,df = 48, p<0.001) as compared to those of non-meditators. Significantly more meditators were in happy status as compared to non-meditators χ^2 (Fisher's exact test) =10.97, 2-tailed p<0.05), which indicated that meditators [24 (96%)] were happier than non-meditators [14 (56%)]. Additionally, meditators expressed significantly higher mean self-satisfaction scores (t=4.47, df=48, p<0.001) as compared to non-meditators, as has been shown in [Table/Fig-2]. No positive or negative correlation was found between happiness scores (r = -0.04205, 95% CI; -0.4301 – 0.3591, p = 0.8418) and self-satisfaction scores (r = -0.1955, 95% CI; -0.5483 - 0.2165, p= 0.3491) of meditators as well as happiness scores (r = 0.2840, 95% CI; -0.1252 - 0.6107, p = 0.1688) and self-satisfaction scores (r = 0.1578, 95% CI; -0.2533 - 0.5205, p = 0.4514) of non-meditators in relation to their age, as has been shown in [Table/Fig-3]. The years of meditation practice also did not correlate with happiness score (r = -0.1992, 95% CI; -0.5510 – 0.2128, p = 0.3398) as well as with self- satisfaction score (r = 0.03078, 95% CI; -0.3689 – 0.4209, p = 0.8839) in meditators, as has been shown in [Table/Fig-4].

DISCUSSION

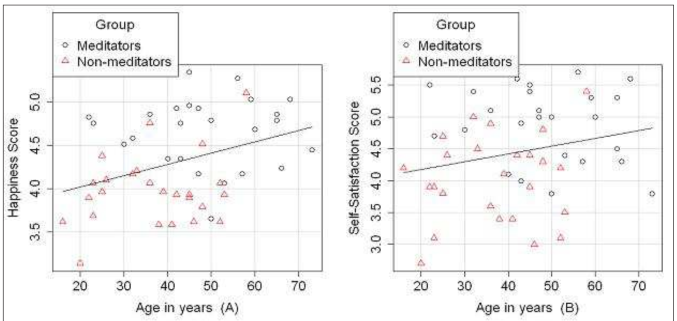
A positive mind anticipates happiness, joy, health and successful results [13]. Gable stated that communicating personal positive events has an impact on the person, for increasing daily positive effects and well-being [14]. Self-focus on positive self-aspects and following positive events were related to lower negative effects [15].

Socio-demographic variables	Meditators (n=25)	Non-Meditators (n=25)
Age (mean±SD)	48.68±13.77*	36.96±11.98
Gender n(%)		
Male	10 (40)	15 (60)
Female	15 (60)	10 (40)
Marital Status n(%)		
Unmarried	7 (28)	8 (32)
Married	18 (72)	17 (68)
Education n(%)		
Non-graduates	11 (44)	10 (40)
Graduates	14 (56)	15 (60)
Employment status n (%)		
Unemployed	11 (52)	10 (40)
Employed	14 (48)	15 (60)
Economic Status n(%)		
No Income	8 (32)	10 (40)
Income	17 (68)	15 (60)

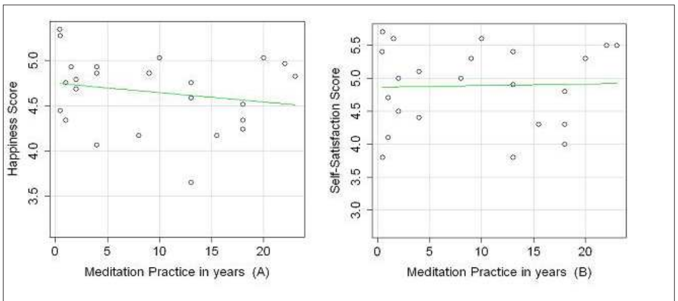
[Table/Fig-1]: Distribution of socio–demographic status of meditators and non-meditators
SD, standard deviation; NA, *p<0.05

Groups (n)	Happiness Score	Happiness Status		Self-Satisfaction Score
	(Mean±SD)	Unhappy n(%)	Happy n(%)	(Mean±SD)
Meditators (25)	4.66±0.39**	1 (4)	24 (96)*	4.80±0.59**
Non-meditators (25)	3.98±0.41	11 (44)	14 (56)	4.09±0.53

[Table/Fig-2]: Comparisons of happiness score, happiness status and self-satisfaction between meditators and non-meditators
¶ Self-Satisfaction items in Oxford Happiness Questionnaire: 1, 3, 6, 9, 12, 14, 17, 22, 24, 29.
SD, standard deviation. *p<0.05, **p<0.001



[Table/Fig-3]: Correlation of age with happiness score (A) and self-satisfaction score (B) in both meditators and non-meditators. Note the higher distribution of both self-satisfaction and happiness scores in meditators through aging



[Table/Fig-4]: Correlation of number of years of meditation practice among meditators with their happiness score (A) and self-satisfaction score (B).

The short-term effect of positive reappraisal could be helpful for youth experiencing difficulties in managing negative effects [16]. Studies have shown that having positive emotions helped people to come out of depression, following aftermath of any crisis in life [17] and that these positive emotions helped in providing a broad mind-set [2]. Positive behaviour recognition is especially important during adolescent development, to cultivate moral reasoning and social perspective thinking on various social systems [18]. Positive thinking helps with stress management and in overcoming negative self-talk [7]. Levy reported in his aging studies, that older individuals with more positive self-perceptions had better functional health than those with more negative self-perceptions of aging and that they lived 7.5 years longer. This advantage remained after age, gender, socio–economic status, loneliness, and functional health were included as covariates [19, 20]. Similarly, results of the present study suggested that practice of BKRM at any age enhanced positive thinking and that it provided happiness in life.

Diener described that positive and negative feelings were associated with fulfillment of psychological desires [21]. Happiness is not simply a matter of desire satisfaction but of personal well–being or life satisfaction as well [22]. In the present study, meditators had significantly highest scores on self-satisfaction, suggesting that BKRM enhanced personal well-being and it thus, expressed a more self-satisfied life.

Happy people have a functioning emotion system that can react appropriately to life events [23]. Research psychologists, Matthew A. Killingsworth and Daniel T Gilbert of Harvard University reported in 2012, that "the ability to think about what is not happening is a cognitive achievement that comes at an emotional cost" and people who achieve this kind of mindfulness are happier [24]. Studies have shown that brief periods of mindfulness meditation intervention were effective in reducing pain ratings and anxiety scores and that they increased mindfulness skills [25]. It was observed that just 4 days of meditation training could enhance the ability to sustain attention, which was usually reported in long-term meditators. Similarly, in the present study, meditators scored significantly higher in happiness scores than non-meditators, suggesting that BKRM helped in achieving mindfulness which elevated them to happier emotional states, irrespective of the period of meditation experience.

LIMITATIONS

1. The sample size was limited to n=25, since the available regular meditators from Manipal and Udupi BKRM Centres were only 25 in number during our study period from July to September 2012.
2. This study did not have adequate representation of samples from different socio-demographic and economic strata. Larger sample sizes from both the groups, which belong to different socio-demographic and economic strata, need to be studied, to analyze their effects on self-satisfaction and happiness in life.

CONCLUSION

Happiness is associated with multiple benefits, including better health [1]. BKRM helps in significantly increasing self-satisfaction and happiness in life by enhancing positive thinking. Irrespective of age and years of short-term or long-term meditation practice, enhanced positive thinking increases self-satisfaction and happiness in life.

REFERENCES

[1] Hershberger PJ. Prescribing happiness: positive psychology and family medicine. *Fam Med*. 2005 Oct;37(9):630-34.
[2] Fredrickson BL. The broaden-and-build theory of positive emotions. *Philos Trans R Soc Lond B Biol Sci*. 2004 Sep 29;359(1449):1367-78.
[3] Tugade MM, Fredrickson BL, Barrett LF. Psychological resilience and positive emotional granularity: examining the benefits of positive emotions on coping and health. *J Pers*. 2004 Dec;72(6):1161-90.
[4] Wirtz D, Chiu CY, Diener E, Oishi S. What constitutes a good life? Cultural differences in the role of positive and negative affect in subjective well-being. *J Pers*. 2009 Aug;77(4):1167-96.
[5] Jain S, Shapiro SL, Swanick S, Roesch SC, Mills PJ, Bell I, et al. A randomized controlled trial of mindfulness meditation versus relaxation training: effects on distress, positive states of mind, rumination, and distraction. *Ann Behav Med*. 2007 Feb;33(1):11-21.
[6] Krisanaprakornkit T, Krisanaprakornkit W, Piyavhatkul N, Laopaiboon M. Meditation therapy for anxiety disorders. *Cochrane Database Syst Rev*. 2006 (1):?.
[7] Mayo Clinic. Meditation: A simple, fast way to reduce stress. Retrieved on June 2012. Available from: http://www.mayoclinic.com/health/meditation/HQ01070.
[8] Telles S, Desiraju T. Autonomic changes in Brahmakumaris Rajayoga meditation. *Int J Psychophysiol*. 1993 Sep;15(2):147-52.
[9] Usha Kiran BM, Venugopal P, Vivekanandhan S, Pandey RM. The Effect of Autogenic Relaxation On chronic tension headache and in modeling cortisol response. *Indian J Anaesth*. 2005 1-9?-2005;49(6):474-78.
[10] Brahmakumaris. Understanding Rajyoga. Retrieved on 12 June 2012. Available from: http://www.brahmakumaris.com/rajayoga-meditation/101.html.
[11] Patel G. Positive Health; Rajayoga meditation for stress-free peaceful and healthy life. 2 ed. Delhi, India.: Prajapitha Brahma Kumaris Ishwarya Vishwa Vidyalaya; 1984.
[12] Hills P, Argyle M. The Oxford Happiness Questionnaire: a compact scale for the measurement of psychological well-being. *Personality and Individual Differences*. 2002;33(7):1073-82.
[13] Sasson R. The Power of Positive Thinking. Retrieved on August 2012. Available from: http://www.successconsciousness.com/index_000009.htm.
[14] Gable SL, Reis HT, Impett EA, Asher ER. What do you do when things go right? The intrapersonal and interpersonal benefits of sharing positive events. *J Pers Soc Psychol*. 2004 Aug;87(2):228-45.
[15] Mor N, Winquist J. Self-focused attention and negative affect: a meta-analysis. *Psychol Bull*. 2002 Jul;128(4):638-62.
[16] Rood L, Roelofs J, Bogels SM, Alloy LB. Dimensions of Negative Thinking and the Relations with Symptoms of Depression and Anxiety in Children and Adolescents. *Cognit Ther Res*. Aug;34(4):333-42.
[17] Fredrickson BL, Tugade MM, Waugh CE, Larkin GR. What good are positive emotions in crises? A prospective study of resilience and emotions following the terrorist attacks on the United States on September 11th, 2001. *J Pers Soc Psychol*. 2003 Feb;84(2):365-76.
[18] Law BM, Siu AM, Shek DT. Recognition for positive behavior as a critical youth development construct: conceptual bases and implications on youth service development. *Scientific World Journal*.2012:809578.
[19] Levy BR, Slade MD, Kasl SV. Longitudinal benefit of positive self-perceptions of aging on functional health. *J Gerontol B Psychol Sci Soc Sci*. 2002 Sep;57(5): P409-17.
[20] Levy BR, Slade MD, Kunkel SR, Kasl SV. Longevity increased by positive self-perceptions of aging. *J Pers Soc Psychol*. 2002 Aug;83(2):261-70.
[21] Diener E, Ng W, Harter J, Arora R. Wealth and happiness across the world: material prosperity predicts life evaluation, whereas psychosocial prosperity predicts positive feeling. *J Pers Soc Psychol*. 2010 Jul;99(1):52-61.
[22] Hasnain N, Ansari SA, Samantray S. Spirituality and Happiness as Correlates of Well-being in Religious Women. *European Journal of Social Sciences*. 2011;20(3):431-42.
[23] Diener E, Seligman ME. Very happy people. Psychol Sci. 2002 Jan;13(1):81-84.
[24] Bradt S. Wandering mind not a happy mind: Harward Science. Retrieved on 1st December 2012. Available from: http://news.harvard.edu/gazette/story/2010/11/wandering-mind-not-a-happy-mind/.
[25] Zeidan F, Gordon NS, Merchant J, Goolkasian P. The effects of brief mindfulness meditation training on experimentally induced pain. *J Pain*. 2010 Mar;11(3):199-209.

PARTICULARS OF CONTRIBUTORS:
1. Lecturer, Department of Physiology, Melaka Manipal Medical College, Manipal University, India.
2. Assistant Professor, Department of Community Medicine, Manipal College of Medical Sciences, Pokhara, Nepal.
3. Assistant Professor, Deparment of Psychiatry, Katurba Medical College, Manipal University, India.
4. Professor, Department of Physiology, Melaka Manipal Medical College, Manipal University, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Ramesh M.G.,
Lecturer, Department of Physiology, Melaka Manipal Medical College, Manipal University,
Manipal - 576104, Karnataka, India.
Phone: +919611362075, E-mail: ramesh.babu@manipal.edu; mgrameshbabu008@gmail.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: Feb 16, 2013
Date of Peer Review: Jul 03, 2013
Date of Acceptance: Aug 14, 2013
Date of Publishing: Oct 05, 2013
Date of Last Amendment: Mar 22, 2014

BRAIN CONNECTIVITY
Volume 8, Number 1, 2018

DOI: 10.1089/brain.2017.0524

Enhanced White Matter Integrity in Corpus Callosum of Long-Term Brahmakumaris Rajayoga Meditators

Kanishka Sharma,[1,2] Richa Trivedi,[3] Sushil Chandra,[1] Prabhjot Kaur,[3] Pawan Kumar,[3]
Kavita Singh,[3] Ashok K. Dubey,[2] and Subash Khushu[3]

Abstract

Meditation has a versatile nature to affect cognitive functioning of human brain. Recent researches demonstrated its effects on white matter (WM) properties of human brain. In this research, we aim to investigate WM microstructure of corpus callosum (CC) in long-term meditators (LTMs) of rajayoga meditation using diffusion tensor imaging. For this cross-sectional analysis, 22 LTMs and 17 control participants of age ranging from 30 to 50 years were recruited. Results show high fractional anisotropy values with low mean diffusivity in whole as well as different segments of CC in the LTM group. Also the experience of meditation was correlated with WM properties of CC tracts. Findings may suggest rajayoga meditation to bring potential changes in microstructure of CC segments. Further studies are suggested in clinical population to check its validity and efficacy against disorders involving agenesis of WM.

Keywords: Brahmakumaris rajayoga meditation; corpus callosum; diffusion tensor tractography; fractional anisotropy; long-term meditation; mean diffusivity

Introduction

Meditation practice allows one's brain to alter at different levels. It might bring transient changes in microstructure of neuronal architecture. Regular meditation may sustain brain anatomy, which in case of normal individual shows atrophy and degenerated connections due to aging. Different meditation types bring positive changes in psychology (Shapiro et al., 2002), physiology (Cahn and Polich, 2006), and anatomy (Fox et al., 2014) of human brain, which results in enhanced well-being. Neuroimaging has been a great tool to explore these changes at functional and structural levels. Magnetic resonance imaging (MRI) revealed region-specific activations in meditators (Schmidt and Walach, 2014), which plays a role in attention, memory, and emotional processing. Diffusion tensor imaging (DTI) enables to visualize structural changes in healthy human brain caused by training (Scholz et al., 2009). Practicing music (Imfeld et al., 2009), video gaming (Zhang et al., 2015), and meditation (Luders et al., 2011; Posner et al., 2014) leads to changes in fractional anisotropy (FA) and diffusivity values. Expertise in Baduk game brings increased FA in white matter (WM) tracts associated with attention, working memory, and problem solving (Lee et al., 2010). Reasoning training led to decreased diffusivity in frontal WM and left frontal and right parietal cortices (Mackey et al., 2012).

Functional and anatomical changes have been observed to establish therapeutic effects of meditation practice. Subtle changes at macroscopic and microscopic level (Cao et al., 2010; Fox et al., 2014) were found in subjects undergone meditation training. Structural changes due to practice leading to neuroplasticity were inconsistently observed in meditation studies (Lazar et al. 2005; Luders et al., 2009). Inconsistent changes in both gray and WM were seen in brain wave vibration meditators compared with those in controls. Meditators with a mean 40 months training have significantly increased FA values in cuneus, precuneus, and majority of occipital regions in comparison with controls, although no correlation was found between meditation experience and FA values (Kang et al., 2013).

Pagnoni and Cekic (2007) have assumed that neuroplastic changes caused by meditation can be independent of training. In their experiments, gray matter volume was found to be reduced due to increasing age in control but no interaction was found in case of meditators.

Even short period of integrative body–mind training (IBMT) for 4 weeks (Tang et al., 2010) and 11 h (Tang et al., 2012)

[1]Department of Biomedical Engineering, Institute of Nuclear Medicine and Allied Science (INMAS), Defence R&D Organization, Timarpur, Delhi, India.
[2]Division of Biological Sciences and Engineering, Netaji Subhas Institute of Technology, Dwarka, Delhi, India.
[3]Division of NMR, Institute of Nuclear Medicine and Allied Science (INMAS), Defence R&D Organization, Timarpur, Delhi, India.

increases FA in anterior corona radiata associated with anterior cingulate cortex and genu of corpus callosum (CC). Overall, these changes in microstructure can predict the role of meditation in influencing cognitive processes and information flow between intrahemispherical and interhemispherical regions. WM related to CC lateralizes functional capacity of brain. In discrete meditators, enhanced FA was found along with thicker callosal regions (Pagnoni and Cekic, 2007), also the thickness of callosum was found to be correlated with intelligence (Luders et al., 2007). Role of rajayoga meditation in alteration of the temporal dynamics of brain activity was studied using simultaneous electroencephalogram/functional magnetic resonance imaging. Right middle frontal and left middle temporal gyri were more active in meditators while meditating. Progressively higher duration of the default mode network microstate was positively correlated with meditation experience (Panda et al., 2016). Along with the mentioned studies, very few were focused on long-term meditators (LTMs) and changes in their WM properties due to regular practice.

CC is an important role player in cognitive process and interhemispheric transfer of perceptual, cognitive, learned, and volitional information between the two brain hemispheres (Cao et al., 2010). Being the largest fiber network of human brain and having a crucial role in cognitive and affective processing, study of micro- and macrostructural WM changes in CC was proposed in the study. To ascertain the role of CC, meditation practice was correlated with measures of WM properties, that is, FA and diffusivities. To our knowledge, this is the first study to evaluate microstructural changes due to regular practice of rajayoga meditation by Brahmakumaris. We have hypothesized to find correlation between meditation experience particulars (daily frequency, total years, and total hours in lifetime) with WM properties. Laneri et al. (2015) have also correlated with reported meditation years by subjects, although daily practice hours can determine the real extent of meditation experience that is reported in our study. Daily frequency of meditation in minutes and accumulated lifetime experience were considered to correlate with FA values and other WM properties (Luders et al., 2011).

Materials and Methods

Subjects

The sample consists of 22 LTMs and 17 control subjects (demographics given in Table 1). Mean age of control group was 38.94 years (standard deviation [SD] = 6.35), whereas the mean age of the LTM group was 39.5 years (SD = 4.69). Approximate meditation experience was calculated by multiplying the subjective description of the daily practice duration of meditation and number of years since they were regularly practicing with the same duration. As all of them were devoted practitioners, they follow a certain routine/timetable for similar duration of meditation practice in a day. However, some meditators have exceeded their practice, except the morning and evening routine. Owing to their fixed time chart, it was precise to calculate approximate hours spent for meditation practice. Participants in the LTM group have already spent 10–30 years (mean 18.65 years, SD = 5.42) in practicing this technique after learning it. Approximate number of hours spent in meditation ranged from 5475 to 44,286 h throughout their life (mean = 17,824 h, SD = 9414.93) at the time of recording the MRI data. Controls subjects confirmed to have no prior experience in meditation. Subjects were comparable in education background and have similar number of years of education (mean of LTMs education years = 15.36, SD = 0.79; mean control education years = 15.94, SD = 1.02). All subjects in both groups were free from cardiac, pulmonary, and other nervous system dysfunctions. Also, they were found to be suitable for exposure under magnetic area. Experimental procedures were explained. A written information consent was obtained from each subject. The research protocol was approved by the Institutional Ethical Committee of the Institute of Nuclear Medicine and Allied Science before the experimental recording. The status of nonconsumption of alcohol, smoking, or any therapeutics by the subjects within past 6 months was confirmed.

Rajayoga meditation

Rajayoga refers to the Brahmakmaris school of thought. The practitioners make concerted daily spiritual efforts toward self-development while following a recommended set of lifestyle guidelines. This includes a daily timetable with early morning and evening time meditation, spiritual study, balance of work and service, spiritual outlook in relationships, maintaining celibacy, strict vegetarian diet, self-checking for progress, and early rest (Ramsay et al., 2010). The process of rajayoga is practiced in four stages, that is, initiation, meditation, concentration, and final steps in realization (Ramesh et al., 2013). In the process, while sitting quietly in a comfortable position with eyes open, subjects get involved in positive thinking about a universal force pervading light all over while remembering God and one's eternal form as point of light (Ramsay et al., 2010; Telles and Desiraju, 1993). Positive thought incorporation may reduce preservative behavior and help in facilitation of set switching. It provides cognitive flexibility and also has interaction

Table 1. Demographics

	Control (n = *17*)	*LTMs* (n = *22*)	*Statistics*	
	Mean (SD)	*Mean (SD)*		
Age	38.94 (6.35)	39.50 (4.69)	t (*p*)	1.08 (0.28)
Gender (male/female)	13/4	15/7	$\chi^2(p)$	1.01 (0.31)
Years of education	15.94 (1.02)	15.36 (0.79)		
Meditation experience (in years)	—	18.65 (5.42)		—
Daily meditation practice (in minutes)	—	143.04 (64)		—
Mean of total experience (in hours)	—	16,866 (9649.69)		—

$p < 0.05$ considered as significant, χ^2 = value of chi square test.
LTMs, long-term meditators; SD, standard deviation.

with higher cognitive processes. Positive thought may modulate cognitive control and provide flexible updating of working memory (Dreisbach, 2006).

MR image acquisition

All MR images were acquired in the axial plane using a 3-Tesla MRI scanner (Megnetom, Skyra, Siemens) with a 20-channel head and neck coil and 25 mT/m actively shielded gradient system. The head was supported and immobilized within the head coil to minimize head movement and gradient noise. The conventional MRI was done before DTI to rule out any structural abnormality using routine T2-weighted turbo spin-echo sequence. DTI data were acquired using a single-shot echo-planar dual spin echo (SE) sequence in 30 directions with ramp sampling. Diffusion-weighted acquisition parameters were b-factor = 0 and 1000 sec/mm^2, slice thickness = 3 mm with no interslice space, number of slices = 45, field of view (FOV) = 230 × 230 mm, matrix size = 128 × 128, flip angle = 90°, repetition time (TR) = 8800 msec, echo time (TE) = 95 msec, and echo train length (NEX) = 2.

DTI preprocessing. Eddy current and motion corrections were done in data using the automated image and registration package (Roger Woods, Los Angeles, CA). Removal of scalp to isolate the brain in the collected raw images was done by an automated stripping procedure. Subsequent DTI processing did not require any filtering, as justified by the absence of unprocessed voxels (Saksena et al., 2008).

DTI processing. The distortion-corrected data were then interpolated to attain isotropic voxels and decoded to obtain the tensor field for each voxel. The tensor field data were then diagonalized using the analytical diagonalization method to obtain the eigenvalues (l1, l2, and l3) and the three orthonormal eigenvectors (e1, e2, and e3). The orthogonality of the computed eigenvectors and the correctness of the eigenvalues were checked using random sampling at a number of voxels. The correctness observed was up to an order of 10–17, indicating that no iterative refinement of the computed eigenvalues/vectors was needed. The tensor field data were then used to compute the DTI metrics for each voxel (Saksena et al., 2008).

Segmentation of WM structures

Tensor field data obtained from the processing step were used for segmentation of WM structures. The key idea of this method is to segment the principal eigenvector field into stable voxels having a minimal e1 variation (curvature). Thus, a voxel P (i, j, k) is a member of the stable fiber mass (SFM), if there is a neighboring voxel Q (x, y, z) such that the principal eigenvectors e1's at P and Q point out to each other. Mathematically, it translates to the relation G (F (P)) = P, where F (P) = ROUND (P + e1(P) +0.5u), u = (1, 1, 1), and G (Q) = ROUND (Q−e1(Q) +0.5u), function ROUND representing component-wise ''integral part'' operation.

The method first generates SFM and then segments volume by coloring voxel P according to the values the components (l, m, n) of the vector joining P and Q take: (±1,0,0), red; (0, ±1,0), green; (0,0,±1), blue; (±1, ±1,0), yellow; (0, ±1, ±1), cyan; (±1,0, ±1), magenta; (±1, ±1, ±1), white. A nonstable voxel is colored gray and a voxel with FA <0.15 remains black. Typical segmented axial, sagittal, and coronal SFM color maps are generated, using that this method narrows

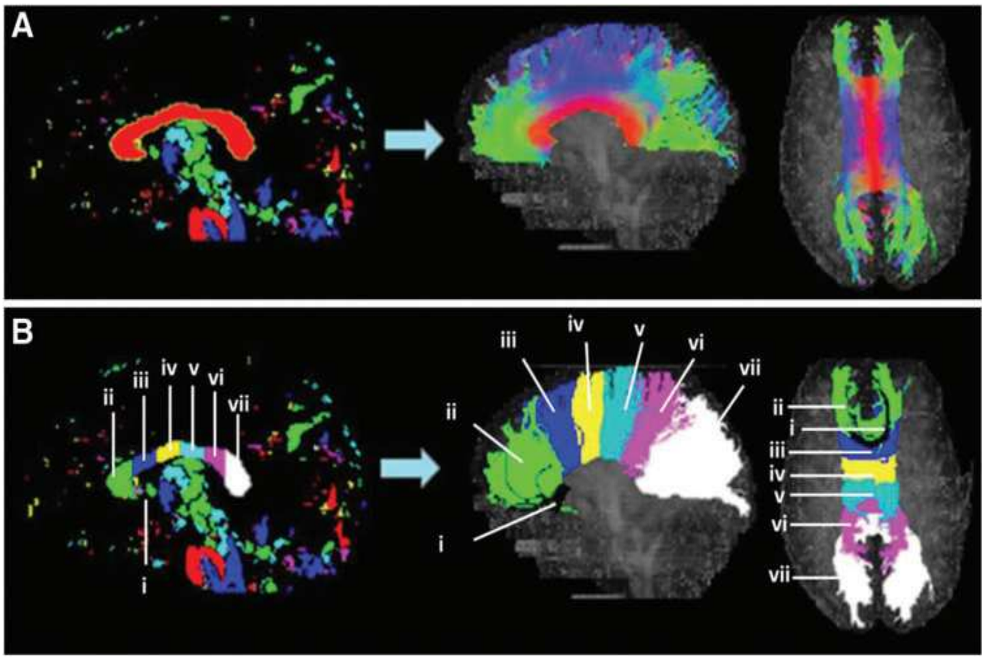


FIG. 1. Figure shows a schematic presentation of the fiber tract reconstruction using FACT algorithm. **(A)** The SFM map of the midsagittal plane, which contains the signature segments of the corpus callosum (CC). By clicking into it, the boundary of the region of interest used for fiber generation is automatically drawn (seen as yellow line) and the corresponding fibers are generated as shown in sagittal and coronal planes (right panel). **(B)** Automatic segmentation of the CC based on Witelson's classification and their corresponding fibers. Each segment is color coded and numbered, namely, rostrum, black (i); genu, green (ii); rostral body, blue (iii); anterior midbody, yellow (iv); posterior mid body, turquoise (v); isthmus, pink (vi); splenium, white (vii). Color images available online at www.liebertpub.com/brain

down the region of interests (ROIs) selection for the standard tractography to pointing out to a color segment inside a broader ROI through a single mouse click (Rathore et al., 2011).

Diffusion tensor tractography

Different fiber bundles are easily reconstructed by the segmented components using fiber assignment by continuous tracking algorithm (Mori et al., 1999). This reconstruction allows the identification of the coordinates of specific WM fiber bundles and relates them to the anatomy. DTI measures were calculated for the entire fiber. FA threshold of 0.15 was used for fiber tracking.

The ROI for generating CC tracts was selected and subdivided into seven segments (rostrum, genu, rostral body, anterior mid body, posterior mid body, isthmus, and splenium) using the scheme proposed by Witelson (1989) in a manner that approximately represents the CC connections hypothesized across cortical brain regions (de Lacoste et al., 1985). From each subregion of CC, fibers were generated and DTI measures were quantified using in-house developed JAVA-based software (Fig. 1). Genu and rostrum were sampled as a single region after averaging, thus six segments of CC were studied for FA and mean diffusivity (MD) changes in both groups.

Statistical analysis

T-statistics with unequal number of observations, by the use of pooled mean square, was performed to study the difference in FA and MD values between controls and LTM group. Correlation analysis was performed between meditation experience variables, age and DTI correlates, and Spearman's rho (r_s) was calculated. For multiple comparison, false discovery rate (FDR) corrections were applied using Benjamini Hochberg procedure. Provided p values survived FDR corrections. All statistical analyses were performed using SPSS (version 15.0; SPSS, Inc., Chicago, IL) statistical software.

Results

FA differences between LTM and control

As summarized (Table 2), significantly larger FA values were found in six callosal regions. Also the overall FA value of CC was found to be significantly larger in LTMs. Differences were found prominent in genu, rostral body, anterior mid body, posterior mid body, isthmus, and splenium. Decreased MD values were found in all regions of CC, where FA values were significantly high in LTMs.

Correlation between FA, MD, and meditation experience

Total hours of meditation in a lifetime were negatively correlated with MD of genu ($r = -0.55$, $p = 0.033$), rostral body ($r = -0.52$, $p = 0.047$), and anterior mid body ($r = -0.543$, $p = 0.036$), whereas whole CC was near to statistical significant level ($r = -0.51$, $p = 0.062$) Table 3.

Inverse relation was also found between daily frequency of meditation (minutes per day) and MD of whole CC ($r = -0.53$. $p = 0.05$), MD of genu ($r = -0.552$, $p = 0.03$), MD of RB ($r = -0.497$, $p = 0.05$), and MD of anterior mid body (AMB; $r = -0.451$, $p = 0.091$) although it did not reach statistical significant level. Except genu ($r = 0.537$, $p = 0.039$), no significant relation was established between FA values of other segments and meditation experience. FA value of genu was correlated positively with daily minutes of meditation frequency.

Discussion

In this study, highly significant increased FA values and reduced MD were observed in each fiber tract of CC between nonmeditating controls and LTMs.

In the LTM group, daily meditation frequency (minutes/day) was negatively correlated with MD of genu, rostral body, AMB, and whole CC. In addition to this, hours calculated in meditation throughout meditators' lifetime were also negatively correlated with MD of genu, RB, AMB, and whole CC.

DTI can measure cellular factors involved in formation of signals through WM. These factors include morphology of neurons (Beaulieu, 2002) and degree of myelination (Gulani et al., 2001). FA is a highly sensitive biomarker for WM integrity. This can effectively diagnose brain pathology due to demyelination, axonal damage, inflammation, and variations in cellular densities (Alexander et al., 2007). During development, myelination increases with high FA value in heavily myelinated fibers. Heavily myelinated fibers conduct neural signals with high velocity, which results in better cognitive functions (Aboitiz et al., 1992). FA and MD were correlated with cognitive performance (Madden et al., 2012), aging

Table 2. Mean Fractional Anisotropy and Mean Diffusivity Analyses in Overall Corpus Callosum and Its Segments

	Mean FA			Mean MD		
Region	*Control*	*LTMs*	*t*(p)	*Control*	*LTMs*	*t* (p)
CC	0.469	0.483	−4.592 (<0.001)	0.956	0.903	7.018 (<0.001)
Genu	0.451	0.465	−3.341 (0.001)	0.994	0.867	4.695 (<0.001)
RB	0.432	0.450	−4.368 (<0.001)	0.946	0.874	6.331 (<0.001)
AMB	0.463	0.482	−4.830 (<0.001)	0.904	0.855	6.039 (<0.001)
PMB	0.465	0.494	−5.233 (<0.001)	0.921	0.859	6.072 (<0.001)
Isthmus	0.439	0.457	−4.464 (<0.001)	1.029	0.970	5.573 (<0.001)
Splenium	0.497	0.510	−4.121 (<0.001)	0.972	0.921	6.704 (<0.001)

$p < 0.05$ considered as significant.
CC, corpus callosum; RB, rostral body; AMB, anterior mid body; PMB, posterior mid body; FA, fractional anisotropy; MD, mean diffusivity.

Table 3. Correlations Between Meditation Experience and Diffusion Tensor Imaging Variables

Variable	*Minutes per day* Pearson's *R* (p)	*Total hours in lifetime* Pearson's *R* (p)
FA genu	0.537 (0.039)*	0.425 (0.115)
FA RB	0.401 (0.139)	0.234 (0.401)
FA AMB	0.222 (0.426)	0.169 (0.547)
FA PMB	0.049 (0.861)	−0.067 (0.812)
FA splenium	−0.071 (0.809)	−0.100 (0.732)
FA whole CC	0.256 (0.376)	0.085 (0.774)
MD genu	−0.552 (0.031)*	−0.554 (0.033)*
MD RB	−0.497 (<0.050)*	−0.521 (0.047)*
MD AMB	−0.451 (0.096)	−0.543 (0.036)*
MD PMB	−0.252 (0.364)	−0.333 (0.224)
MD splenium	−0.293 (0.308)	−0.272 (0.345)
MD whole CC	−0.530 (<0.050)*	−0.516 (0.062)

*Considered significant at $p < 0.05$.

(Grieve et al., 2007), and experience in any functional task (Mackey et al., 2012). It was postulated that meditation experience can lead to increase in brain fibers and their myelination. Learning was found to influence axon diameter that ultimately regulates myelination and survival of axons (Zatorre et al., 2012).

Increased electrical activity at axons of CNS increases myelination. Increased myelination occurs due to increased firing in brain areas involved in training-based learning (Demerens et al., 1996). Consecutively, changes in axon diameter during learning can alter thickness of myelin sheath. Thus, regular meditation over a long term may induce myelinogenesis (Luders, 2014).

During the course of brain maturation, previous studies have reported gradual increase in FA along with decrease in MD in the WM, and this is believed to be associated with the process of myelination. Factors that influence MD include increased binding of water to macromolecules such as myelin, reducing free water content, and the formation of new structural barriers to water diffusion and progressive myelination within WM (Mukherjee and McKinstry, 2006). In our study, increased myelination may have contributed for high FA and lower MD values observed in CC of LTMs in comparison with controls.

Using seven-segment classification scheme of CC on LTMs (meditation practice ranged from 5 to 30 years) with different types of meditation, Luders et al. (2012) have shown high FA in middle region (RB and AMB) of CC in their segment-specific FA analysis but found no changes in anterior (genu and rostrum) and posterior segments (isthmus and splenium). In another longitudinal study, improved FA in anterior and middle segments of CC was also reported after 40 days of IBMT meditation practice compared with baseline study (Tang et al., 2010). Both of the studies orchestrate effects of meditation on CC. Our findings with high FA in entire CC can be explained in light of earlier studies as well as on the basis of type of meditation and duration of meditation practice.

Observation of increased FA in genu and callosal body by Tang et al. (2010) may consequently increase hemispheric transfer between ventral and dorsal anterior cingulate. Strong cingulate connections may indicate training of self-regulatory mechanisms (Posner et al., 2007) exercised by meditation practice.

Anterior mid body inclusively contains crossing fibers for motor, somatosensory, and auditory cortices (Ryberg et al., 2007). In detail, AMB associates dorsomedial prefrontal cortex (dmPFC) and lateral prefrontal cortex of both sides. Their role in conflict monitoring and emotion regulation, respectively, is revealed in previous studies of brain mapping (Catani et al., 2012; Viviani, 2014). However, dmPFC also regulates integration of emotional response during goal selection. Emotion regulation has been a critical trait of meditators that helps them to become resilient (Gray, 2004) and increase performance in any cognitive task.

Splenium carries posterior cortical connections (Aboitiz et al., 1992). Increased FA of splenium in LTMs indicates its role in strengthening the parietal networks involved in interhemispherical processing of attention networks (Niogi et al., 2010; Noudoost et al., 2006). Networks evident to be suitable for meditation accomplishment are strengthened due to training-influenced changes. This reaffirms the effects of concentrative meditation on brain areas mediating orientation of attention, that is, splenium. Distinctive processes of attention network (alertness, orientation, and conflict resolution) may become more efficient by tract-based microstructural changes (Niogi et al., 2010).

In previously attempted neuroimaging studies, microstructure changes in meditators brain at acute or experienced level of meditation were revealed. Meditation is often considered as a state training (Tang and Posner, 2014) and it may involve enhancement of cognitive functions. Training-induced effects were seen in healthy individuals after short period of training (Scholz et al., 2009) or in long-term practice effects (Bengtsson et al., 2005).

Meditation-induced changes were prominently observed in networks wherein degeneration occurred due to any disorder/lesion. In patients of migraine, reduced FA was found in genu, splenium, and body of CC. Similar findings were followed in mind cognitive impairment (Hanyu et al., 1999) or due to aging (Bennett et al., 2010, 2012). Also, these changes in WM can indicate possibility of larger gray matter in middle and superior frontal gyrus (Lazar et al., 2005) as development of more neurons accelerates more number of axonal processes for enhanced interhemispherical information flow.

Smaller splenial regions were found in attention deficit hyperactivity disorder (ADHD) (Semrud-Clikeman et al., 1994). Splenium is a possible/crucial ROI for orienting attention as it is involved in coordination of information across left and right posterior parietal regions (Niogi et al., 2010). Decreased area of entire CC, anterior mid body, and isthmus was found in ADHD children and reduced FA in isthmus was also seen (Cao et al., 2010). In substance-dependent subjects, tracts of rostral body and genu were found to be deteriorated (Moeller et al., 2005), which radiates to presupplementary motor regions, also found to be reduced in autistic population. Autistic children were observed for reduced FA in CC segments (Keary et al., 2009). With increased FA in meditators, regular practice of meditation might be used as potential therapy for autism to increase interhemispheric connections. Size reduction demonstrates poor connectivity between frontal and other brain regions' involvement of frontal CC connections, which results in poor executive functions, problem solving, and social deficits (Paul et al., 2007).

Age-related thinning of CC is more susceptible in anterior and mid part (Persson et al., 2006), which may lead to failed inhibition of hemispheres mediated by CC. Practicing meditation may reduce this thinning in CC fibers so that functional integrity remains exceptionally good in aged meditators. During high demands, attention resource allocation is interchanged between hemispheres. This interhemispheric transfer can provide independent regulation over information exchange by both hemispheres, which results in enhanced attention functioning (Banich, 1998). As the study is cross-sectional, it may not establish the exclusive effects of meditation practice. Rajayoga meditators also follow a routine life style that may have an effect on their metabolism, which can be separately studied.

Conclusion

Observed group differences were not confined to any specific region but to all parts of CC, which may establish the previously assumed theory (Luders et al., 2011) that meditation being a potential exercise has the capability to bring physical changes in brain structures. Meditation can prove to be effective against a patient population suffering with WM degeneration as well as against a training module for performance enhancement. Specifically, rajayoga being an easy-to-learn method can be examined on a larger population with different age groups.

Acknowledgments

This study was supported by project grant (INM 311/4.2) from the DRDO, New Delhi, India. Kanishka Sharma acknowledges the financial assistance as fellowship from the DRDO, New Delhi, India. The authors are grateful to BK Srikant and BK Jain for constant support in availability of LTMs from Brahmakumaris. Ms. Arpita supported in statistical validation of the data. The authors would also like to thank every participant involved in the study.

Disclaimer

Views expressed in the article are the authors' own and not an official position of the institution or funder.

Author Disclosure Statement

No competing financial interests exist.

References

Aboitiz F, Scheibel AB, Fisher RS, Zaidel E. 1992. Fiber composition of the human corpus callosum. Brain Res 598:143–153.

Alexander AL, Lee JE, Lazar M, Field AS. 2007. Diffusion tensor imaging of the brain. Neurotherapeutics 4:316–329.

Banich MT. 1998. The missing link: the role of interhemispheric interaction in attentional processing. Brain Cogn 36:128–157.

Beaulieu C. 2002. The basis of anisotropic water diffusion in the nervous system—a technical review. NMR Biomed 15:435–455.

Bennett IJ, Madden DJ, Vaidya CJ, Howard DV, Howard JH. 2010. Age-related differences in multiple measures of white matter integrity: a diffusion tensor imaging study of healthy aging. Hum Brain Mapp 31:378–390.

Bennett IJ, Motes MA, Rao NK, Rypma B. 2012. White matter tract integrity predicts visual search performance in young and older adults. Neurobiol Aging 33:433.e21–31.

Bengtsson SL, Nagy Z, Skare S, Forsman L, Forssberg H, Ullén F. 2005. Extensive piano practicing has regionally specific effects on white matter development. Nat Neurosci 8:1148–1150.

Cahn BR, Polich J. 2006. Meditation states and traits: EEG, ERP, and neuroimaging studies. Psychol Bull 132:180.

Cao Q, Sun L, Gong G, Lv Y, Cao X, Shuai L, et al. 2010. The macrostructural and microstructural abnormalities of corpus callosum in children with attention deficit/hyperactivity disorder: a combined morphometric and diffusion tensor MRI study. Brain Res 1310:172–180.

Catani M, Dell'acqua F, Vergani F, et al. 2012. Short frontal lobe connections of the human brain. Cortex 48:273–291

De Lacoste MC, Kirkpatrick JB, Ross ED. 1985. Topography of the human corpus callosum. J Neuropathol Exp Neurol 44: 578–591.

Demerens C, Stankoff B, Logak M, Anglade P, Allinquant B, Couraud F, et al. 1996. Induction of myelination in the central nervous system by electrical activity. Proc Natl Acad Sci 93:9887–9892.

Dreisbach G. 2006. How positive affect modulates cognitive control: the costs and benefits of reduced maintenance capability. Brain Cogn 60:11–19.

Fox KC, Nijeboer S, Dixon ML, Floman JL, Ellamil M, Rumak SP, et al. 2014. Is meditation associated with altered brain structure? A systematic review and meta-analysis of morphometric neuroimaging in meditation practitioners. Neurosci Biobehav Rev 43:48–73.

Gray JR. 2004. Integration of emotion and cognitive control. Curr Dir Psychol Sci 13:46–48.

Grieve SM, Williams LM, Paul RH, Clark CR, Gordon E. 2007. Cognitive aging, executive function, and fractional anisotropy: a diffusion tensor MR imaging study. Am J Neuroradiol 28:226–235.

Gulani V, Webb AG, Duncan ID, Lauterbur PC. 2001. Apparent diffusion tensor measurements in myelin-deficient rat spinal cords. Magn Reson Med 45:191–195.

Hanyu H, Asano T, Sakurai H, Imon Y, Iwamoto T, Takasaki M, Abe K. 1999. Diffusion-weighted and magnetization transfer imaging of the corpus callosum in Alzheimer's disease. J Neurol Sci 167:37–44.

Imfeld A, Oechslin MS, Meyer M, Loenneker T, Jancke L. 2009. White matter plasticity in the corticospinal tract of musicians: a diffusion tensor imaging study. Neuroimage 46:600–607.

Kang DH, Jo HJ, Jung WH, Kim SH, Jung YH, Choi CH, et al. 2013. The effect of meditation on brain structure: cortical thickness mapping and diffusion tensor imaging. Soc Cogn Affect Neurosci 8:27–33.

Keary CJ, Minshew NJ, Bansal R, Goradia D, Fedorov S, Keshavan MS, Hardan AY. 2009. Corpus callosum volume and neurocognition in autism. J Autism Dev Disord 39:834–841.

Laneri D, Schuster V, Dietsche B, Jansen A, Ott U, Sommer J. 2015. Effects of long-term mindfulness meditation on brain's white matter microstructure and its aging. Front Aging Neurosci 7:254.

Lazar SW, Kerr CE, Wasserman RH, Gray JR, Greve DN, Treadway MT, et al. 2005. Meditation experience is associated with increased cortical thickness. Neuroreport 16: 1893–1897.

Lee B, Park JY, Jung WH, Kim HS, Oh JS, Choi CH, et al. 2010. White matter neuroplastic changes in long-term trained players of the game of "Baduk" (GO): a voxel-based diffusion-tensor imaging study. Neuroimage 52:9–19.

Luders E. 2014. Exploring age-related brain degeneration in meditation practitioners. Ann N Y Acad Sci 1307:82–88.

Luders E, Clark K, Narr KL, Toga AW. 2011. Enhanced brain connectivity in long-term meditation practitioners. Neuroimage 57:1308–1316.

Luders E, Narr KL, Bilder RM, Thompson PM, Szeszko PR, Hamilton L, Toga AW. 2007. Positive correlations between corpus callosum thickness and intelligence. Neuroimage 37:1457–1464.

Luders E, Phillips OR, Clark K, Kurth F, Toga AW, Narr KL. 2012. Bridging the hemispheres in meditation: thicker callosal regions and enhanced fractional anisotropy (FA) in long-term practitioners. Neuroimage 61:181–187.

Luders E, Toga AW, Lepore N, Gaser C. 2009. The underlying anatomical correlates of long-term meditation: larger hippocampal and frontal volumes of gray matter. Neuroimage 45: 672–678.

Mackey AP, Whitaker KJ, Bunge SA. 2012. Experience-dependent plasticity in white matter microstructure: reasoning training alters structural connectivity. Front Neuroanat 6:32.

Madden DJ, Bennett IJ, Burzynska A, Potter GG, Chen NK, Song AW. 2012. Diffusion tensor imaging of cerebral white matter integrity in cognitive aging. Biochim Biophys Acta 1822:386–400.

Moeller FG, Hasan KM, Steinberg JL, Kramer LA, Dougherty DM, Santos RM, et al. 2005. Reduced anterior corpus callosum white matter integrity is related to increased impulsivity and reduced discriminability in cocaine-dependent subjects: diffusion tensor imaging. Neuropsychopharmacology 30:610–617.

Mori S, Crain B, Chacko V, van Zijl P. 1999. Three dimensional tracking of axonal projections in the brain by magnetic resonance imaging. Ann Neurol 45:265–269.

Mukherjee P, McKinstry RC. 2006. Diffusion tensor imaging and tractography of human brain development. Neuroimaging Clin N Am 16:19–43.

Niogi S, Mukherjee P, Ghajar J, McCandliss BD. 2010. Individual differences in distinct components of attention are linked to anatomical variations in distinct white matter tracts. Front Neuroanat 4:2.

Noudoost B, Afraz SR, Vaziri-Pashkam M, Esteky H. 2006. Visual spatial integrity in the absence of splenium. Brain Res 1076:177–186.

Pagnoni G, Cekic M. 2007. Age effects on gray matter volume and attentional performance in Zen meditation. Neurobiol Aging 28:1623–1627.

Panda R, Bharath RD, Upadhyay N, Mangalore S, Chennu S, Rao SL. 2016. Temporal dynamics of the default mode network characterize meditation-induced alterations in consciousness. Front Hum Neurosci 10:1–12.

Paul LK, Brown WS, Adolphs R, Tyszka JM, Richards LJ, Mukherjee P, Sherr EH. 2007. Agenesis of the corpus callosum: genetic, developmental and functional aspects of connectivity. Nat Rev Neurosci 8:287–299.

Persson J, Nyberg L, Lind J, Larsson A, Nilsson LG, Ingvar M, Buckner RL. 2006. Structure—function correlates of cognitive decline in aging. Cereb Cortex 16:907–915.

Posner MI, Rothbart MK, Sheese BE, Tang YY. 2007. The anterior cingulate gyrus and the mechanism of self-regulation. Cogn Affect Behav Neurosci 7:391–395.

Posner MI, Tang YY, Lynch G. 2014. Mechanisms of white matter change induced by meditation training. Front Psychol 5:1220.

Ramesh MG, Sathian B, Sinu E, Kiranmai SR. 2013. Efficacy of rajayoga meditation on positive thinking: an index for self-satisfaction and happiness in life. J Clin Diagn Res 7:2265–2267.

Ramsay T, Manderson L, Smith W. 2010. Changing a mountain into a mustard seed: spiritual practices and responses to disaster among New York Brahma Kumaris. J Contemp Relig 25: 89–105.

Rathore RK, Gupta RK, Agarwal S, Trivedi R, Tripathi RP, Awasthi R. 2011. Principal eigenvector field segmentation for reproducible diffusion tensor tractography of white matter structures. Magn Reson Imaging 29:1088–1100.

Ryberg C, Rostrup E, Stegmann MB, Barkhof F, Scheltens P, Van Straaten ECW, Erkinjuntti T. 2007. Clinical significance of corpus callosum atrophy in a mixed elderly population. Neurobiol Aging 28:955–963.

Saksena S, Husain N, Malik GK, Trivedi R, Sarma M, Rathore RS, et al. 2008. Comparative evaluation of the cerebral and cerebellar white matter development in pediatric age group using quantitative diffusion tensor imaging. Cerebellum 7: 392–400.

Schmidt S, Walach H. eds. 2014. *Meditation-Neuroscientific Approaches and Philosophical Implications*. Cham, Switzerland: Springer.

Scholz J, Klein MC, Behrens TE, Johansen-Berg H. 2009. Training induces changes in white-matter architecture. Nat Neurosci 12:1370–1371.

Semrud-Clikeman M, Filipek PA, Biederman J, Steingard R, Kennedy D, Renshaw P, Bekken K. 1994. Attention-deficit hyperactivity disorder: magnetic resonance imaging morphometric analysis of the corpus callosum. J Am Acad Child Adolesc Psychiatry 33:875–881.

Shapiro SL, Schwartz GE, Santerre C. 2002. Meditation and positive psychology. In: Snyder CR, Lopez S (eds.) *Handbook of Positive Psychology*. Oxford, UK: Oxford University Press; pp. 632–645.

Tang YY, Lu Q, Fan M, Yang Y, Posner MI. 2012. Mechanisms of white matter changes induced by meditation. Proc Natl Acad Sci 109:10570–10574.

Tang YY, Lu Q, Geng X, Stein EA, Yang Y, Posner MI. 2010. Short-term meditation induces white matter changes in the anterior cingulate. Proc Natl Acad Sci 107:15649–15652.

Tang YY, Posner MI. 2014. Training brain networks and states. Trends Cogn Sci 18:345–350.

Telles S, Desiraju T. 1993. Automatic changes in Brahmakumaris Raja yoga meditation. Int J Psychophysiol 15:147–152.

Viviani R. 2014. Neural correlates of emotion regulation in the ventral prefrontal cortex and the encoding of subjective value and economic utility. Front Psychiatry 5:123.

Witelson SF. 1989. Hand and sex differences in the isthmus and genu of the human corpus callosum. Brain 112:799–835.

Zatorre RJ, Fields RD, Johansen-Berg H. 2012. Plasticity in gray and white:neuroimaging changes in brain structure during learning. Nat Neurosci 15:528–536.

Zhang Y, Du G, Yang Y, Qin W, Li X, Zhang Q. 2015. Higher integrity of the motor and visual pathways in long-term video game players. Front Hum Neurosci 9:98.

Address correspondence to:
Richa Trivedi
Division of NMR
Institute of Nuclear Medicine and Allied Science (INMAS)
Defence R&D Organization
Timarpur 110054
Delhi
India

E-mail: tririchа@gmail.com

Bringing attention to next level: Electrophysiological correlates of Rajyoga meditation

KanishkaSharma1,2, Sushil Chandra1, Ashok K Dubey2 Dept. of Biomedical Engg. Inst. Of Nuclear Medicine and Allied Sciences, DefenceR&D Organization, Delhi, Division of Biological Sciences and Engg, Netaji Subhas Institute of Technology, Delhi

Abstract: Meditation is a non invasive intervention for enhancement of cognitive indices. Practicing meditation can bring changes in physiological variables. These physiological variables can be correlated with cognitive traits of human brain. Rajyoga meditation is a positive thought based meditation which is taught by Brahmakumaris. It is a renowned spiritual organization as well as having a consultative status with the Economic and Social Council at the United Nations. In this cross sectional study, high density EEG (64 channel) of Long term meditators of

Rajyoga and controls were recorded during baseline (5 minutes) and for meditation (10 minutes). Controls were age matched and had no prior experience of meditation. To ensure that all meditators perform exact same type of meditation, an audio tape of instructions was played before beginning of recording. Raw data was processed in EEGLAB and segmented in different frequency bands (alpha, beta, theta, delta and gamma). Power spectral density (PSD) was calculated for each band by method of P. Welch and engagement index was measured with the psd ratio of beta/(alpha+theta). Engagement index is a parameter of cognitive performance and attentional resource index. Significant differences were seen in many EEG band and engagement index was lower in LTM group. These effects were pronounced in lateral frontal, temporal and posterior parietal regions (respective EEG electrodes). Separately, performance in Attention Network Test (ANT) was also high in meditators w.r.t. accuracy but not in reaction time. Although, alerting and conflict resolution scores were higher in meditators. Findings of this study may suggest Rajyoga meditation as a potential intervention for cognitive enhancement and rehabilitation of attention disorders. There is a need to conduct a longitudinal study on Rajyoga meditation to check its benefits after short/long term practice.

Introduction

EEG-engagement reflects information-gathering, visual processing, and allocation of attention, while EEG-workload is associated with increased working memory load during problem solving, integration of information, and analytical reasoning (Berka et al., 2007). Engagement index (EI) reflects the allocation of processing resources (Anderson, 2004) including the cognitive processes associated with decision making, such as information gathering, visual scanning, audio processing, and selectively sustaining concentrated attention on one aspect of the environment while ignoring other distractions. Focused and relaxed mental state that is a prerequisite for better task performance Band Power and EI was calculated in relaxed state in both class unlikely to task condition. Default state engagement index was calculated.

Rajyoga Meditation

Rajayoga is a regulated exercise in which recollection, contemplation, concentration and attention are used in a methodical way to achieve blissful state. Technique of self exploration, leading to the experience of heightened and expanded awareness reaching to supreme and bridging itself to soul's awareness. It is based on thought generation and propagation of mind to blissful state using the same thought. During this practice meditators gets mind transformed into a reservoir accepting positive thoughts and neglecting negative thoughts.

Methods

- Two groups: Long term meditators (LTM) = 21 and control = 14.
- Age ranged 30-50 Yrs. (LTM mean = 44.6 yrs., control mean = 42.1 yrs.)
- Meditators with over 10 yrs. of regular meditation practice with around 100-150 min. daily. Control as meditation naive.
- Both groups were education and sex matched.

EEG Data Recording

64 channel portable EEG (ANT corp.) | Low impedance (< 10 k.ohms) | 5 min. settling time after subject preparation

Pre processing in EEGLAB

Artefact removal by visual analysis (cleaned epochs) | Notch filter (50 Hz), butterworth with cut off frq. (0.5-75 Hz) | Blind Source separation using ICA (Delsanto et al., 2003)

Decomposition

Segregation of EEG signal into constituent bands was done through wavelet decomposition. | Daubechies type 4 wavelet was used for decomposition

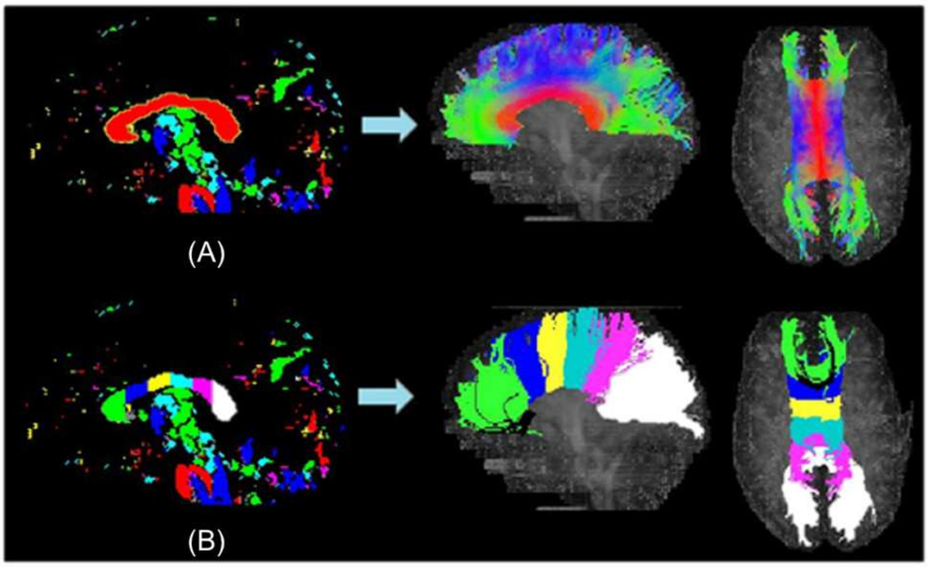
calculation of power and Engagement index (EI)

Power calculated using welch's method | EI was calculated using (beta/alpha+theta)

Impact on Rajayoga meditation on Integrity of White matter. Corpus callosum showed white matter increase in all six regions (Sharma K. et al., 2017)

Segmentation of Corpus Callosum (Witelson, 1989)

- Rostrum: Black
- Genu: Green
- Rostral body: Blue
- Ant. mid body: Yellow
- Post. mid body: Turquoise
- Isthmus: Pink
- Splenium: White



Region	Control vs. LTM Mean FA	Mean MD
	t(p)	t(p)
CC	-4.592 (<0.001)	7.018 (<0.001)
Genu	-3.34 (0.001)	4.695 (<0.001)
RB	-4.368 (<0.001)	6.331 (<0.001)
AMB	-4.830 (<0.001)	6.039 (<0.001)
PMB	-5.233 (<0.001)	6.072 (<0.001)
Isthmus	-4.464 (<0.001)	5.573 (<0.001)
Splenium	-4.121 (<0.001)	6.704 (<0.001)

Tract	Control vs LTM (Mean FA)		MD	
	Calc.t	p	Calc.t	p
RPTR	-1.981	0.054	2.738	0.009
LPTR	-1.877	0.067	2.454	0.018
LIFO	-2.405	0.021*	0.595	0.555
RATR	-3.554	0.001**	2.536	0.015*
RUNC	-6.001	0.000**	4.970	0.000**
LUNC	-7.858	0.000**	4.409	0.000**
RILF	-1.398	0.169	2.200	0.033*
LILF	-0.274	0.785	2.911	0.006**

Correlation with meditation experience:

Variable	Minutes per day	Total Hours in lifetime
	Pearson's R (p)	Pearson's R (p)
MD genu	-0.552 (0.031)	-0.554 (0.033)
MD RB	-0.497 (<0.050)	-0.521 (0.047)
MD AMB	-0.451 (0.096)	-0.543 (0.036)
MD whole CC	-0.530 (<0.050)	-0.516 (0.062)

- Increased FA in genu and callosal body suggest strong cingulate connections which may indicate training of self-regulatory mechanisms (Posner et al., 2007) exercised by meditation practice.

- Anterior mid body inclusively contains crossing fibers for motor, somatosensory and auditory cortices (Ryberg et al., 2007). In detail, AMB associates dorso-medial PreFrontal Cortex (dmPFC) and lateral Pre Frontal Cortex (lPFC) of both side. Their role in conflict monitoring and emotion regulation respectively is revealed in previous studies of brain mapping (Viviani, 2014, Catani et al., 2012).

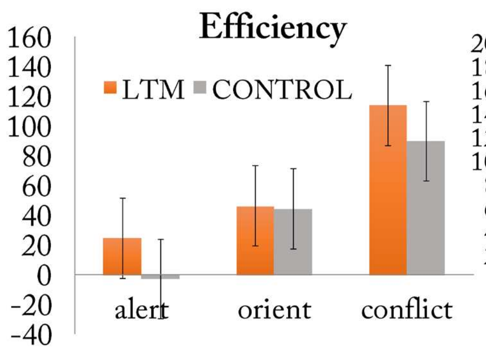
- Increased FA of splenium in LTM indicates its role in strengthening the parietal networks involved in inter-hemispherical processing of attention networks (Niogi et al., 2010, Noudoost et al., 2006).

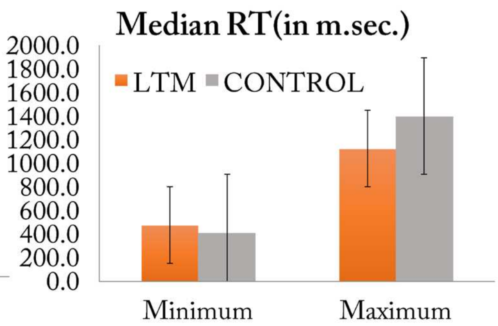
- Distinctive processes of attention network (alertness, orientation and conflict resolution) may become more efficient by tract based microstructural changes (Niogi et al., 2010).

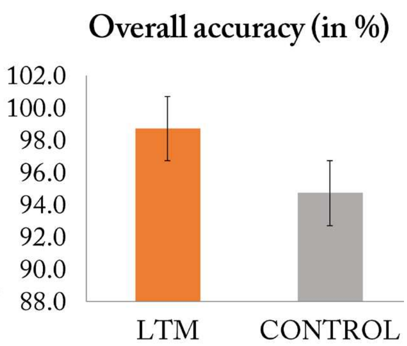
Result

Performance in Attention Network Test

- Higher efficiency for alertness, conflict monitoring in LTM
- Lower maximum RT in LTM
- Higher overall accuracy in LTM

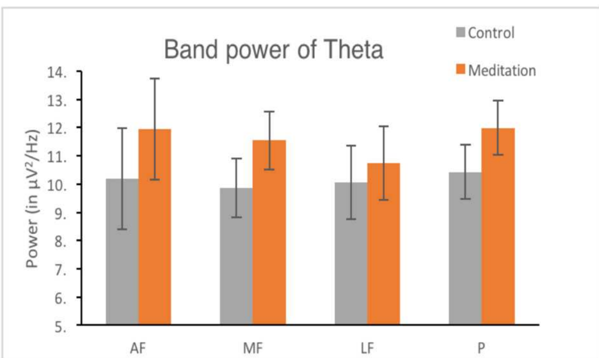


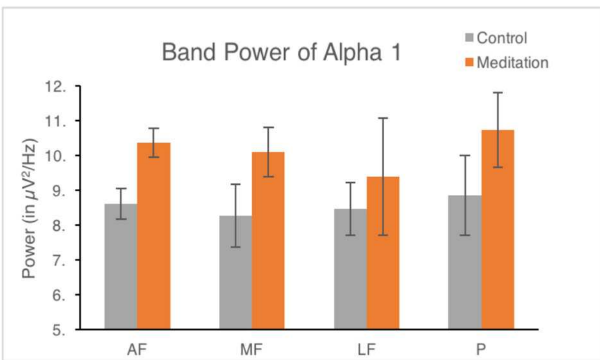




Band power

- Increased power in lower bands (alpha and theta) in frontal and parietal channels.





Engagement Index

- Lower in LTM in following channels
- Lateral frontal (AF7, F5, AF8, F6)
- Frontotemporal (FT7, FT8, T7, TP7, TP9, T8, TP8, T10)
- Post Parietal (PO3, PO4, PO7, PO8)

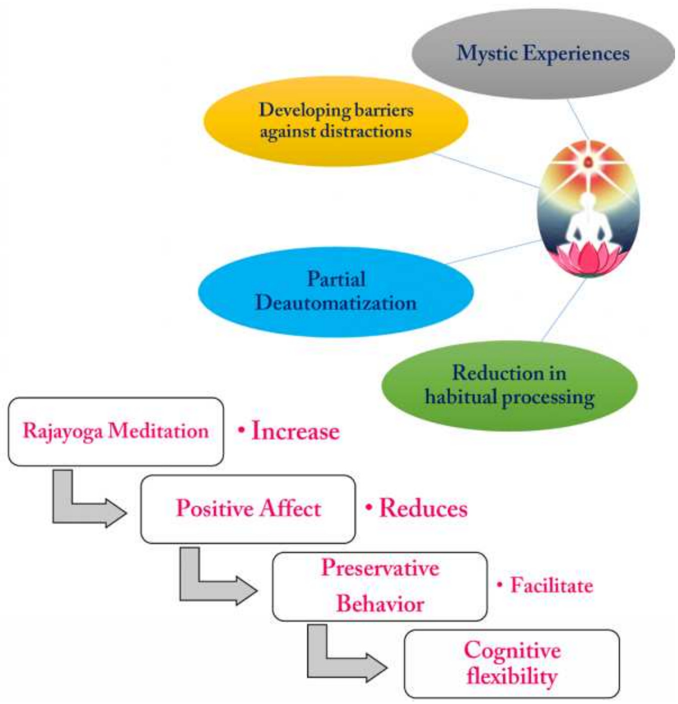
Correlation between EI and ANT performance

EI & Mean RT		
Channel	R	p
AF7	-.653**	.000
AF8	-.593**	.000
F5	-.597**	.000
F6	-.596**	.000
T7	-.328	.055
FT7	-.602**	.000
FT8	-.601**	.000
TP7	-.601**	.000
TP8	-.601**	.000
T8	-.344*	.043
FT7	-.602**	.000
FT8	-.601**	.000
PO3	-.601**	.000
PO4	-.601**	.000
PO7	-.600**	.000
PO8	-.601**	.000

EI & Accuracy		
Channel	R	p
AF7	.588**	.000
AF8	.513**	.002
F5	.518**	.001
F6	.516**	.002
T7	.273	.113
FT7	.524**	.001
FT8	.524**	.001
TP7	.523**	.001
TP8	.523**	.001
T8	.282	.100
FT7	.524**	.001
FT8	.524**	.001
PO3	.523**	.001
PO4	.523**	.001
PO7	.523**	.001
PO8	.524**	.001

Conclusion

- Performance in ANT was correlated with alertness and executive attention networks.
- Index of engagement was lower in LTM during rest irrespective of better performance indicate "Effortless awareness"(Garrison et al., 2013).
- Lower EI: lower Beta power in LTM indicate relaxed mind (Cahn & Polich, 2006)



References

- Anderson, J. R. (2005). Cognitive psychology and its implications. Macmillan.
- Berka, C., Levendowski, D. J., ... & Craven, P. L. (2007). EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. Aviation, space, and environmental medicine, 78(5), B231-B244.
- Delsanto, S., F. Lamberti,. Automatic ocular artifact rejection based on independent component analysis and eye blink detection. in First International IEEE EMBS Conference. 2003.
- Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. Neuroimage, 26(2), 471- 479.
- Garrison, K. A., Santoyo, J. F.,…. & Brewer, J. A. (2013). Effortless awareness: using real time neurofeedback to investigate correlates of posterior cingulate cortex activity in meditators' self-report. Frontiers in human neuroscience, 7.
- Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. Psychological bulletin, 132(2), 180.

Acknowledgement

- Indian Council of Medical Research for travel grant.
- Spiritual practice and research center (SpARC) Brahmakumaris, Mt. Abu for support in Meditation practitioners.
- Director, Inst. Of Nuclear Medicine & Allied Sciences, Defence R&D Organisation, Delhi.

REDUCED VARIANCE IN THETA AND ALPHA DURING RAJYOGA PRACTICE IN LONG TERM MEDITATORS

Pradeep Kumar G (pradeepkg@iisc.ac.in), Kanishka Sharma (sharmakan17@hotmail.com),
A.G. Ramakrishnan (agr@iisc.ac.in),
MILE Lab, Electrical engineering,
Indian Institute of Science, Bengaluru, India

Sumukh B (sumukh.bakshi@gmail.com)
Department of Telecommunication Engineering, B.M.S College of Engineering
Bengaluru, India

Abstract

The psychosomatic effects of meditation have been critically explored in the past decades. Neurophysiological mechanisms behind meditation were empirically postulated using the different frequency bands of electroencephalography (EEG) data. EEG was recorded from rajyoga meditators practiced by Prajapita Brahmakumaris Spiritual University. Wavelet decomposition was used to extract frequency bands of interest. Theta (4-8 Hz), alpha (8 to 12 Hz) and betal (12 to 16 Hz) bands are considered for the analysis. A novel approach of using the variance of power is proposed to study the meditation and non-meditation states. Decreased variance is observed during the state of meditation. Correlation between the states is higher across the meditation states than the non-meditation states.

Keywords: Meditation, EEG, wavelet decomposition, variance, correlation.

Introduction

Little is known about the process and impact of meditation on the brain. Previous studies show that wavelets are effective in analysing EEG data. Wavelet based analysis of EEG is employed in [1] to study the effects of meditation and in [2], for epileptic seizure detection. The analysis of meditation EEG is discussed in [1],[3] and [4]. In this work, we analyze the EEG during rajyoga meditation, which is practiced with the eyes open, which makes it unique among meditation techniques. An attempt is made to understand the changes in the neural activity of the brain during meditative states by extracting features based on wavelet coefficients.

Power in the alpha (8~12 Hz) and theta (4~8 Hz) bands has been used as a feature to compare the meditative state with non-meditative state. However, the results have not been consistent across different types of meditation. This can be seen in [5], where an increase in power is reported for both alpha and theta bands during meditation (push-push effect), whereas in [6], a decrease in alpha power and increase in theta power (push-pull effect) is reported.

Methods

A. Subject selection

EEG data collected from fifteen healthy right-handed subjects [7] practicing rajyoga meditation regularly for a period of more than 10 years (age 30-52 years, mean 43.9 (SD=3.96) years) is used in this study. With a record of regular practice, these meditators have spent 11-17 years in practicing this technique after learning the same. Total number of hours spent in meditation ranged from 4000-7200 hours throughout their life at the time of recording the EEG data. Subjects did not have any history of cardiac, pulmonary and other nervous system dysfunctions. The experimental procedures were explained to subjects. A written information consent was obtained from each subject. The status of non-consumption of alcohol, cigarette or any therapeutics by the subjects within last six months was confirmed.

B. Experimental Protocol

EEG data was recorded using ANTNeuro amplifier and EEGO software using 64-channel waveguard cap. The electrode placement in waveguard cap follows the international 10-10 system. The signal was recorded at a sampling frequency of 1024 Hz. EEG signals were digitally filtered at 0.5-75 Hz.

Subjects were asked to sit straight on floor mat during the whole recording session. Baseline recording (rest) was carried out for 5 minutes, when the subjects were asked to relax with their eyes open. Baseline was followed by the peaceful soul (PS) state of meditation, wherein the subjects meditate by focusing their attention on the positive thought about themselves as peaceful souls. This lasts for around 10 minutes. This is followed by another post PS baseline for 5 minutes. After this baseline, subjects were asked to delve themselves into angelic (ANG) state of meditation for 10 minutes, where they assumed to attain a blissful state. A post angelic state baseline was recorded for 5 minutes. Soul conscious state was aimed to be attained for peaceful soul state, while the progression of soul conscious state was aimed to be attained during the angelic state. Fundamental difference between these two states is believed to be generated due to self-observing experience in PS and state of being detached from the physical body, its sensual pleasures, relationships and material assets [8].

C. Preprocessing

The collected EEG data was subjected to line noise (50 Hz) removal using notch filter. Further, a band pass filter (0.5 – 45 Hz) was used and independent component analysis (ICA) was performed using runica algorithm in EEGLAB v 13.4. Components with eye movements, muscle artifacts and electrode popping were removed in order to make the data artifact free. Data from only 13 subjects was considered after preprocessing for further analysis. Data from the other two subjects was dropped out of final analysis due to excessive eye movement and bad quality of data.

D. Wavelet Decomposition

Wavelet coefficients corresponding to the different bands of frequency are obtained using wavelet decomposition of the EEG data. Wavelet transform is particularly effective for representing various aspects of signals such as trends, discontinuities, and repeated patterns, where other signal processing approaches fail or are not as effective. It is especially powerful for non-stationary signal analysis [2].
For our analysis, theta (4-8 Hz), alpha (8-12 Hz) and beta1 (12-16 Hz) bands are considered. 4^{th} order Daubechies (db4) wavelet is used for the decomposition. The advantage of wavelet analysis is that the time context is maintained even during the frequency analysis.

E. Feature Extraction

E1. Global Variance (GV)

Wavelet coefficients corresponding to epochs of one second are considered for feature extraction. Average powers of the wavelet coefficients of theta and alpha bands are calculated. The variance of the average power is calculated across the entire duration of each state, i.e. rest, peace, post-peace, angelic and post-angelic, resulting in a row vector of length 5 corresponding to each electrode.
Henceforth, the matrix obtained at this step is referred to as the "variance matrix". For global variance, the mean of values across the electrodes corresponding to a given state is considered, resulting in 5 values corresponding to the five states for each subject for a frequency band of interest. The flowchart for obtaining global variance is given in figure 1.

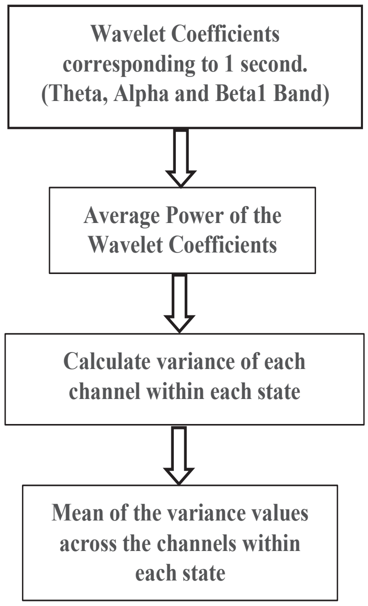


Figure. 1: Flowchart for calculating global variance. Average power of wavelet coefficients is calculated for each second in theta, alpha and beta1 bands. Variance of these average power values is calculated within each state for all the bands. Finally, the mean of variance across all the channels within each state is calculated.

The GV values of each subject are normalized to lie between 0 and 1, hence making sure that the range of values are relative across the subjects. In this way, no single subject's results will outlie the other results during averaging because of large changes between values of different states. This normalized matrix is averaged across subjects by taking the mean of the values corresponding to a state. This analysis was done in theta, alpha and beta1 bands and the results are given in Figure 4.

E2. Variance of Variance (VoV)

The procedure followed is the same as that for global variance until the variance matrix is obtained. Variance is calculated thereby revealing the "spatial variance" across the electrodes. Figure 2 shows the procedure followed to obtain the variance of variance in the form of a flowchart.

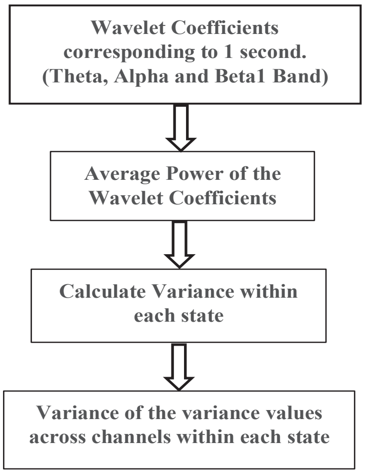


Figure 2: Flowchart for calculating variance of variance. Average power of wavelet coefficients is calculated for each second in theta, alpha and beta1 bands. Variance of these average power values is calculated within each state for all the bands. Finally, the variance of variance across all the channels within each state is calculated.

The VoV values of each subject are normalized to lie between 0 and 1, hence making sure that the range of values are relative across the subjects.

E3. Correlation of States

After the variance matrix is calculated, the correlation between states across channels is calculated. Figure 3 gives the flowchart corresponding to the procedure followed to obtain the correlation between the states.

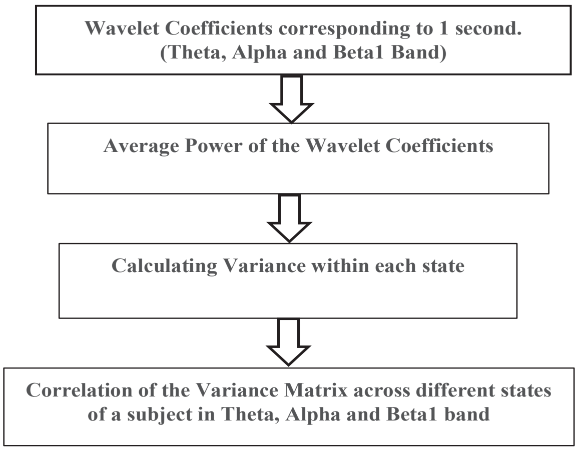


Figure.3: Flowchart for finding the correlation between states. Average power of wavelet coefficients is calculated for each second in theta, alpha and beta1 bands. Variances of these average power values are calculated within each state for all the bands. Correlation between matrices of different states is found in theta, alpha and beta1 bands.

Results

a. Global Variance

The analysis is done in theta, alpha and beta1 bands. As seen in Figure 4, an increase in GV is seen during the meditative states in alpha and beta1 bands, compared to the non-meditative states, whereas a decrease in GV is observed in the theta band during the meditative states.

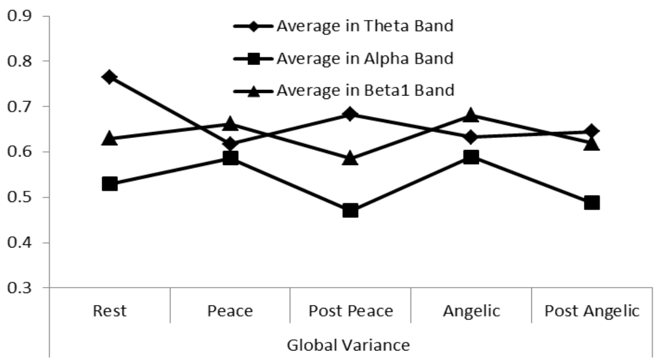


Figure 4: Global variance in theta, alpha and beta1 bands. Y-axis represents the variance and X-axis represents the five states (rest, peace, postpeace, angelic, postangelic). Each plt gives the average global variance across all the subjects after normalizing each subject's global variance values between 0 and 1.

b. Variance of Variance

There is a decrease in VoV during the meditative states in the theta and beta1 bands, compared to the non-meditative states. In the alpha band, no consistent pattern is observed across the subjects as shown by figure 5.

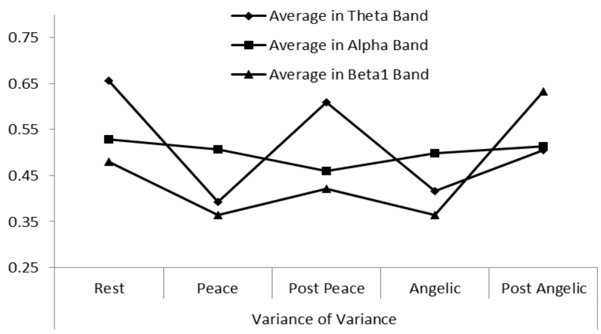


Figure 5: Variance of variance in theta, alpha and beta1 bands. Y and X-axes represent the VoV and the five states (rest, peace, postpeace, angelic, postangelic). Each plot is that of the average VoV across all the subjects after normalizing each of the subject VoV between 0 and 1 with respect to the same subject's VoV.

c. Correlation between the States

Correlation is observed between the two meditative states: peace and angelic. The results are consistent for all the subjects in all the three frequency bands of interest. This shows that for each subject, there is a pattern of variance of power that is followed. The average of the correlation coefficients across all the subjects in theta, alpha and beta1 bands is plotted in figure 6 as a color map with darker color corresponding to higher correlation and lighter color corresponding to lower correlation.

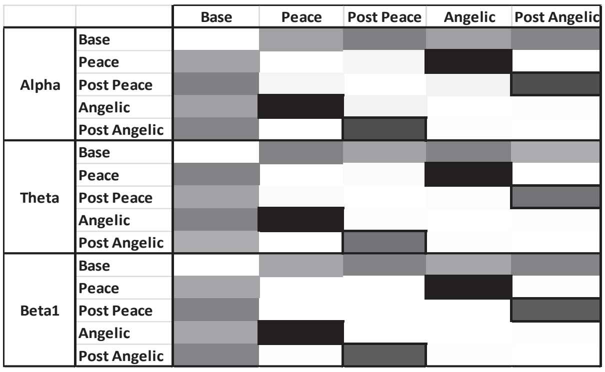


Figure 6: Correlation between the states in theta, alpha and beta1 bands. Dark color represents higher correlation. Correlation between peace and angelic states is higher in all the three bands and is consistent across all the subjects. Note: The diagonal elements having a correlation of 1 are not shown in the figure to better use the scale of dark colors for higher correlation across the states.

Discussion

The decrease in GV and VoV can be an indication of lower changes in the neural activity that is claimed to be achieved during meditation. This can be used as an alternative to the conventional use of power as a parameter to indicate the neural activity during meditation. Each practitioner may exhibit different baseline band power, but the variance is low for all the subjects during meditation.
Though a clear pattern is not visibly consistent among all the subjects, it gives better insight about the dynamics of the meditative states. The proposed features capture the degree of neural activity during rest and meditation. Variance in theta band is less during meditation than the baseline. Alpha and beta followed a rise in variance during meditation. Variance of variance being another measure, has uniformly reduced in meditative states providing a meta index of stability of all band (theta, alpha, beta1) activities during the practice of meditation. Overall, the meditation state is clearly visible and identified using our variance indices. We expect them to provide better results in a larger sample dataset.

The high correlation (almost equal to 1) across electrodes, between the two meditative states suggest the fact that every subject, irrespective of the increase or decrease in activity during meditation, follows a definite pattern. Peaceful soul and angelic states are highly corelated. Weak correlations are visible between baseline and the meditation sessions. Correlation matrix also supports our analysis, using variance to differentiate among resting and meditative states as well as experientially different meditative states. Proposed future work will be the segmentation of the data based on different lobes, along with increased size of the dataset.

Acknowledgments

Authors thank the kind support given by SpARC wing of Brahmakumaris Organization.

References

1. Chang, K. M., & Lo, P. C. (2005). Meditation EEG interpretation based on novel fuzzy-merging strategies and wavelet features. Biomedical Engineering: Applications, Basis and Communications, 17(04), 167-175.
2. Adeli, H., Zhou, Z., & Dadmehr, N. (2003). Analysis of EEG records in an epileptic patient using wavelet transform. Journal of neuroscience methods, 123(1), 69-87.
3. Banquet, J. P. (1973). Spectral analysis of the EEG in meditation. Electroencephalography and clinical neurophysiology, 35(2), 143-151.
4. Takahashi, T., Murata, T., …& Wada, Y. (2005). Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. International Journal of Psychophysiology, 55(2), 199-207.
5. Lagopoulos, J., Xu, J., …& Davanger, S. (2009). Increased theta and alpha EEG activity during nondirective meditation. The Journal of Alternative and Complementary Medicine, 15(11), 1187-1192.
6. Milz, P., Theodoropoulou, A., Tei, S., Faber, P. L., Kochi, K., & Lehmann, D. (2011). P02-347-Common EEG spectral power characteristics during meditation in five meditation traditions. European Psychiatry, 26, 943.
7. Kanishka Sharma, "Attention networks in long term rajayoga meditators". Ph D thesis, University of Delhi, 2019.
8. Dadi Janki. (2019, July 29). Attaining angelic attributes By Brahma Kumaris. Retrieved from https://www.soulveda.com/seekers-solace/attaining-angelic-attributes/

High frequency to low frequency band power ratio in Rajayoga meditators: an indicator for meditation experience

Kanishka Sharma, Pradeep Kumar G, A.G. Ramakrishnan

Department of Electrical Engineering, Indian Institute of Science, Bangalore, India
sharmakan17@hotmail.com, pradeepkg@iisc.ac.in, agr@iisc.ac.in

Abstract

Meditation or contemplative practices in some form are popular throughout the world and part of almost every religion. However, the east has been considered as the origin of these practices. Three decades of empirical research have found low frequency bands i.e. alpha and theta after processing the EEG signals. However, some research showed high bands visible during meditation. In the current research, we have explored the ratio of EEG band power between high frequency (24-42 Hz) and low frequency (4-14 Hz) components. The experimental subjects are long term meditators with practice experience of at least ten years. After processing the 64-channel EEG data, the high frequency component is found to be increased during meditation compared to their baseline. Also, the increase in the ratio is higher with increasing time in meditation. Findings of the study suggest the role of neural generators of gamma during meditation and rest in long term meditators.

Keywords: Meditation, Rajayoga, Electroencephalography, band power, Alpha band, Theta band, Gamma band

Introduction

Dynamics of brain waves have been explored in different meditation types (Cahn and Polich, 2006). Changes in EEG frequency bands, localization of brain centers involved in meditation practice and relation of particular bandwidth with functional/cognitive aspects have been studied. Across many practices, alpha and theta waves have been reported to be prominent when subjects are asked to meditate (Fell et al., 2011). Hinterberger et al (2011) have classified EEG based mental states during meditation. Another study with short term meditation (around 2 hours) practice has shown higher alpha power during resting period in the post- meditation recordings of EEG data (Fan et al.,2014). In a longitudinal study of pre, post and mid of the focused attention meditation, beta band was localized in midline anterio-central-posterior cluster. Results suggested training-related changes in beta-band power (Saggar et al., 2012). Vipassana meditators exhibited a relative increase in frontal theta (4–8 Hz) power, as well as significantly increased parieto-occipital gamma (35–45 Hz) power during meditation (Cahn, Delorme and Polich, 2010). Degree of change in EEG during meditation may be highly relevant to the length of practice and expertise attained by the meditator. An increase of occipital gamma has also been reported in Buddhist mediators (Lutz et al., 2004). Meditation is reported to induce an arousal state shift to high frequency dynamics with an assumption of involvement of focused networks in advanced Zen meditators (Lo et al., 2003; Huang and Lo., 2009).

In the current study, we have recruited long term meditators practicing Rajayoga meditation taught by Brahma Kumaris. Earlier, the lower frequency spectrum was reported in Rajayoga meditators (Sharma et al., 2018; Nair et al., 2017). The aim of the current study is to explore EEG dynamics of long-term meditators in terms of the ratio of the powers in the high to the low frequency bands.

Methods

Subjects

Ten healthy right-handed male subjects, who have been practicing Rajayoga meditation regularly for more than 10 years (age 37-50 years, mean 43.37 (SD=5.12) years), are recruited for this study. With an excellent record of regular practice, these meditators have already spent 11-17 years in practicing this technique after learning it. The total number of hours spent in meditation ranged from 11,000-35,000 hours throughout their life at the time of recording the EEG data. All subjects are free from cardiac, pulmonary and other nervous system dysfunctions. The experimental procedures were explained to the subjects, and written informed consent was obtained from each subject. The status of non-consumption of alcohol, cigarette or any therapeutics by the subjects within the last six months was confirmed.

Experimental procedure

EEG data has been recorded using ANT neuro eego mylab amplifier and eego software using 64-channel waveguard cap. The electrode placement in wavegaurd cap follows the international 10-10 system. The signal has been recorded at a sampling frequency of 1024 Hz. EEG signals have been digitally filtered at 0.5-75 Hz.

Subjects are asked to sit straight on the floor mat during the whole recording session. Baseline (rest) is recorded for 5 minutes and subjects are then asked to relax with their eyes open. The baseline is followed by the peaceful soul (PS) state of Meditation, wherein the subject meditates by focusing their attention on the positive thought about themselves as a peaceful soul. This lasts for around 10 minutes. This is followed by another post-peaceful soul baseline for 3 minutes.

After this baseline, subjects are asked to delve themselves into angelic (ANG) state of meditation for 10 minutes, where they are assumed to attain a blissful state. A post angelic state baseline was recorded for 3 minutes. Soul conscious state is aimed to attain during the peaceful soul meditation, while the progression of soul-conscious state is required to be attained during the angelic meditation. The fundamental difference between these two states is believed to be generated due to the self-observing experience practiced in PS meditation and being detached from attachment to the physical body, its sensual pleasures, relationships, and material assets during the angelic meditation.

Data processing

Pre-processing: The collected EEG data is subjected to line noise (50 Hz) removal using notch filter. Further, the data is band pass filtered (0.5 – 45 Hz) and independent component analysis (ICA) is performed using runica algorithm in EEGLAB v13.4. Components with eye movements, muscle artifacts, and electrode popping have been removed to make data artifact free. The final data includes 7 subjects for further analysis. Three subjects were dropped out of the final analysis due to excessive eye movement and bad quality of data.

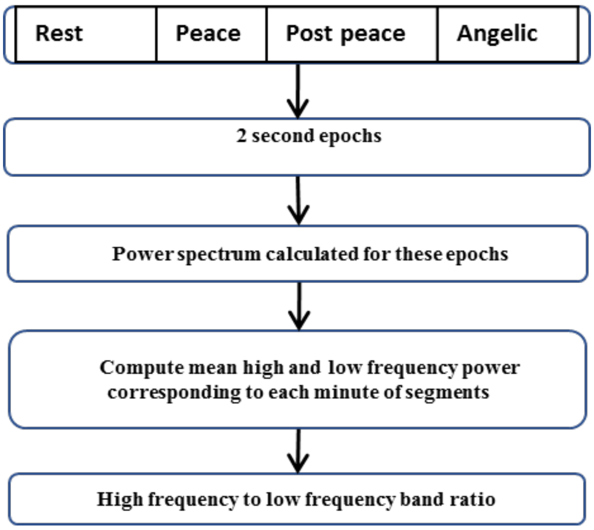


Figure 1: Post-processing of ICA-removed EEG data to obtain high to low frequency power ratio for different states.

Post processing: Band power of high frequency and low frequency is computed for each epoch of 2 sec. Mean across all the channels were calculated for each minute. High frequency (24-42 Hz) to low frequency (4-14 Hz) band power ratio is computed.

Results

We have obtained the ratio of total power in high frequency band (24-42 Hz) to that in the low frequency band (4-14 Hz) for the 61 channels. Auricular (M1. M2) and electrooculogram (EOG) channels are excluded from the 64-channel data recorded. The values are obtained for each minute (61,400 samples) during (1) baseline, (2) Peaceful soul meditation, (3) post peaceful soul baseline, and (4) Angelic meditation.

The values of the power ratio during both the sessions of meditation are higher than those during baseline/non-meditation sessions. Higher values correspond to increased power in the high band (24-42 Hz). The value of this ratio escalates in both the meditation sessions w.r.t. time. A sharp drift in post-meditation baseline is also visible in five out of seven subjects.

In terms of the grand average for the total duration of different sessions (baseline, meditation), the ratio value follows the similar trend of increased value during the meditation sessions for all the subjects except S5.

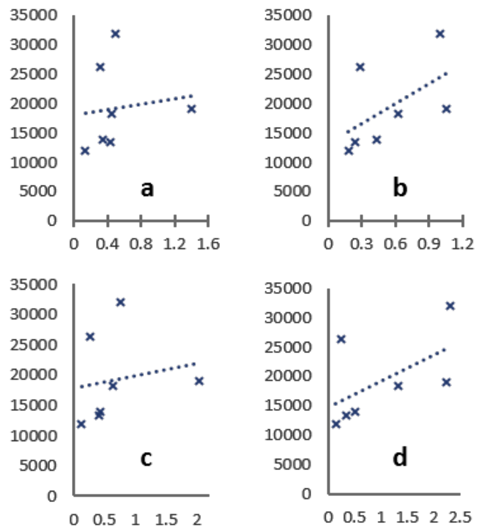


Figure 2: Correlation between lifetime practice hours (Y axis) and ratio of high to low band power (X axis). Each cross point denotes a subject. (a) during pre-meditation baseline, (b) peaceful soul meditation, (c) post-meditation baseline, (d) angelic meditation. During both meditation sessions, the power ratio has a positive slope with respect to the practice hours.

We have analyzed the Pearson's correlation between the power ratio of high to low band and the total hours of meditation practice in their lifetime. We have obtained a weak, yet positive correlation ($r = 0.31$, $p > 0.1$) between these.

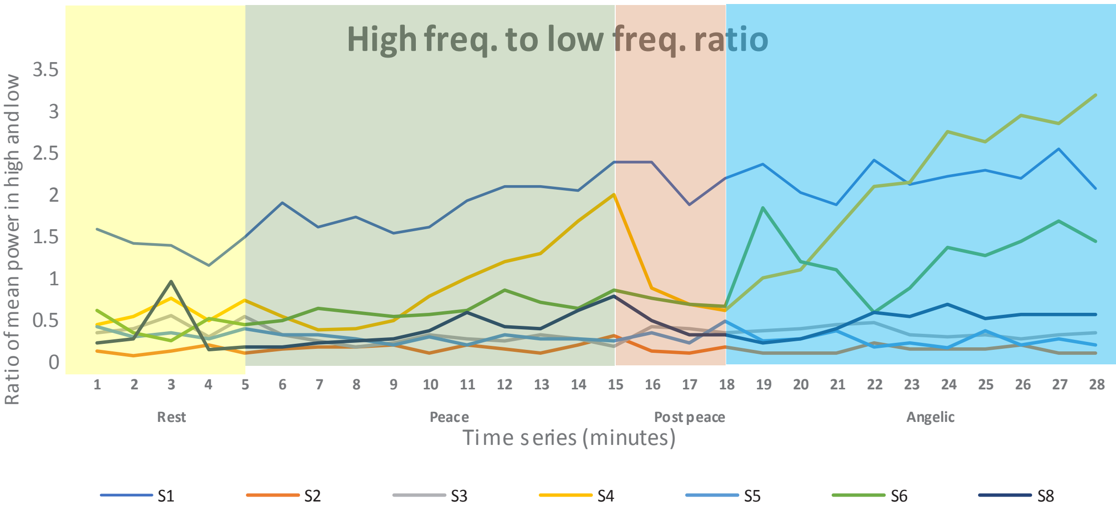


Figure 3: Line plot showing changes in the ratio of power in the high to low frequencies for each minute of four states of rest and meditation. Abscissa gives the time into the study. S1-S8 denote the seven different subjects studied.

Discussion

The study has found not only the occurrence of gamma activity during meditation but its dominance in some long-term meditators as compared to their baseline states. The study has explored neural dynamics of high to low frequency in terms of the ratio of grand averaged power in these frequency bands. Depth of meditation and realization is subjective to the individual practitioner and hence the results we obtained are not uniform for every subject. Our study results follow the findings of (Lutz et., 2004) in the experiment conducted on eight long term Buddhist meditators during the pure compassion state of loving-kindness meditation. This state is similar to the angelic state of Rajayoga meditation.

Another important observation is the increase of the value of this ratio in both meditation sessions with increasing time into the state. This escalation may indicate strengthening of oscillations of focused smaller networks (Cooper et al., 2003; Vago, 2012) as the time into the meditation increases. The highest value of the ratio is visible during the last minutes of meditation.

In this study, we have not checked the channel or region-specific changes in the ratio of high frequency to low frequency band power. It is possible that specific regions exhibit gamma centers during the meditation.

A positive, yet non-significant correlation between the total lifetime practice hours of meditation and the value of this ratio may indicate the experience-based neuroplasticity in long-term meditators. A similar, but significant correlation was found by Cahn and Polich (2010) in Buddhist meditators, where from 10,000-50,000 hours while their neuroelectric activity recorded using 128 channel EEG setup (Lutz et al., 2004). long-term Vipassana meditation practice contributed to increased occipital gamma power and enhanced sensory awareness. However, while somatosensory experience is the key to learn Vipassana meditation, in Rajayoga, soul-conscious aspects are contemplated while one practices it. Which is more focused to imagery of distant world and attaining blissful qualities.

Conclusion and possible future work

The overall findings suggest experience-based neuroplasticity with meditation practice. Results have evoked curiosity to further study the dynamics of high-frequency components w.r.t. Rajayoga meditation. Different states in this tradition may reveal their cortical processes linked with positive impact on cognitive processes. This index (high to low band power ratio) can be utilized as a standard to determine experience of meditation practice. However, the difference in practice variables of meditation are crucial to consider.

Further study of laterality of the gamma band (24-42 Hz) and localization of its sources is recommended for Rajayoga meditation.

Acknowledgments

Authors are grateful to all the volunteers for their contribution and SpARC wing, Brahma Kumaris for facilitating their availability.

References

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological bulletin*, 132(2), 180.

Cahn, B. R., Delorme, A., & Polich, J. (2010). Occipital gamma activation during Vipassana meditation. *Cognitive processing*, 11(1), 39-56.

Cooper, N. R., Croft, R. J., Dominey, S. J., Burgess, A. P., & Gruzelier, J. H. (2003). Paradox lost? Exploring the role of alpha oscillations during externally vs. internally directed attention and the implications for idling and inhibition hypotheses. *International Journal of Psychophysiology*, *47*(1), 65-74.

Fan, Y., Tang, Y. Y., Tang, R., & Posner, M. I. (2014). Short term integrative meditation improves resting alpha activity and stroop performance. *Applied psychophysiology and biofeedback*, 39(3-4), 213-217.

Fell, J., Axmacher, N., & Haupt, S. (2010). From alpha to gamma: electrophysiological correlates of meditation-related states of consciousness. *Medical hypotheses*, 75(2), 218-224.

Hinterberger, T., Kamei, T., & Walach, H. (2011). Psychophysiological classification and staging of mental states during meditative practice. *Biomedizinische Technik/Biomedical engineering*, 56(6), 341-350.

Huang, H. Y., & Lo, P. C. (2009). EEG dynamics of experienced Zen meditation practitioners probed by complexity index and spectral measure. *Journal of medical engineering & technology*, 33(4), 314-321.

Lo, P.-C., Huang, M.-L. and Chang, K.-M., 2003, EEG Alpha blocking correlated with perception of inner light during Zen meditation. *American Journal of Chinese Medicine*, 31, 629–642.

Lutz, A., Greischar, L. L., Rawlings, N. B., Ricard, M., & Davidson, R. J. (2004). Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *Proceedings of the national Academy of Sciences*, 101(46), 16369-16373.

Lutz, A., Greischar, L.L., Rawlings, N.B., Ricard, M. and Davidson, R.J., 2004, Long-term meditators self-induced high-amplitude gamma synchrony during mental practice. *Proceedings of the National Academy of Sciences* USA, 101, 16369–16373.

Nair, A. K., Sasidharan, A., John, J. P., Mehrotra, S., & Kutty, B. M. (2017). Just a minute meditation: Rapid voluntary conscious state shifts in long term meditators. *Consciousness and cognition*, 53, 176-184.

Saggar, M., King, B. G., Zanesco, A. P., MacLean, K. A., Aichele, S. R., Jacobs, T. L., ... & Ferrer, E. (2012). Intensive training induces longitudinal changes in meditation state-related EEG oscillatory activity. *Frontiers in human neuroscience*, 6, 256.

Sharma, K., Chandra, S., & Dubey, A. K. (2018). Exploration of lower frequency EEG dynamics and cortical alpha asymmetry in long-term rajyoga meditators. *International journal of yoga*, 11(1), 30.

Vago, D. R., & David, S. A. (2012). Self-awareness, self-regulation, and self-transcendence (S-ART): a framework for understanding the neurobiological mechanisms of mindfulness. *Frontiers in human neuroscience*, 6, 296.

Exploration of Lower Frequency EEG Dynamics and Cortical Alpha Asymmetry in Long-term Rajyoga Meditators

Kanishka Sharma, Sushil Chandra, Ashok Kumar Dubey[1]

Department of Biomedical Engineering, Institute of Nuclear Medicine and Allied Science, DRDO, [1]Division of Bioscience and Engineering, Netaji Subhas Institute of Technology, Delhi University, New Delhi, India

Abstract

Background: Rajyoga meditation is taught by *Prajapita Brahmakumaris* World Spiritual University (*Brahmakumaris*) and has been followed by more than one million followers across the globe. However, rare studies were conducted on physiological aspects of rajyoga meditation using electroencephalography (EEG). Band power and cortical asymmetry were not studied with Rajyoga meditators. **Aims:** This study aims to investigate the effect of regular meditation practice on EEG brain dynamics in low-frequency bands of long-term Rajyoga meditators. **Settings and Design:** Subjects were matched for age in both groups. Lower frequency EEG bands were analyzed in resting and during meditation. **Materials and Methods:** Twenty-one male long-term meditators (LTMs) and same number of controls were selected to participate in study as par inclusion criteria. Semi high-density EEG was recorded before and during meditation in LTM group and resting in control group. The main outcome of the study was spectral power of alpha and theta bands and cortical (hemispherical) asymmetry calculated using band power. **Statistical Analysis:** One-way ANOVA was performed to find the significant difference between EEG spectral properties of groups. Pearson's Chi-square test was used to find difference among demographics data. **Results:** Results reveal high-band power in alpha and theta spectra in meditators. Cortical asymmetry calculated through EEG power was also found to be high in frontal as well as parietal channels. However, no correlation was seen between the experience of meditation (years, hours) practice and EEG indices. **Conclusion:** Overall findings indicate contribution of smaller frequencies (alpha and theta) while maintaining meditative experience. This suggests a positive impact of meditation on frontal and parietal areas of brain, involved in the processes of regulation of selective and sustained attention as well as provide evidence about their involvement in emotion and cognitive processing.

Keywords: *Brahmakumaris Rajyoga meditation, electroencephalography, frontal alpha asymmetry, long-term meditator, spectral band power*

Introduction

Meditation is presently accepted as a tool to achieve altered state of consciousness.[1] It has been studied extensively by philosophers to physiologists. Meditative practice brings significant changes in neurophysiological state[2] which drive toward enhanced cognition and cognitive processes. Extensive research has been performed worldwide to explore the physiological basis of different styles of meditation.[3] The brief practice of meditation has shown improvement in the cognitive ability,[4] psychological well-being, and sleep.[5-7] Slight improvements in cognitive abilities due to meditation[8] practice may lead to mental well-being and healthy day-to-day life.

Regulation of emotion and attention has been regimen of meditation practices.[9] Due to the involvement of regulatory training of emotions, meditation positively affects the mental health of individuals[10] and efficacy to fight mental disorders.[11] Different types of meditation practice reported an increase in psychological functions with associated pattern of electroencephalography (EEG) in different frequency bands.[12,13] Particularly, low-frequency oscillations governs internalized attention and positive affect state. Alpha and theta band oscillations have been associated with the activity of multifunctional neuronal networks[14] and correspondingly related to the attention,[15] orientation,[16] memory,[17] and emotions.[18]

Rajyoga meditation is taught by *Prajapita Brahmakumaris* World Spiritual University (*Brahmakumaris*) and is different from the practice of Rajyoga described in ancient

How to cite this article: Sharma K, Chandra S, Dubey AK. Exploration of lower frequency eeg dynamics and cortical alpha asymmetry in long-term rajyoga meditators. Int J Yoga 2018;11:XX-XX.

Received: February, 2017. **Accepted:** July, 2017.

Address for correspondence:
Dr. Sushil Chandra, Department of Biomedical Engineering, Institute of Nuclear Medicine and Allied Science, DRDO, Lucknow Road, New Delhi - 110 054, India. E-mail: sushil.inmas@gmail.com

Access this article online

Website: www.ijoy.org.in

DOI: 10.4103/ijoy.IJOY_11_17

Quick Response Code:

Hindu texts. It involves transcendence of individual from body-conscious to soul-conscious.[19] Sukhsohale and Phatak[20] evaluated physiological variables such as heart rate, respiratory rate, systolic, and diastolic blood pressure for the effects of short- and long-term (STM and LTM) Rajyoga meditation. They found that during resting period, there were no significant differences between the STM and LTM, but significant differences were reported when pre-post comparisons were made. The result suggested improvements in the basic cardio-respiratory functions due to the shifting of symphovagal balance toward parasympathetic nervous system. Another study carried out by Telles and Desiraju[21] explored respiratory and autonomic effects of Rajyoga meditation; however, concluded incompetence of a single model of sympathetic activation to describe the effects of meditation practice. Till date, we have not found any EEG study which can demonstrate effect of Rajyoga meditation on the brain dynamics of the LTMs and compared with the subjects who have no exposure to any meditation using high-density EEG system.

The present study examines the effect of meditation on multifunctional neural networks of the brain in the LTMs. Objective of the study is to explore changes in the neural activity for the low-frequency oscillation in the LTM and compared the same with the control subjects.

Calculated results include the band spectrum power and cortical asymmetry (why power in EEG is important to calculate). Alpha asymmetry has been a prominent marker for neurological conditions such as depression,[22] emotional disorders, and neurodevelopmental disorders, however, in meditation, it is relatively less explored. It was hypothesized that band power during meditation will increase significantly in distinct brain regions during meditation. A similar trend has been already established in the previous research in mindfulness practice[23] and nondirective meditation.[24]

Materials and Methods

Subjects

Twenty-one healthy right-handed male subjects: LTM who practiced Rajyoga meditation regularly for a period of more than 10 years (age 30–52 years, mean 43.9 (standard deviation [SD] = 3.96) years) were agreed to take part in this study. With excellent record of regular practice, these meditators had already spent 13–35 years in practicing this technique after learning it. Total number of hours spent in meditation ranged from 9000 to 31,000 h throughout their life (mean = 18,457 h) at the time of recording the EEG data. The same numbers of controls (aged 30–50 years, mean 41.23 [SD = 3.95] years) with no prior experience in meditation were also recruited. All subjects in both groups were free from cardiac, pulmonary, and other nervous system dysfunctions. No subjects were having artificial pacemaker implanted. The experimental procedures were explained. Written information consent was obtained from each subject. Research protocol was approved by the Institutional Ethical Committee of INMAS-DRDO before the experimental recording. The status of nonconsumption of alcohol, cigarette, or any therapeutics by the subjects within last 6 months was confirmed. We approached to study homogenous groups matched with age.

Physiological measurements

Sixty-one channel EEG activity was recorded using eego™ Software and 64 channel waveguard™ cap. Onestep cleargel (ANT Corp, The Netherlands) was applied in each electrode hole to make active connections between scalp and electrodes. Electrode placement in waveguard™ cap follows international 10–20 system. EEG signals of sampling frequency (1024 Hz), with an input impedance (>1 GΩ), were acquired for 61 active scalp sites and referenced to CPz electrode. Grounding was done with AFz electrode. Preparation of EEG cap was done carefully and a stabilization time of 5 min was given after filling gel into all locations. Impedance was kept below 5 kΩ throughout the experiment. EEG signals were digitally filtered at 0.5–75 Hz and amplified by eego™ sports ultramobile EEG and EMG recording amplifier (ANT Corp, The Netherlands) which includes a magnetic optical disk that simultaneously stores the data for offline analysis. Data were stored in the same disc for the further analysis.

Electroencephalography data acquisition

EEG data were acquired during premeditation baseline for 5 min and during meditation for 10 min. After scalp preparation and before recording the EEG data, an audio file-based instructions was played for subjects to understand the protocol for baseline and meditation. This audio file was recorded as voiceover of a senior Rajyoga meditator. Uniformity of meditation experience was ensured with these instructions, and discourse was done with each LTM subject postmeditation. Control subjects were asked to sit in a relaxed wakefulness condition while their eyes were open.

Rajyoga meditation

Rajyoga meditation is a method without rituals or mantras and can be practised anywhere at any time. It enables the mind to rule over the physical organs as a righteous king and to cease to act as a slave to sense gratification. Rajyoga is a way to self-realization and realization of supreme almighty. It helps an individual in divinization or self-purification.[19] Rajyoga meditation technique requires considerable commitment and involves concentrated thinking.[21] During the practice of meditation, subjects sit in a comfortable posture with eyes open and fix their gaze on a meaningful symbol (a light source). At the same time, they actively think positive thoughts about the universal force pervading all over as light and peace. Practicing with open eyes makes this method unique and versatile.

Processing of electroencephalography signals

The EEG signals are nonstationary signals that pick up various noise components along with the relevant information while recording signals from the brain. Preprocessing steps become crucial to minimize these noise components. A 50 Hz notch filter was used to remove DC power line interference. A fourth-order Butterworth filter with cutoff frequency 0.5–75 Hz was used to select the frequency of interest. FASTICA algorithm in EEGLAB v1 (13.5.4b) was applied on data to identify independent components and components with artifacts were removed from the signal.[25] Independent component analysis attempts to reverse the superposition by separating the EEG into mutually independent scalp maps, or components.[26] Components with noise were removed manually. It proves to be an efficient tool for artifact identification and extraction from electroencephalographic data.[27] To extract various features during meditation, as well during the baseline the signals were segmented over time-based markers. Features such as power and frontal asymmetry were calculated for respective time frames of meditation and resting. EEG electrodes were topographically divided into the clusters provided in Table 1 for the analysis.

Power

Spectral power was measured in μV^2/Hz for theta, alpha, and alpha subbands (alpha1 and alpha 2) in anterior frontal, medial frontal, lateral frontal, central, parietal, occipital, and temporal regions. The log power transformations were also calculated considering the absolute value of the signal. The spectral percentage power of theta, alpha 1, and 2 bands was computed in log values using the Welch's method[28] by computing the Fourier transform of the autocorrelation function of the signal. Mean power was computed across each region by taking the average of the respective band power from each of the measured scalp site.

Frontal asymmetry

Lateralization of brain functions can be mapped with asymmetry index. Commonly, this index is calculated by subtracting the natural log of left hemisphere alpha power from the natural log of right hemisphere alpha power (ln [right alpha] − ln [left alpha]). In each lobe, major electrode pairs (F7/F8 for lateral frontal, FP1/FP2 for anterior frontal AF3/AF4 for medial frontal, P3/P4 for parietal, O1/O2 for occipital, T7/T8 for temporal, and C3/C4 for central) were considered for asymmetry index calculation. Higher values indicate a greater proportion of activity in the left cortical region;[29] which in case of frontal region, reveals a pattern associated with positive, approach-oriented emotional states. However, it provides no information regarding the particular contribution of each hemisphere.[30]

Table 1: Topographic distribution of electrodes according to specific region

EEG clusters	Channels
Anterior frontal	FP1, FP2, AFz, FPz
Lateral frontal	AF7, F5, F7, F3, AF8, F6, F8, F4
Medial frontal	AF3, F1, Fz, F2, AF4
Occipital	POz, Oz, O1, O2
Parietal	P1, P2, P3, P4, P5, P6, P7, P8, Pz, PO3, PO4, PO7, PO8
Temporal	FT7, FT8, T7, TP7, TP9, T8, TP8, T10
Central	C1, C2, C3, C4, C5, C6, Cz, FC1, FC2, FC3, FC4, FC5, FC6, FCz, Cz, CPz

EEG = Electroencephalography

Statistical analysis

To find significant difference between both groups and conditions of LTMs, one-way ANOVA was used. Data in charts were presented by mean ± standard error of mean. Minimum significant level was fixed at $P < 0.05$. For the analysis of self-reported data which included years of regular practice of meditation and age, Pearson's Chi-square test was used. Compared groups for significant difference were pre meditation baseline, during meditation for LTM group, and resting in control group. *Post hoc* (Scheffe's) was applied for multiple comparisons between groups' scores.

Results

Comparison between spectral properties including band power and cortical asymmetry was analyzed in premeditation resting and during meditation in LTMs as well as in resting of control subjects. No correlation was found between the total number of hours spent in meditation and any of the EEG band power variations. This result reflects that duration of practicing meditation among LTMs have no reported difference on EEG indices.

Alpha 1 and 2

Due to the distinct functional characteristics of Alpha 1 (8–9 Hz) and Alpha 2 (10–13 Hz), they were separately calculated for spectral properties. There was a significant difference found in alpha 1 powers of groups during meditation compared with control subjects at resting [Figure 1]. At anterior frontal channels (F [1, 40] = 10.32, P = 0.007) and medial frontal channels (F [1, 40] = 7.917, P < 0.001) which reflects an increase in band powers during meditation. At lateral frontal channels, difference was not significant (F [1, 40] = 8.443, P = 0.30). At parietal channels, it was significantly higher in meditators (F [1, 40] = 5.221, P < 0.001). Alpha 2 band power was also seen to follow similar trend with significant higher power [Figure 2] at anterior frontal channels (F [1, 40] = 12.551, P = 0.001), medial frontal channels (F [1, 40] = 9.65, P < 0.001), and parietal channels (F [1, 40] = 5.52, P = 0.002). Lateral frontal channels were shown to follow the trend but did not reach up to statistically significant level (F [1, 40] = 10.982, P = 0.07).

Theta

For theta power calculated at anterior frontal channels F (1, 40) = 11.95, P = 0.000, meditators have highly significant theta power [Figure 3] during meditation compared with relaxed resting of control subjects. However, it was found to be high in lateral frontal (F [1, 40] = 10.74, P = 0.183) and medial frontal channels (F [1, 40] = 11.54, P = 0.595) at nonsignificant level.

Cortical asymmetry

Mean values of asymmetry scores were calculated for alpha band (8–13 Hz). Mean and SD are summarized in Table 2. For frontal channels, it showed almost similar pattern. The mean medial frontal alpha asymmetry of meditators was higher than the controls [Figure 4] with t (21) = 1.8 with P = 0.034, whereas the difference was not reached up to statistical significant in lateral frontal alpha asymmetry t (21) = 0.86 with P = 0.058. At other EEG clusters, alpha asymmetry was not found to be significantly different [Figure 5].

Discussion

The present study shows high concentration of low-frequency bands (alpha 1, alpha 2, and theta) in LTM as compared to control. Powers of these low-frequency bands were significantly higher at anterior frontal, medial frontal, and parietal locations. Cortical asymmetry was significantly higher on positive side at medial frontal location. In addition, at lateral frontal and anterior frontal, it

Table 2: Means and standard deviation of hemispherical asymmetry scores in premeditation baseline (*n*=21) and during meditation for long-term meditators group (*n*=21) and resting for control group

EEG cluster	Mean (SD)		
	Baseline	Meditation	Control
Anterior frontal	0.012 (0.006)	0.145 (0.043)	0.003 (0.001)
Lateral frontal	1.153 (0.288)	1.478 (0.325)	1.072 (0.386)
Medial frontal	0.684 (0.137)	0.884 (0.221)	0.630 (0.756)
Central	0.066 (0.013)	0.068 (0.017)	0.287 (0.344)
Occipital	0.015 (0.004)	0.030 (0.007)	0.021 (0.025)
Parietal	0.008 (0.002)	0.010 (0.003)	0.167 (0.200)
Temporal	0.187 (0.047)	0.204 (0.051)	0.405 (0.487)

SD = Standard deviation, EEG = Electroencephalography

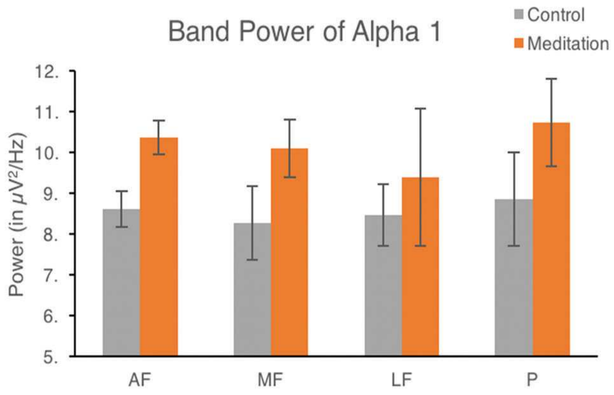


Figure 1: Band power of Alpha 1 (8–10 Hz) electroencephalography band measured in anterior frontal, medial frontal, lateral frontal, and parietal regions for resting and during meditation in control and meditators groups, respectively

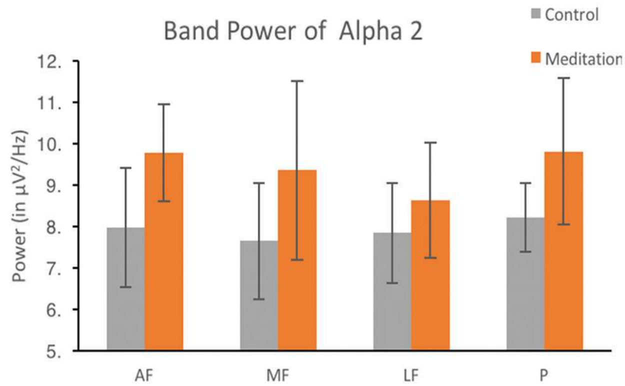


Figure 2: Band power of Alpha 2 electroencephalography band (11–13 Hz) measured in anterior frontal, medial frontal, lateral frontal, and parietal electrode clusters for resting and during meditation in control and meditators groups, respectively

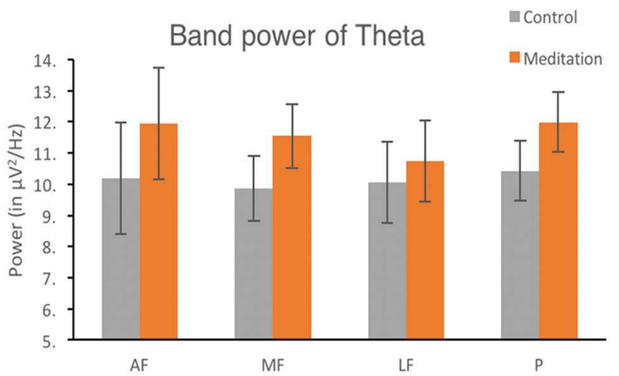


Figure 3: Band power of theta electroencephalography band (3–7 Hz) measured in anterior frontal, medial frontal, lateral frontal, and parietal electrode clusters for resting and during meditation in control and meditators groups, respectively

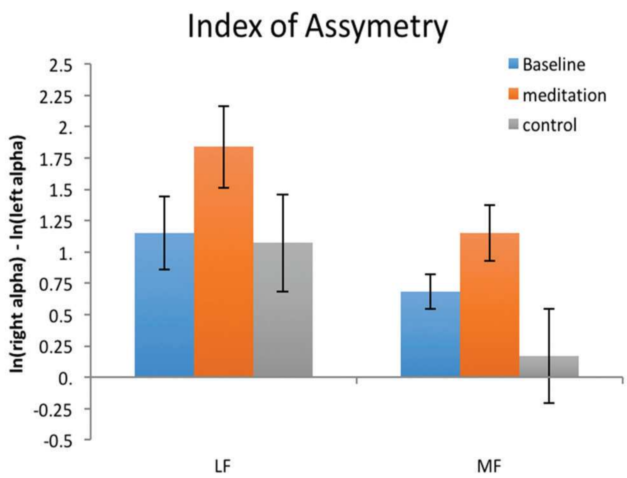


Figure 4: Index of alpha asymmetry measured from alpha band power at lateral frontal and medial frontal electrode clusters in premeditation baseline, during meditation for long-term meditator group, and resting in control group

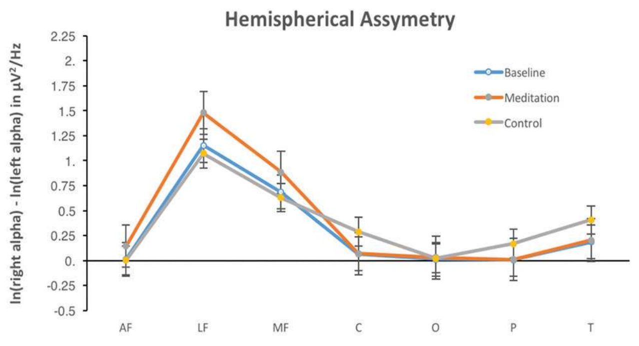


Figure 5: Index of hemispherical alpha band asymmetry measured at anterior frontal, medial frontal, lateral frontal, central, occipital, parietal and temporal electrode clusters in premeditation baseline, during meditation for long-term meditator group, and resting in control group

was high on positive side yet not reached up to significant level.

High power in alpha bands is indicative of less engaged brain[29] which can be traced as more relaxed and an affirmative brain state to entertain meditation practice. Positive asymmetry scores reflect greater left-sided activity (i.e., greater alpha band power density on the right than on the left). Lower frequencies are most significant contributors for resting brain although spatial prominence of alpha in frontal regions has regulatory function related to emotional challenges and attentional engagements.

As, our research was focused on lower frequencies in frontal region, in a way it corroborates the previous research where increased alpha during mindfulness was identified in frontal regions.[31] Some network-related theories[32-34] have also assumed that small networks oscillate at faster frequencies (>40 Hz) while large networks oscillate at slower frequencies (<20 Hz); however, beta and other computation of faster brain waves are not collected in this research, it is assumed to have alpha as aftermath of coverage of large networks. It has to be kept indisputable that larger networks consist of more number of neurons and connection involved but not the Euclidian space. Lower alpha band (alpha 1) appears for vigilance and attention while upper alpha band (alpha 2) is thought to reflect task specific processes, i.e., perceptual and cognitive processes.[18] Upper band alpha (10–13 Hz) was higher in more creative individuals at frontal and parietal sites.[34]

Initially due to parietal prominence of alpha power was assumed to be reflected in cortical idling[35] and decrease in alpha power was thought to reflect increase in activation[36] which are no longer tenable. In recent advances, alpha synchronization considered as a marker of activation of functionally involved brain areas in higher functions[37] and regarded as a signature of meditative practices irrespective of the type of practice and degree.[2] However, it is indicative of increased processing in various attention modalities with respect to internally generated stimuli.[38] In different meditative practices also, alpha power was prominently seen to be increased but decreased in idiosyncratic meditation.[39] More alpha power means greater mental silence, however, tasks requiring memory[40] and imagination[41] lead to increase in alpha power.

Theta power increase reflects the essential core of meditative experience whereas alpha power increase reflects internalized attention. The deactivation of cortical areas occurs in brain idling since it occurs during eyes closed wakefulness[42,43] may also synchronization of alpha frequency. Although decreased alpha power was also noted during mindfulness,[44] meditation generates greater cortical deactivation than during eye closed resting.[45] Thoughtless awareness and bliss are accounted by enhanced theta and alpha activities along with decreased EEG dimensional complexity.[13,46] Anterior cingulate cortex (ACC) elicits theta rhythm and stimulation of ACC seen to affect cognitive and affective processes during Zen meditation. Midline theta is seen to induce relaxed concentration and enhanced interaction between cognitive and affective processes.[47] In simultaneous EEG-functional magnetic resonance imaging experiments, theta was found to be negatively correlated with (Default Mode Network) DMN activity which suggest crucial role of theta during initial stages of meditation-related relaxation.[48] ERP experiment by Trujillo and Allen has defined role of theta band in error-related processing[49]

The amplitude of theta and Alpha was also found to be great during mindfulness.[3] Overall cortical synchronization, i.e., increased power in alpha and theta band indicate lower tonic arousal, a prerequisite for meditative state. In our observation, copresence of alpha and theta waves in frontal regions may reflect a state of relaxed alertness[50] by guarding against extremes of arousal toward high end and low end. Both alpha and theta can be interpreted as signifiers of increased attention with alpha specifically representing internalized attention as well as indexing states of relaxation.[45]

Frontal asymmetry in alpha band gets affected by many factors. It regulates emotions under challenging circumstances[3] is well defined by approach withdrawal model.[51] However, alpha asymmetry phenotype is attributable to trait characteristic, and it is defined by temporally stable and trans-situational consistent individual differences.[52] Relative left frontal trait activation is linked with approach and behavior activation motivation system. Sociability in children and adults was also seen with left cortical activation, which may be a suggestive of positive social behavior displayed by meditators. Individual differences in frontal EEG asymmetry are indeed more pronounced during emotional challenges than during resting tasks. Many factors, including experience of meditators, type of control task, and location of the EEG oscillations moderate the impact of meditation on neurophysiological markers. This led to a distinct phenomenology related to meditation types, which was considered as one of the essential objective to work with a very less explored yet most followed meditation technique, i.e., *Brahmakumaris* Rajyoga meditation.

Conclusion

Overall, this research has attempted to present how a meditation technique with different kind of practice strategy affects neurophysiological markers measured by EEG. However, in meditation researches role of frontal alpha asymmetry has not been well established which has formed the basis for experimental design of the present work. The experimental results clearly establish occurrence of high frontal alpha asymmetry in LTMs which links state of positive mind with positive scores of alpha asymmetries. High-band power of alpha subbands and theta contributes for meditative state experience. This outcome may suggest the interaction of positive emotion circuitry with attention and well-being. This study led a foundation on physiological research on *Brahmakumari's* Rajyoga meditation, which can prove to be one of the most effective meditation technique for performance enhancement. Although future studies can be proposed to find effects of short-term practice of this meditation techniques. There is also a need to formulate experimental paradigms for unique groups based on limited age so that this technique can be utilized at different population level.

Financial support and sponsorship

This study was financially supported by the Defence R and D Organization.

Conflicts of interest

There are no conflicts of interest.

References

1. Shapiro DH Jr. Meditation: Self-Regulation Strategy and Altered State of Consciousness. Transaction Publishers; 2008. p. 61-81.
2. Fell J, Axmacher N, Haupt S. From alpha to gamma: Electrophysiological correlates of meditation-related states of consciousness. Med Hypotheses 2010;75:218-24.
3. Cahn BR, Polich J. Meditation states and traits: EEG, ERP, and neuroimaging studies. Psychol Bull 2006;132:180-211.
4. Alfonso JP, Caracuel A, Delgado-Pastor LC, Verdejo-García A. Combined Goal Management Training and Mindfulness meditation improve executive functions and decision-making performance in abstinent polysubstance abusers. Drug Alcohol Depend 2011;117:78-81.
5. Thachil AF, Mohan R, Bhugra D. The evidence base of complementary and alternative therapies in depression. J Affect Disord 2007;97:23-35.
6. Nagendra RP, Maruthai N, Kutty BM. Meditation and its regulatory role on sleep. Front Neurol 2012;3:54.
7. Ding X, Tang YY, Cao C, Deng Y, Wang Y, Xin X, *et al.* Short-term meditation modulates brain activity of insight evoked with solution cue. Soc Cogn Affect Neurosci 2015;10:43-9.
8. MacLean KA, Ferrer E, Aichele SR, Bridwell DA, Zanesco AP, Jacobs TL, *et al.* Intensive meditation training improves perceptual discrimination and sustained attention. Psychol Sci 2010;21:829-39.
9. Lutz A, Slagter HA, Dunne JD, Davidson RJ. Attention regulation and monitoring in meditation. Trends Cogn Sci 2008;12:163-9.
10. Gross JJ, Muñoz RF. Emotion regulation and mental health. Clinical Psychol Sci Pract 1995;2:151-64.
11. Slade M. Mental illness and well-being: The central importance of positive psychology and recovery approaches. BMC Health Serv Res 2010;10:26.
12. Kasamatsu A, Hirai T. An electroencephalographic study on the zen meditation (Zazen). Folia Psychiatr Neurol Jpn 1966;20:315-36.
13. Aftanas L, Golosheykin S. Impact of regular meditation practice on EEG activity at rest and during evoked negative emotions. Int J Neurosci 2005;115:893-909.
14. Lieske SP, Ramirez JM. Pattern-specific synaptic mechanisms in a multifunctional network. II. Intrinsic modulation by metabotropic glutamate receptors. J Neurophysiol 2006;95:1334-44.
15. Aftanas LI, Lotova NV, Koshkarov VI, Makhnev VP, Mordvintsev YN, Popov SA. Non-linear dynamic complexity of the human EEG during evoked emotions. Int J Psychophysiol 1998;28:63-76.
16. Aftanas LI, Golocheikine SA. Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: High-resolution EEG investigation of meditation. Neurosci Lett 2001;310:57-60.
17. Basar E, Basar-Eroglu C, Karakas S, Schürmann M. Gamma, alpha, delta, and theta oscillations govern cognitive processes. Int J Psychophysiol 2001;39:241-8.
18. Klimesch W. EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. Brain Res Brain Res Rev 1999;29:169-95.
19. Jagdish CB. Easy Rajyoga: Taught by God Shiva. Prajapita Brahma Kumaris Ishwariya Vishavidyalaya; 1977.
20. Sukhsohale ND, Phatak MS. Effect of short-term and long-term Brahmakumaris Raja Yoga meditation on physiological variables. Indian J Physiol Pharmacol 2012;56:388-92.
21. Telles S, Desiraju T. Autonomic changes in Brahmakumaris Raja yoga meditation. Int J Psychophysiol 1993;15:147-52.
22. Allen JJ, Reznik SJ. Frontal EEG asymmetry as a promising marker of depression vulnerability: Summary and methodological considerations. Curr Opin Psychol 2015;4:93-7.
23. Ahani A, Wahbeh H, Miller M, Nezamfar H, Erdogmus D. Oken B. 2013, November. Change in physiological signals during mindfulness meditation. In Neural Engineering (NER), 6th International IEEE/EMBS Conference on Neural Engineering (NER), San Diego, CA, 2013:1378-81.
24. Lagopoulos J, Xu J, Rasmussen I, Vik A, Malhi GS, Eliassen CF, *et al.* Increased theta and alpha EEG activity during nondirective meditation. J Altern Complement Med 2009;15:1187-92.
25. Delorme A, Makeig S. EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. J Neurosci Methods 2004;134:9-21.
26. Ungureanu M, Bigan C, Strungaru R, Lazarescu V. Independent component analysis applied in biomedical signal processing. Meas Sci Rev 2004;4:18.
27. Vigário RN. Extraction of ocular artefacts from EEG using independent component analysis. Electroencephalogr Clin Neurophysiol 1997;103:395-404.
28. Welch P. The use of fast Fourier transform for the estimation of power spectra: A method based on time averaging over short, modified periodograms. IEEE Trans Audiol Electroacoustics 1967;15:70-3.

29. Coan JA, Allen JJ. Frontal EEG asymmetry as a moderator and mediator of emotion. Biol Psychol 2004;67:7-49.
30. Harmon-Jones E, Allen JJ. Anger and frontal brain activity: EEG asymmetry consistent with approach motivation despite negative affective valence. J Pers Soc Psychol 1998;74:1310-6.
31. Takahashi T, Murata T, Hamada T, Omori M, Kosaka H, Kikuchi M, *et al.* Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. Int J Psychophysiol 2005;55:199-207.
32. von Stein A, Sarnthein J. Different frequencies for different scales of cortical integration: From local gamma to long range alpha/theta synchronization. Int J Psychophysiol 2000;38:301-13.
33. Buzsáki G, Draguhn A. Neuronal oscillations in cortical networks. Science 2004;304:1926-9.
34. Fink A, Benedek M. EEG alpha power and creative ideation. Neurosci Biobehav Rev 2014;44:111-23.
35. Pfurtscheller G. Event-related synchronization (ERS): An electrophysiological correlate of cortical areas at rest. Electroencephalogr Clin Neurophysiol 1992;83:62-9.
36. Lindsley DB, Wicke JD. The electroencephalogram: Autonomous electrical activity in man and animals. Bioelectric Recording Tech 1974;1:3-83.
37. Cooper NR, Croft RJ, Dominey SJ, Burgess AP, Gruzelier JH. Paradox lost? Exploring the role of alpha oscillations during externally vs. internally directed attention and the implications for idling and inhibition hypotheses. Int J Psychophysiol 2003;47:65-74.
38. Vago DR, Silbersweig DA. Self-awareness, self-regulation, and self-transcendence (S-ART): A framework for understanding the neurobiological mechanisms of mindfulness. Front Hum Neurosci 2012;6:296.
39. Hinterberger T, Schmidt S, Kamei T, Walach H. Decreased electrophysiological activity represents the conscious state of emptiness in meditation. Front Psychol 2014;5:99.
40. Jensen O, Gelfand J, Kounios J, Lisman JE. Oscillations in the alpha band (9-12 Hz) increase with memory load during retention in a short-term memory task. Cereb Cortex 2002;12:877-82.
41. Cooper NR, Burgess AP, Croft RJ, Gruzelier JH. Investigating evoked and induced electroencephalogram activity in task-related alpha power increases during an internally directed attention task. Neuroreport 2006;17:205-8.
42. Shaw FZ, Chen RF, Tsao HW, Yen CT. Algorithmic complexity as an index of cortical function in awake and pentobarbital-anesthetized rats. J Neurosci Methods 1999;93:101-10.
43. Amihai I, Kozhevnikov M. Arousal vs. relaxation: A comparison of the neurophysiological and cognitive correlates of Vajrayana and Theravada meditative practices. PLoS One 2014;9:e102990.
44. Lomas T, Cartwright T, Edginton T, Ridge D. A qualitative analysis of experiential challenges associated with meditation practice. Mindfulness 2015;6:848-60.
45. Aftanas LI, Golocheikine SA. Non-linear dynamic complexity of the human EEG during meditation. Neurosci Lett 2002;330:143-6.
46. Britton WB, Lindahl JR, Cahn BR, Davis JH, Goldman RE. Awakening is not a metaphor: The effects of Buddhist meditation practices on basic wakefulness. Ann N Y Acad Sci 2014;1307:64-81.
47. Kubota Y, Sato W, Toichi M, Murai T, Okada T, Hayashi A, *et al.* Frontal midline theta rhythm is correlated with cardiac autonomic activities during the performance of an attention demanding meditation procedure. Brain Res Cogn Brain Res 2001;11:281-7.
48. Scheeringa R, Bastiaansen MC, Petersson KM, Oostenveld R, Norris DG, Hagoort P. Frontal theta EEG activity correlates negatively with the default mode network in resting state. Int J Psychophysiol 2008;67:242-51.
49. Trujillo LT, Allen JJ. Theta EEG dynamics of the error-related negativity. Clin Neurophysiol 2007;118:645-68.
50. Davidson RJ. Parsing affective space: Perspectives from neuropsychology and psychophysiology. Neuropsychology 1993;7:464.
51. Davidson RJ, Ekman P, Saron CD, Senulis JA, Friesen WV. Approach-withdrawal and cerebral asymmetry: Emotional expression and brain physiology. I. J Pers Soc Psychol 1990;58:330-41.
52. Hagemann D, Hewig J, Seifert J, Naumann E, Bartussek D. The latent state-trait structure of resting EEG asymmetry: Replication and extension. Psychophysiology 2005;42:740-52.

Mapping of Default Mode Network in Long-Term Meditators using Simultaneous EEG-fMRI

Rajanikanth Panda[1], Sandhya Mangalore[2], Neeraj Upadhyay[3], Rose Dawn Bharath[4], Thamodharan A[5], Silpa Kanungo[6] and Arun Gupta Kumar[7]

[1,2,3,4,5,6]Cognitive Neuroscience Center, National Institute of Mental Health and Neuro Science (NIMHANS), Bangalore, India.

[4,7]Dept. of Neuroimaging and Interventional Radiology, National Institute of Mental Health and Neuro Science (NIMHANS), Bangalore, India.

Corresponding Author: Dr Rose Dawn Bharath.

Cognitive Neuroscience Center and Dept. of Neuroimaging and Interventional Radiology, National Institute of Mental Health and Neuro Science (NIMHANS).
Hosur Road, Bangalore, India, Zip Code- 560029
phone No: 091-080-26995454, Fax No-091-080-26564830
Email: cns.researchers@gmail.com, drrosedawn@yahoo.com

ABSTRACT:

Understanding the role of brain in bringing about awareness and consciousness has always been a challenging area of neuroscience and has been a subject of many debates. In the last 10 years researchers have been looking towards the effect of meditation on various aspects. The practice of meditation is expected to cause a shift in the various networks of brain. We hypothesized that meditation can modify ruminative thoughts. Our study aims at understanding how the Default Mode Network (DMN) of meditators is different from the non-meditative healthy person when they are not in meditative state and also at examining the difference in the DMN in meditators during rest and while meditating. We studied the DMN of long term (>10 years) Raj Yoga Meditators. For this we used Functional magnetic resonance imaging (fMRI) derived spatial information for examining the DMN and Electroencephalography (EEG) derived temporal parameters to demonstrate the increased stability over the time. The analysis of simultaneous EEG-fMRI was done both at individual and group level. We observed that the long term meditators have lower DMN activity as compared to healthy people at rest and this activity is further reduced during meditation. We observed fluctuations of EEG-Microstates decreased with an increase in the duration of individual EEG-microstates suggestive of increased stability in meditators. From this result we conclude that the meditator was lowering ruminative and mind wandering thoughts even if they are not in meditative state and that long term meditation had caused a shift in the DMN networks. From this we conclude that meditation could find application in situations where we need to reduce the internal conflicts and hence helps increase the ability to keep the brain stable and more aware of the surroundings.

Keywords: Resting state, Functional magnetic resonance imaging, Electroencephalography, EEG microstates, Default Mode Network.

1. INTRODUCTION:

Meditation can be defined as a process of self regulation and training of attention which also pertains to regulated attention involving all domains of cognition in conflict with the environment. Neuro plasticity of brain and change in consciousness network has been revealed during meditation by different techniques such as neuro-imaging, electroencephalographic and behavioral studies (Cahn and Polich, 2006).

EEG studies during meditation have exhibited a decrease in self reference network and an increase in the attention and sensory awareness network. A study has highlighted the neuro- plasticity effect of continued meditation practice (Tei et al., 2009). Increased cortical thickness and gray matter density, suggestive of structural changes associated with meditation practice, has also been reported using MRI (Lutz et al., 2008;

Manna et al., 2010) especially in the left hippocampus, posterior cingulate cortex, temporo-parietal junction and cerebellum (Hölzel et al., 2011). These areas form important nodes in the networks involved in learning and memory processes, emotion regulation and self-referential processing.

Specifically organized functionally relevant resting-state networks (RSNs) can be studied using resting fMRI (Biswal et al., 1995; Cordes et al., 2001; Lowe et al., 1998). One such network is the DMN. It has been associated to episodic memory, memory consolidation and self reference in a task free state. (D'Argembeau et al., 2005; Macrae et al., 2004; Manna et al., 2010; Mitchell et al., 2006). DMN network associates with meditation (Brewer et al., 2011; Hasenkamp et al., 2012; Taylor et al., 2012; Travis et al., 2010) and also increases functional connectivity in the anterior MPFC region suggesting neuronal plasticity role of meditation (Jang et al., 2011).

Electroencephalography (EEG) studies are highlighting the role of multiple smaller variances noted in the brain functional states which are concatenated in to quasi-stable states known as EEG microstates. These form the "atoms of thoughts and consciousness" (Changeux and Michel, 2004; Lehmann, 1990; Lehmann et al., 2005; Lehmann et al., 2004; Lehmann et al., 1987; Lehmann et al., 1998). The duration of microstates is influenced by the state of wakefulness or sleep (Cantero et al., 2002; Cantero et al., 1999). It is known to increase during in meditation (Faber et al., 2005).

From all these different studies we can conclude that meditation does have an effect on cognitive brain networks. But does long term meditation cause a shift in the networks needs to be examined. To address this question in our study we have used EEG-fMRI derived scalp quasi- stability (EEG microstates) convolved in the resting fMRI data. The DMN was examined both at individual level and group level, for meditators and non meditators (healthy controls). We have also analyzed the meditators during resting state and meditative state to understand the effect of meditation on the DMN.

2. METHODOLOGY

Thirty eight healthy people (meditator and non meditator) adult right-handed, male subjects with a mean age of 35 years (SD ± 10 years) were recruited. Subjects had no history of neurological or psychiatric diseases and did not take any medications that could affect the experiment. The subjects were age, gender, education and ethnicity matched, multi linguals with Kannada as L1
(first language) in both the groups.

2.1 Healthy Control

Twenty healthy controls were recruited. Good quality data was available in fifteen controls only. None of the controls had experience on any type of meditation.

2.2 Meditators Subject:

We recruited eighteen expert meditators. However good quality EEG fMRI was obtained in fifteen subjects only. They are regular enrolment of Brahma Kumaris spirituality knowledge with more than ten years of Raja Yoga meditation practice. They were practicing at least one hour of meditation regularly in every day early morning.

2.3 Experiment Design:

The subjects were instructed to lie with their eyes closed, in an awake and relaxed state. They were to avoid thinking of the same situation or object for long periods (notably > 30-40sec) and if they do drift into such a state, to consciously try to revert back to a relaxed state. It was important to refrain from any cognitive, language or motor tasks during the acquisition. While a single resting EEG-fMRI was obtained in healthy controls, in meditators EEG-fMRI was recorded once during resting wakefulness and once during meditation (Soul Consciousness Meditation State).

Subjects with claustrophobia were excluded from the study. Such data which showed uncorrectable cardio-ballistic and motion artifacts during post processing of the recorded EEGfMRI data were also excluded.

3. Data Acquisition:

3.1. EEG Data Acquisitions:

EEG data was recorded using a 32-channel MR compatible EEG system (BrainProducts, Gilching, Germany). The EEG cap (BrainCap MR, Brain Products) consisted of 31 scalp electrodes placed according to the international 10-20 system electrode placement and one additional electrode dedicated to the ECG which was placed on the back of the subject. Data were recorded relative to an FCz reference and a ground electrode (GND) according to 10–20 electrode system, (Oostenveld and Praamstra, 2001). Data was sampled at 5000 Hz. The impedance between electrode and scalp was kept below 5 kΩ. EEG was recorded using the Brain Recorder software (Version 1.03, BrainProducts). To prevent the movement of the subjects' head, we placed sufficient padding between the head and the head support of the MRI scanner. The braided cable of BrainCap MR was immobilized using adhesive tapes.

3.2. fMRI Data Acquisition

Resting Functional MR-images were acquired using a 3T scanner (Skyra, Siemens, Erlangen, Germany). Echo-Planar Images (EPI) using BOLD contrast. 185 volumes were obtained using the following EPI parameters: 36 slices, 4 mm slice thickness in interleaved manner with an FOV of 192×192 mm, matrix 64×64, repetition time 3000ms, echo time 35ms, re-focusing pulse 90°, matrix- 256 x 256 x 114, voxel size-3 x 3 x 4mm. We also acquired T1 MPRAGE data of voxel size 1x 1x 1mm for better registration and overlay of brain activity.

4. Data Analysis

4.1. EEG signal Analysis

4.1.1. Artifact Removal from EEG signal

Raw EEG data were processed offline using BrainVision Analyzer version 2 (BrainProducts). Gradient artifact correction was performed using modified versions of the algorithms (Allen et al., 1998). Here a gradient artifact template is subtracted from the EEG using a baseline corrected sliding average of 20 MR-volumes. Data were then down-sampled to 250 Hz and low-pass filtered with an IIR (Infinite Impulse Response) filter with a cut-off frequency of 70Hz. Following gradient artifact correction, the data were corrected for cardio ballistic artifacts (a cardiac pulse artifact in the static field B0 resulting from the expansion and relaxation of the scalp arteries between the diastolic and systolic phases). (Allen et al., 2000; Goldman et al., 2000). Presumably to a lesser extent, there may also be fluctuations in the Hall-voltage (a potential which is created across a conductor with a current flow perpendicular to a surrounding magnetic field) due to the pulsating speed changes of the blood in the arteries [13]. For this, an average artifact subtraction method (Allen et al., 2000) was implemented in Brain Vision Analyzer2. This method involves subtracting the artifact on a second by second basis using heartbeat events (R peaks) detected in the previous 10s. As such it requires accurate detection of R peaks which is aided by the employment of a moving average low pass filter and a finite impulse response high pass filter (Allen et al., 2000). In the present study, the R peaks were detected semi- automatically, with manual adjustment for peaks misidentified by the software. To average the artifact in the EEG channels, the R peaks are transferred from the ECG to the EEG over a selectable time delay. The average artifact was then subtracted from the EEG. Once gradient, cardio ballistic had been removed, the data were then inspected for artifacts resulting from muscular sources or head movement artifact and any epoch containing more than 150 micro volts was rejected. Finally, very high and low frequency signal was filtered with a band-pass of 0.01–45 Hz.

4.1.3. Feature extraction from Resting State EEG

Analyzing the resting EEG data is a big challenge. Past studies have shown ICA and EEG microstates are the best ways to describe resting brain electrical activity. The brain electric activity as a series of scalp maps of momentary potential distributions which change over time, those can be clustered into successive time epochs ("microstates") that are defined by quasi- stable landscapes of the brain electric field (Brandeis and Lehmann, 1989; Michel et al., 2004; Pascual-Marqui et al., 1995). We used this EEG microstate to analyze the resting fMRI data at the single subject level via extraction using sLORETA software. The microstate was considered as explanatory variables (regressor) in the GLM design for the analysis of fMRI data. To compute the microstate the maxima of the Global Field Power (GFP) will be determined. Since topography remains stable around peaks of the GFP, they are the best representative of the momentary map topography in terms of signal to-noise ratio (Koenig et al., 2002). The algorithm implemented for estimating the microstates, is based on a modified version of the classical k- means clustering method, in which cluster orientations are estimated. The optimal number of template maps was determined by means of a cross-validation criterion(Pascual-Marqui et al., 1995).

4.2. fMRI Analysis

4.2.1. Resting fMRI Analysis

Our study aims to detect hemodynamic response changes during rest and meditative conditions among control and meditators. The fMRI analysis was performed using FSL software (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl) specially FEAT and MELODIC modules. The first five functional image frames of each time series were discarded to allow for signal equilibration, giving a total of 180 frames used in analysis. We conducted motion correction using MCFLIRT (Jenkinson et al., 2002), non-brain tissue (Scalp, CSF etc.) removal using BET (Smith, 2002). Spatial smoothing done using a Gaussian kernel of FWHM 5 mm, mean based intensity normalization of all volumes by the same factor, and High temporal band-pass filtering with sigma 100s. These temporal filtering parameters were selected based on the work of Biswal et al. (Biswal et al., 1995). Co-registration of functional images done with the individuals structural images in standard space and re-sampled the filtered data into standard space keeping the re- sampled resolution at the FMRI resolution (4mm). Individual and Group ICs (independent components) were created by applying single-session and multi-session temporal concatenated ICA.

4.2.2. Analysis of Independent Components (ICs) for Resting fMRI

It is really difficult to identify the components from, artifacts represent challenging confounding factor, which often account for a large part of data variance, leading to a problematic data interpretation. To reduce these noises we approached to deal with such confounds to model them (e.g. motion-related noise) within the GLM (Friston et al., 1996). Independent components were
qualitatively selected by visual inspection and applying "best fit" template matching procedure (Greicius et al., 2003) for anatomically relevant areas across subjects, potentially depicting functionally relevant Default Mode Networks. Components were excluded for further analysis show clearly interpretable distinct artifact patterns and lower correlation with the standard template (not represented). After identified the artifact components, these were removed using the MELODIC command "reg_filt" (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). Later we applied t-test on selected DMN IC's of Controls and Meditators in both resting and meditation states in SPM8 software (SPM8; Wellcome Department of Cognitive Neurology, London) for group level Negative and Positive Bold analysis (Greicius et al., 2004).

4.2.3. EEG Microstate Informed Resting-fMRI Analysis

The EEG microstates carried out as single-trial event related potentials (ERPs) for the resting functional data analysis at single subject level. In an event related design, EEG microstates are considered as explanatory variables for GLM design of fMRI analysis. We modeled the input function using the onset time, and the duration of each EEG microstate and convolved them with a gamma hemodynamic response function (Musso et al., 2010). Threshold of Z-stats (Gaussians T or F) maps were created by convolving the EEG microstates with Gamma hemodynamic response function using customized three column format shape

(FMRI Expert Analysis Tool) Version 5.98, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). Z stats images were thresholded using clusters determined by Z>1.4 and a (corrected) cluster significance threshold of P=0.05 (Worsley, 2001).

4.2.4. DMN Selection from z-Stat and Independent Component of Resting-fMRI. DMN were identified in individual level and group level based on study by Beckmann and Smith et al. (Beckmann and Smith et al., 2005). For analysis DMN component of resting brain, was first examined at individual level followed by group level analysis (meditator and control).

5. Result

Although the adverse conditions of MRI scanning (gradient acoustic noise, fixed head and body position), selected data of subjects were able to stay in awake relax condition and meditator subjects were able to perform the meditation. The EEG data was of sufficient quality to classify EEG-Microstates.

5.1. DMN Examination in Individual Level and Group Level Using Independent Component Analysis. (Figure 1-4)

DMN were identified in individual level and group level based on study by Beckmann and Smith (Beckmann and Smith, 2005). Positive BOLD activations with threshold maps at level 0.99 (FSL, FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl) in the DMN were examined and noted in comparison with controls the DMN in meditators during rest showed significant decreases in all the components of the DMN that is in the cingulate cortex, precuneus and the medial frontal cortex. Furthermore the DMN were decrease during meditation as compared to resting state of meditators and activations were noted to decrease significantly in the cingulate cortex, precuneus and the medial frontal cortex during meditation as compared to resting states
of meditators.

Power spectrum of independent components of DMN showed high frequency band during meditation as compared to resting state of meditators and when compared with controls resting state with meditators rest state, the DMN showed higher frequency band which validates the significant difference in the DMN (Beckmann and Smith, 2005).

EEG microstates convolved on resting fMRI (z-stat) and ICA (spatial correlation map) of DMN was compared. FMRI data processing was carried out using FEAT (FMRI Expert Analysis Tool) Version 5.98, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). Z (Gaussians T/F) statistic images were threshold using clusters determined by Z>1.4 and a (corrected) cluster significance threshold of P=0.05 (Worsley 2001). Similar results were noted at individual level. The EEG-Microstates correlated with DMN activation in z-stat (EEG-microstate informed BOLD activation map), showed a decreased fluctuation and increased duration in meditators both in resting states and during meditation compared to healthy controls. The average duration of microstate in healthy control was 30ms to 240ms and mean duration was 80ms however the average duration of microstate in meditator was 50ms to 310ms and mean duration was 90ms at resting condition. Further the duration of microstate is increased in meditator at meditative state, which was average duration of 60ms to 370ms and the mean duration was 110ms.

5.2. DMN Analysis at Group Level using Statistical Parametric Mapping (Figure5-6)

Positive BOLD activations in the DMN were examined using group level analysis of SPM8 with P<0.05 for FWE (SPM8; Welcome Department of Cognitive Neurology, London) and were noted to decrease during meditation as compared to resting state in DMN of meditators .When resting state DMN of controls and meditators were compared no significant difference was noted at FWE p< 0.05.

Negative BOLD activations indicate an increase in inhibition in the DMN .Using group level analysis of SPM8 with P<0.001 uncorrected we noted an increase in negative BOLD during meditation as compared to resting state of meditators and controls. The negative BOLD activations were noted to decrease significantly in the anterior cingulate cortex, insula, claustrum and inferior frontal gyrus during meditation as compared to resting states. When compared with controls the DMN in meditators during rest had greater negative bold activations in the insula, anterior cingulate and inferior frontal gyrus.

6. Discussion

This is the first study using simultaneous EEG-fMRI, to understand simultaneously neuronal and heamodynamic changes occurring during meditation and highlighting our hypothesis that long term meditation causes a shift in the activity of DMN even at rest.

Many reports noted the DMN correspond to task independent introspection, mind wandering, ruminative thought in rest and a mental state that has been studied during undirected cognition or sporadically during periods of sustained attention. In our study we observed the neuro heamodynamic activity of DMN decreased during meditation as compared to resting state of meditators. This pattern was observed both on the z-stat images which represent combination of neuro heamodynamic activity and ICA maps which represent heamodynamic activity. Further when resting fMRI of controls was compared with meditators we observed low neuro heamodynamic activity in DMN of meditators thus proving the role of meditation on neuro plasticity. A reduced DMN activity indicates lowering of ruminative and mind wandering thoughts in meditators both at rest and during meditation. We also observed an increase in negative BOLD in the DMN during meditation suggestive of an increase in the inhibition on this network. Power spectrum analysis revealed higher frequency band in the DMN of meditators but the role of this finding in a biological system needs to be explored. The EEG-Microstates showed a decreased fluctuation and increased duration in meditators both in resting states and during meditation suggestive of stability of the neuronal activity and a decrease in internal conflict. From our result, it's predicted the soul consciousness meditation as a task of monitoring and feeling free of self referential thought to sustain present focused attention, was that long term expert meditators would be more likely to activate brain regions and improve stability of thought fluctuation and self regulation such as those implicated in conflict monitoring and cognitive control.

7. Conclusion

Hence our study emphasizes the role of meditation to reduce the internal and external conflict and increase the brain stability. Long term regular meditation practice may be cause to shift the functional brain networks which related to regular inner attention even when meditator is not being meditative state. This phenomenon was examined at neuronal and heamodynamic level simultaneously.

Acknowledgement

We thanks to Sisters Bk.Ambika, Bk.Sneha, Bk.Chaya and Spiritual Application Research Center (SpARC), Prajapita Brahamakumari Iswariya Viswa Vidyalaya for providing long term expert meditators for carrying out the above research. We thanks to Dr. S. R. Chandra to examine the EEG signal quality and Dr. Shobini L. Rao for inspiring us to carry this research. We grateful to the Department of Science and Technology (DST), India for supporting to the Cognitive Neuroscience Center, NIMHANS.

References:

Allen, P.J., Josephs, O., Turner, R., 2000. A method for removing imaging artifact from continuous EEG recorded during functional MRI. Neuroimage 12, 230-239.

Allen, P.J., Polizzi, G., Krakow, K., Fish, D.R., Lemieux, L., 1998. Identification of EEG events in the MR scanner: the problem of pulse artifact and a method for its subtraction. Neuroimage 8, 229-239.

Beckmann, C.F., Smith, S.M., 2005. Tensorial extensions of independent component analysis for multisubject FMRI analysis. Neuroimage 25, 294-311.

Biswal, B., Zerrin Yetkin, F., Haughton, V.M., Hyde, J.S., 1995. Functional connectivity in the motor cortex of resting human brain using echo-planar mri. Magnetic resonance in medicine 34, 537-541.

Brandeis, D., Lehmann, D., 1989. Segments of event-related potential map series reveal landscape changes with visual attention and subjective contours. Electroencephalography and clinical neurophysiology 73, 507-519.

Brewer, J.A., Worhunsky, P.D., Gray, J.R., Tang, Y.Y., Weber, J., Kober, H., 2011. Meditation experience is associated with differences in default mode network activity and connectivity. Proceedings of the National Academy of Sciences 108, 20254-20259.

Cahn, B.R., Polich, J., 2006. Meditation states and traits: EEG, ERP, and neuroimaging studies. Psychological bulletin 132, 180.

Cantero, J.L., Atienza, M., Salas, R.M., 2002. Human alpha oscillations in wakefulness, drowsiness period, and REM sleep: different electroencephalographic phenomena within the alpha band. Neurophysiologie Clinique/Clinical Neurophysiology 32, 54-71.

Cantero, J.L., Atienza, M., Salas, R.M., Gómez, C.M., 1999. Brain spatial microstates of human spontaneous alpha activity in relaxed wakefulness, drowsiness period, and REM sleep. Brain topography 11, 257-263.

Changeux, J., Michel, C., 2004. Mechanisms of neural integration at the brain-scale level. The neuronal workspace and microstate models. Cambridge: MIT Press.

Cordes, D., Haughton, V.M., Arfanakis, K., Carew, J.D., Turski, P.A., Moritz, C.H., Quigley, M.A., Meyerand, M.E., 2001. Frequencies contributing to functional connectivity in the cerebral cortex in "resting-state" data. American Journal of Neuroradiology 22, 1326-1333.

D'Argembeau, A., Collette, F., Van der Linden, M., Laureys, S., Del Fiore, G., Degueldre, C., Luxen, A., Salmon, E., 2005. Self-referential reflective activity and its relationship with rest: a PET study. Neuroimage 25, 616-624.

Faber, P.L., Lehmann, D., Barendregt, H., Kaelin, M., Gianotti, L.R.R., 2005. Increased duration of EEG microstates during meditation. Brain topography 18, 131.

Friston, K.J., Williams, S., Howard, R., Frackowiak, R.S.J., Turner, R., 1996. Movement-related effects in fMRI time-series. Magnetic resonance in medicine 35, 346-355.

Goldman, R.I., Stern, J.M., Engel, J., Cohen, M.S., 2000. Acquiring simultaneous EEG and functional MRI. Clinical Neurophysiology 111, 1974-1980.

Greicius, M.D., Krasnow, B., Reiss, A.L., Menon, V., 2003. Functional connectivity in the resting brain: a network analysis of the default mode hypothesis. Proceedings of the National Academy of Sciences 100, 253-258.

Greicius, M.D., Srivastava, G., Reiss, A.L., Menon, V., 2004. Default-mode network activity distinguishes Alzheimer's disease from healthy aging: evidence from functional MRI. Proceedings of the National Academy of Sciences of the United States of America 101, 4637-4642.

Hasenkamp, W., Wilson-Mendenhall, C.D., Duncan, E., Barsalou, L.W., 2012. Mind wandering and attention during focused meditation: a fine-grained temporal analysis of fluctuating cognitive states. Neuroimage 59, 750-760.

Hölzel, B.K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S.M., Gard, T., Lazar, S.W., 2011. Mindfulness practice leads to increases in regional brain gray matter density. Psychiatry Research: Neuroimaging 191, 36-43.

Jang, J.H., Jung, W.H., Kang, D.H., Byun, M.S., Kwon, S.J., Choi, C.H., Kwon, J.S., 2011. Increased default mode network connectivity associated with meditation. Neuroscience letters 487, 358-362.

Jenkinson, M., Bannister, P., Brady, M., Smith, S., 2002. Improved optimization for the robust and accurate linear registration and motion correction of brain images. Neuroimage 17, 825-841.

Koenig, T., Prichep, L., Lehmann, D., Sosa, P.V., Braeker, E., Kleinlogel, H., Isenhart, R., John, E.R., 2002. Millisecond by millisecond, year by year: normative EEG microstates and developmental stages. Neuroimage 16, 41-48.
Lehmann, D., 1990. Brain electric microstates and cognition: the atoms of thought. Machinery of the Mind. Boston: Birkhäuser, 209-224.

Lehmann, D., Faber, P.L., Galderisi, S., Herrmann, W.M., Kinoshita, T., Koukkou, M., Mucci, A., Pascual- Marqui, R.D., Saito, N., Wackermann, J., 2005. EEG microstate duration and syntax in acute, medication- naive, first-episode schizophrenia: a multi-center study. Psychiatry Research-Neuroimaging Section 138, 141-156.

Lehmann, D., Koenig, T., Henggeler, B., Strik, W., Kochi, K., Koukkou, M., Pascual-Marqui, R., 2004. Brain areas activated during electric microstates of mental imagery versus abstract thinking. Klin Neurophysiol 35, 169.

Lehmann, D., Ozaki, H., Pal, I., 1987. EEG alpha map series: brain micro-states by space-oriented adaptive segmentation. Electroencephalography and clinical neurophysiology 67, 271-288.

Lehmann, D., Strik, W., Henggeler, B., Koenig, T., Koukkou, M., 1998. Brain electric microstates and momentary conscious mind states as building blocks of spontaneous thinking: I. Visual imagery and abstract thoughts. International Journal of Psychophysiology 29, 1-11.

Lowe, M., Mock, B., Sorenson, J., 1998. Functional connectivity in single and multislice echoplanar imaging using resting-state fluctuations. Neuroimage 7, 119-132.

Lutz, A., Slagter, H.A., Dunne, J.D., Davidson, R.J., 2008. Attention regulation and monitoring in meditation. Trends in cognitive sciences 12, 163.

Macrae, C.N., Moran, J.M., Heatherton, T.F., Banfield, J.F., Kelley, W.M., 2004. Medial prefrontal activity predicts memory for self. Cerebral Cortex 14, 647-654.

Manna, A., Raffone, A., GIANNI PERRUCCI, M., Nardo, D., Ferretti, A., Tartaro, A., Londei, A., Del Gratta, C., OLIVETTI BELARDINELLI, M., Romani, G.L., 2010. Neural correlates of focused attention and cognitive monitoring in meditation. Brain research bulletin 82, 46-56.

Michel, C.M., Murray, M.M., Lantz, G., Gonzalez, S., Spinelli, L., Grave de Peralta, R., 2004. EEG source imaging. Clinical Neurophysiology 115, 2195-2222.

Mitchell, J.P., Macrae, C.N., Banaji, M.R., 2006. Dissociable medial prefrontal contributions to judgments of similar and dissimilar others. Neuron 50, 655-663.

Musso, F., Brinkmeyer, J., Mobascher, A., Warbrick, T., Winterer, G., 2010. Spontaneous brain activity and EEG microstates. A novel EEG/fMRI analysis approach to explore resting-state networks. Neuroimage 52, 1149.

Oostenveld, R., Praamstra, P., 2001. The five percent electrode system for high-resolution EEG and ERP measurements. Clinical Neurophysiology 112, 713-719.

Pascual-Marqui, R.D., Michel, C.M., Lehmann, D., 1995. Segmentation of brain electrical activity into microstates: model estimation and validation. Biomedical Engineering, IEEE Transactions on 42, 658- 665.

Smith, S.M., 2002. Fast robust automated brain extraction. Human brain mapping 17, 143-155.

Taylor, V.A., Daneault, V., Grant, J., Scavone, G., Breton, E., Roffe-Vidal, S., Courtemanche, J., Lavarenne, A.S., Marrelec, G., Benali, H., 2012. Impact of meditation training on the default mode network during a restful state. Social Cognitive and Affective Neuroscience.

Tei, S., Faber, P.L., Lehmann, D., Tsujiuchi, T., Kumano, H., Pascual-Marqui, R.D., Gianotti, L.R.R., Kochi, K., 2009. Meditators and non-meditators: EEG source imaging during resting. Brain topography 22, 158- 165.

Travis, F., Haaga, D.A.F., Hagelin, J., Tanner, M., Arenander, A., Nidich, S., Gaylord-King, C., Grosswald, S., Rainforth, M., Schneider, R.H., 2010. A self-referential default brain state: patterns of coherence, power,
and eLORETA sources during eyes-closed rest and Transcendental Meditation practice. Cognitive Processing 11, 21-30.

Worsley, K., 2001. Statistical analysis of activation images. Functional MRI: an introduction to methods 14, 251-270.

Figure legends:

Figure 1: Comparison of seed-voxel based correlation analysis and G(group)ICA in Control and Meditator groups in both resting and meditating state: for seed-voxel based analysis, an activation dataset is first analyzed to identify the location of most significant Default Mode Networks (a) The Spatial correlation map of Control group represent coinciding voxel in the DMN. The resulting correlation map (b) shows significant correlation in similar DMN in Meditators resting state as the activation map. (c) Group DMN IC identified in Meditators Meditation state. The multiple regression framework implicit in a GICA decomposition separates resting correlations in DMN. This separation is induced by the fact that the associated time courses are significantly different: the associated normalized power spectra show different peak frequencies(Beckmann and Smith et al., 2005). All spatial maps were thresholded using mixture modelling (at p > 0.99) and are shown in radiological convention.

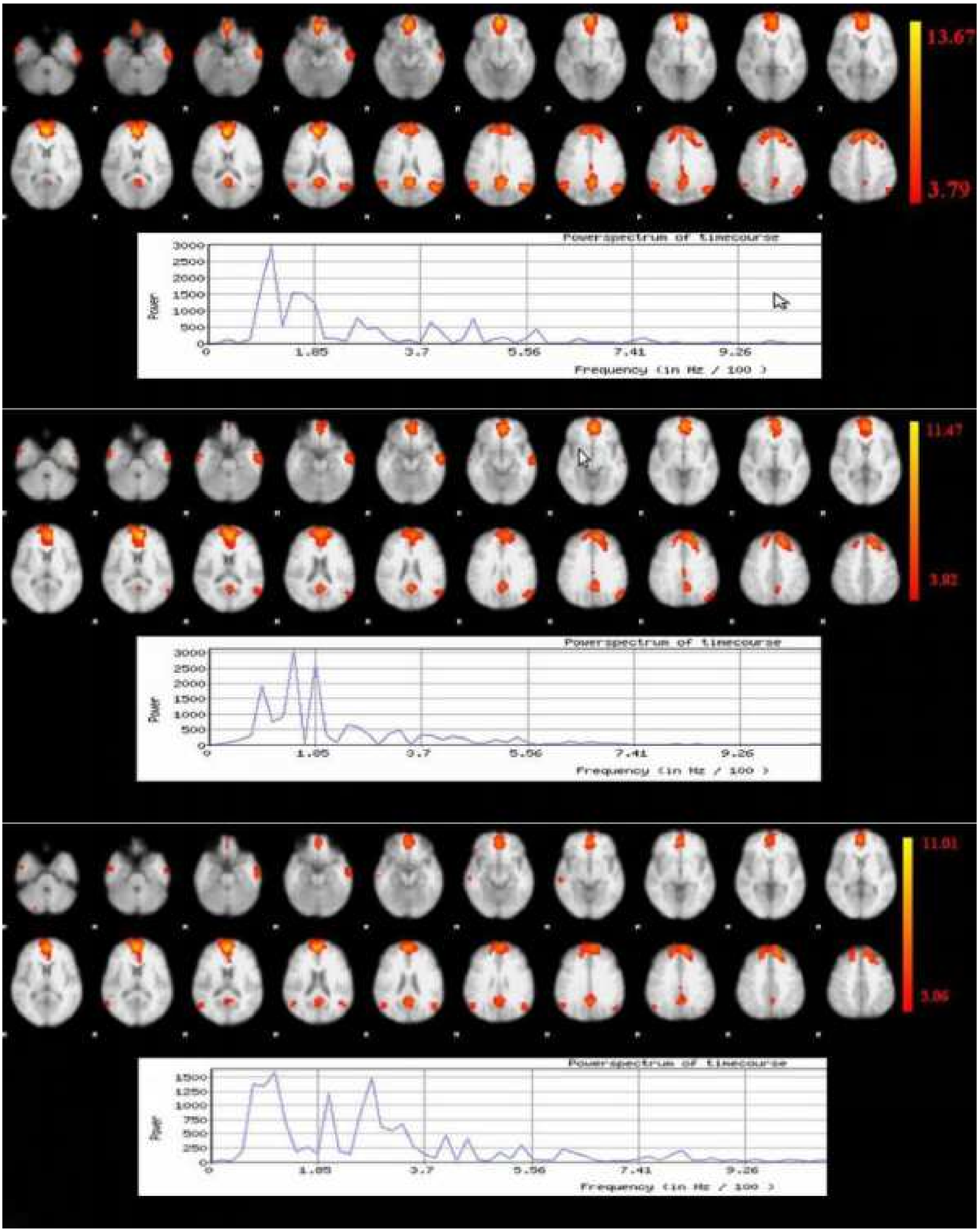


Figure 2: EEG microstates informed fMRI analysis and ICA-BOLD cross validation analysis in single subject level of healthy control at rest and the images are shown in radiological convention. a) BOLD activation maps (Z-stat) of DMN extract using the EEG-microstate informed in the GLM analysis b) Spatial correlation IC maps of DMN c) Power spectrum maps at individual level in controls at rest showing the neuronal and hemodynamic similarities in the DMN.

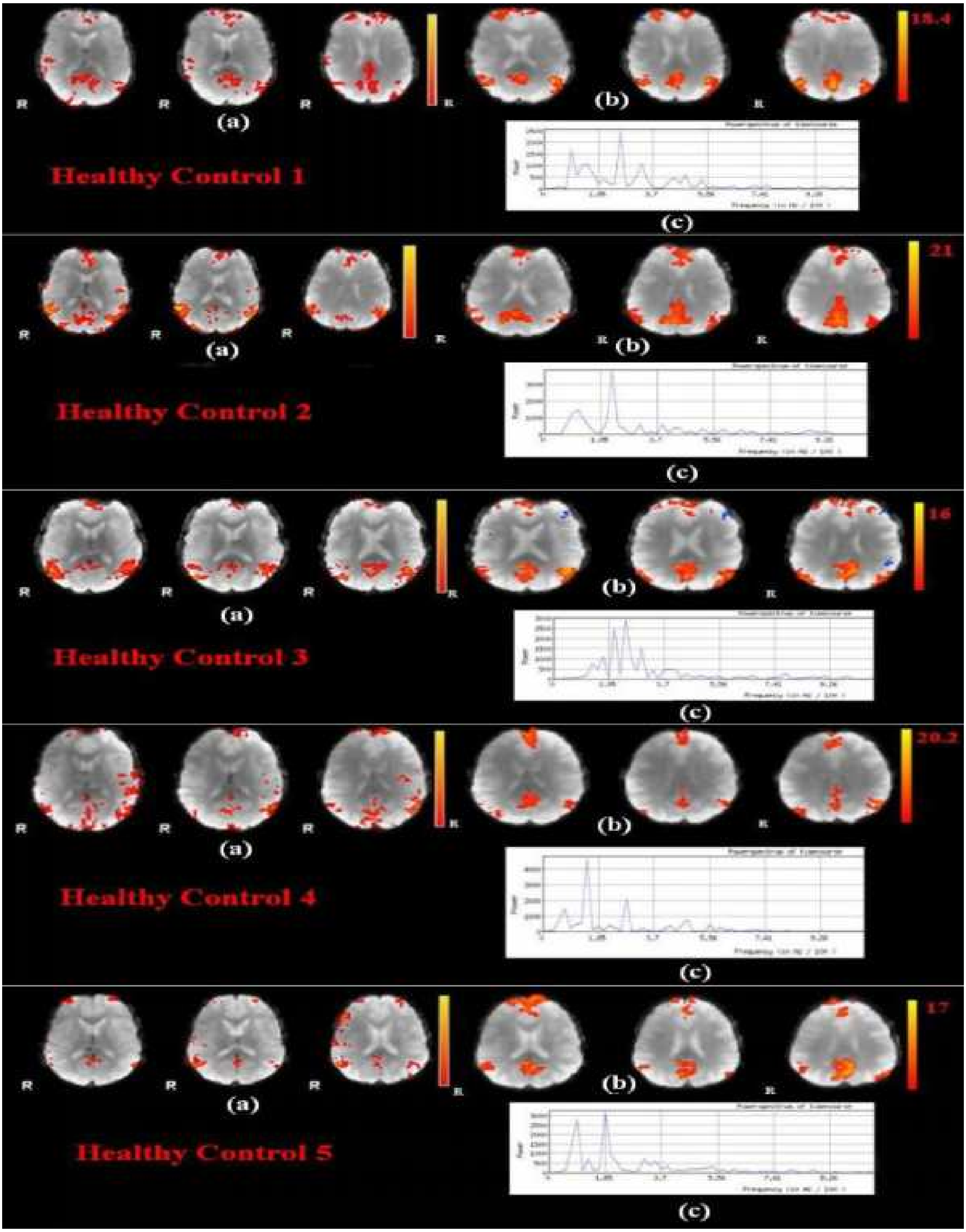


Figure 3: EEG microstates informed fMRI analysis and ICA-BOLD cross validation analysis in single subject level of meditator at rest and the images are shown in radiological convention. a) BOLD activation maps (Z-stat) of DMN extract using the EEG-microstate informed in the GLM analysis b) Spatial correlation IC maps of DMN c) Power spectrum maps at individual level in meditator at rest showing the significant decrease in the neuronal and hemodynamic activity in the DMN as compared to controls.

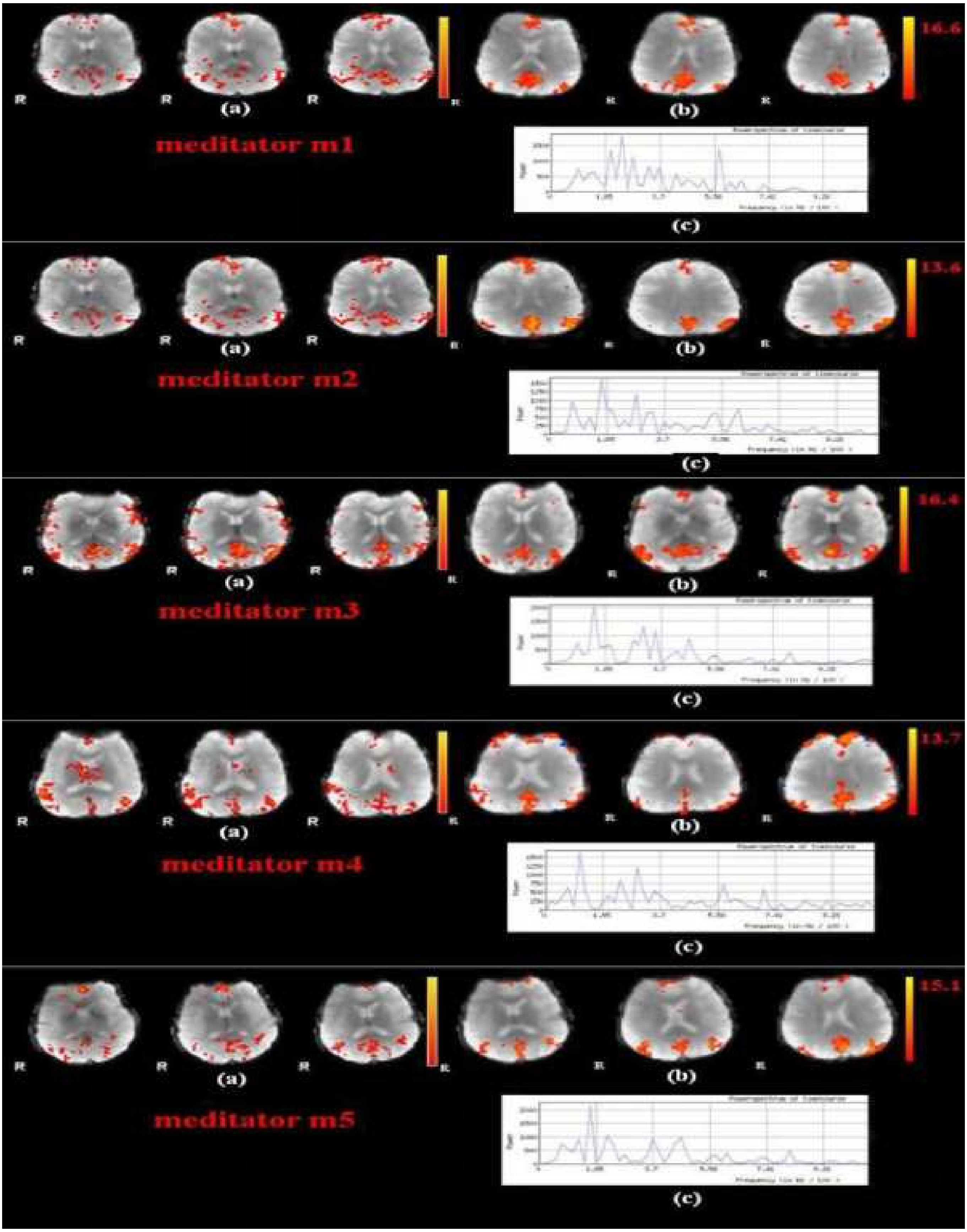


Figure 4: EEG microstates informed fMRI analysis and ICA-BOLD cross validation analysis in single subject level of meditator at meditative state and the images are shown in radiological convention. a) BOLD activation maps (Z-stat) of DMN extract using the EEG-microstate informed in the GLM analysis b) Spatial correlation IC maps of DMN c) Power spectrum maps at individual level in meditator during meditation showing further decrease in the neuronal and hemodynamic activity in the DMN during meditation as compared to resting states of controls and meditators.

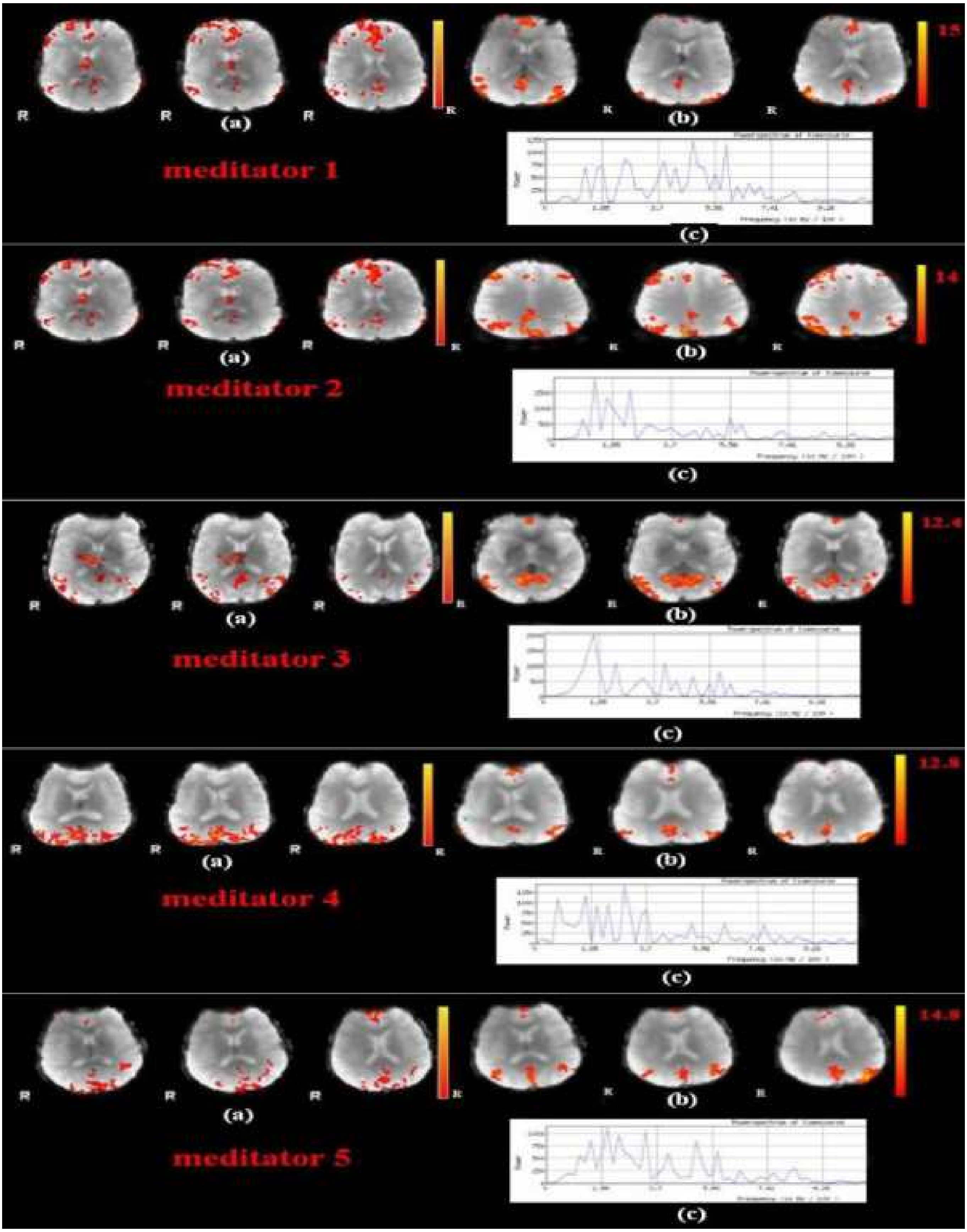


Figure 5: Positive BOLD changes using SPM 8 p<0.05 FWE corrected a)mediator at rest b) during meditation showing significant decrease in BOLD activations in the posterior cingulate during meditation.

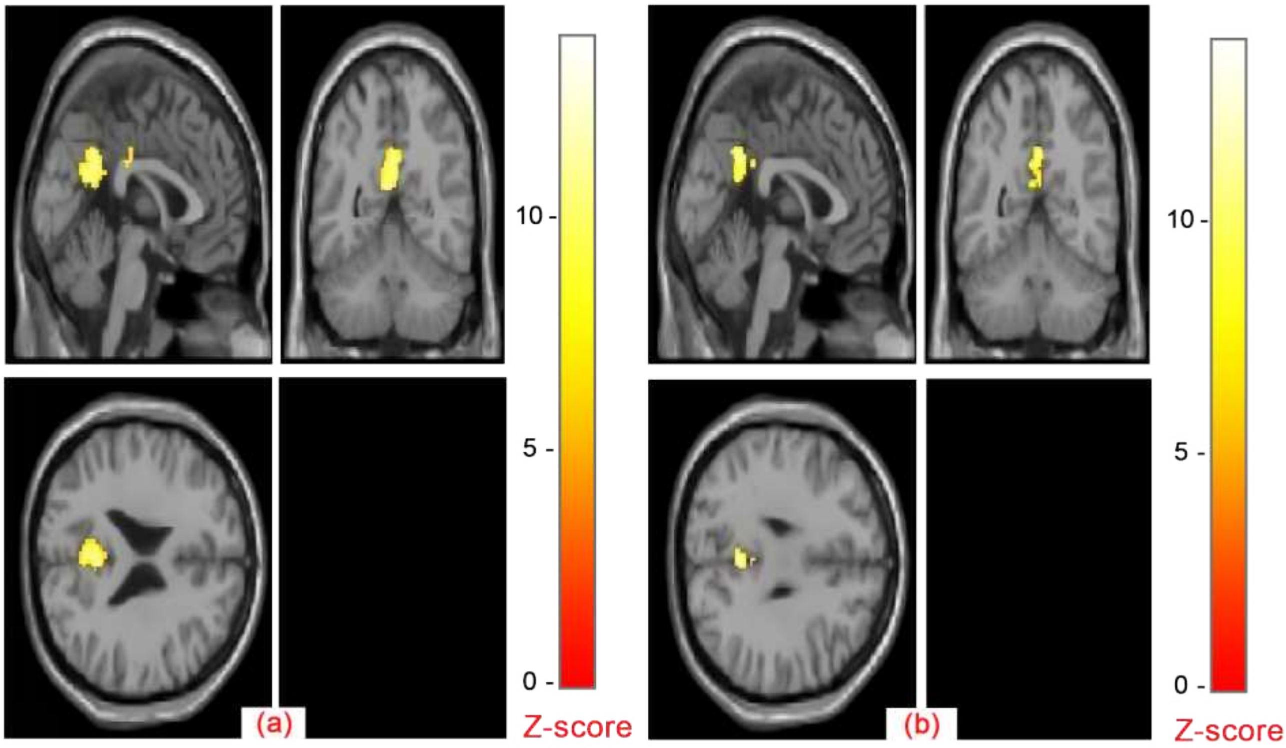
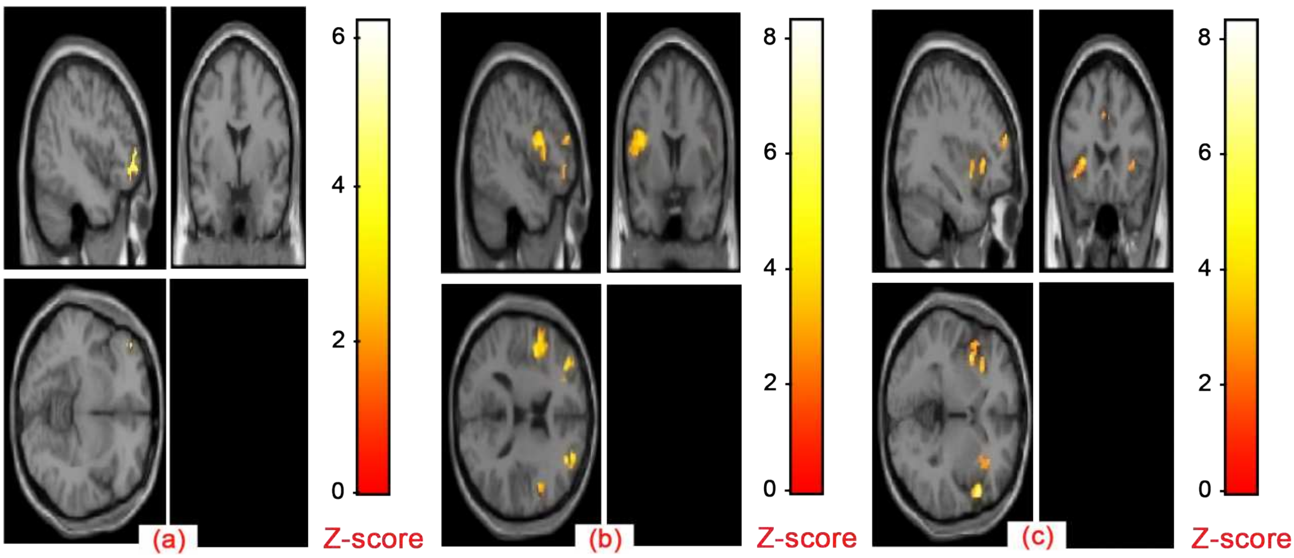


Figure 6: Negative BOLD changes using SPM 8 p<0.001 uncorrected >48 clusters a)controls at rest b)meditator at rest c) during meditation showing significant decrease in BOLD activations in all the components of DMN.



REPORT ON THE STUDY CONDUCTED ON BRAHMAKUMARI'S RAJA YOGA MEDITATION

By
Naveen K.V., Ph.D., Joint Director (Research),

THE DATA OF THIS STUDY IN DHARANA & DHYANA IN BRAHMAKUMARI'S RAJA YOGA MEDITATION IS BEING PUBLISHED BY SWAMI VIVEKANANDA YOGA ANUSANDHAN SAMSTHANA (SVYASA), BENGALURU - 560019

ACKNOWLEDGEMENT

We express our profound gratitude to Ambika didi and all the Brahmakumaris Raja yoga meditation practitioners for their active participation in this study without whose co-operation this study would not have been a success.

Introduction

The system of yoga teaches the means by which the individual human spirit (jivatma) can be in communion with the Supreme Universal spirit (Paramatma). Specific to meditation, it has been described that in the absence of a specific task the mind is very distractible (cancalata), and has to be taken through the stages of 'streamlining the thoughts' (ekagrata), and one-pointed concentration (dharana), before reaching the meditative state (dhyana) (Chinmayananda, 1984).

The present study after ascertaining that the meditation techniques fitted this model (i.e., meditation on OM and Brahmakumaris Raja Yoga meditation), the subjects were instructed to practice dharana and dhyana as distinct states. This was done to prevent, as far as possible, averaging changes across the two states. The two meditation techniques (i.e., meditation on OM and Brahmakumaris Raja Yoga meditation) were selected as both of them are Raja Yoga meditation (Taimini, 1961).

Aims and Objectives

To evaluate whether the physiological correlates of two distinct mental states (i.e. attending to, or ignoring an external stimulus), were different and distinct for a meditation session as compared with a non-meditation session. This was done for two different meditation techniques (i.e., meditation on 'OM' and Brahmakumaris Raja yoga meditation).

"Anything that is secret and mysterious in these systems of yoga should be at once rejected. The best guide in the life is strength. In religion, as in all other matters, discard everything that weakens you, have nothing to do with it."

Swami Vivekananda

Methodology

Subjects

1. Sample size:
The sample size and number of experimental sessions: 40 subjects (20 subjects in each group, i.e., 'OM' meditation and Brahmakumaris Raja Yoga (BK) meditation); were studied in 4 sessions each, making it a total of 160 session (i.e., 40 subjects x 4 sessions).

2. Age and Gender:
Subjects with an age range of 20 to 55 years were selected for the OM meditation subjects the group average age + S.D. was 29.75 + 3.99 years, while for the BK subjects the group average age + S.D. was 35.70 + 10.65 years. Male subjects were studied.

3. Inclusion criteria:

- age range - 20 to 55 years,
- all males,
- normal healthy volunteers with not less than 3 years of meditation experience (minimum of 30 minutes per day, 5 days per week).

4. Exclusion criteria:

- any health problem,
- specifically any autonomic dysfunction (based on polygraph testing) and auditory deficits (as gauged by the individual ear auditory thresholds).

5. Source of subjects:

Bangalore centers of Ishwariya Prajapita Brahmakumari Raja Yoga Vishwa Vidyalaya and Vivekananda Yoga Research Foundation, Bangalore were the sources for recruiting subjects for the study.

Design

Each subject was assessed in four sessions. There were two meditation sessions, i.e., first, recording of autonomic functions and second, recording of the evoked potentials. Each subject also had two non-meditation sessions, i.e., first, recording of autonomic functions and second, recording of the evoked potentials.

The two meditation (A) and two non meditation (B) sessions were recorded alternately. The Design is schematically illustrated in Figure 1.

Figure 1: Design of the Recording Session.

Design for OM Meditation:

Meditation Session:

TIME :	5min.	5min.	5min.	5min.	5min.	5min.	
STATES :	Random Thinking	"Get-into"	Dharana	Dhyana	Attend	Ignore	Random Thinking
	Pre	During					Post

Non-Meditation Session:

TIME :	5min.	5min.	5min.	5min.	5min.	5min.	
STATES :	Random Thinking	Random Thinking	Focusing 'one'	Random Thinking	Attend	Ignore	Random Thinking
	Pre	During					Post

Design for BK Meditation:

Meditation Session:

TIME :	5min.	5min.	5min.	5min.	5min.	5min.	
STATES :	Random Thinking	"Get-into"	Dharana	Dhyana	Attend	Ignore	Random Thinking
	Pre	During					Post

Non-Meditation Session:

TIME :	5min.	5min.	5min.	5min.	5min.	5min.	
STATES :	Random Thinking	Random Thinking	Focusing 'one'	Random Thinking	Attend	Ignore	Random Thinking
	Pre	During					Post

Assessments:

All subjects were assessed using following autonomic and respiratory variables: Heart rate in beats per minute [HR], Respiratory rate in cycles per second [RR], Finger plethysmogram amplitude in centimeters [FPA], Skin conductance level in micro Siemens [SCL] and the Heart rate variability [HRV-Low frequency power in normalized units (LF power); High frequency power in normalized units (HF power); LF/HF ratio].

Also, the long latency auditory evoked potentials [LLAEPs] were recorded frontally and centrally using binaural click stimuli. Data were analyzed using repeated measures ANOVA with two within subjects factors viz. sessions (meditation and non-meditation 'two levels') and states (six levels). Comparisons of the values obtained in each of the five states followed by the pre-state were compared with values of the pre-state using the paired t-test.

Result and Discussion:

During meditation on 'OM' the changes during the dharana and dhyana phases were different and distinct. In the dharana phase the change suggested reduced physiological arousal whereas in dhyana phase the changes were suggestive of 'alertful rest'. Also, the evoked potential changes suggested facilitated neural transmission and better cortical neural synchrony. In the two phases of BK meditation the changes were almost directly opposite to those during meditation on 'OM'. During the dharana phase there was a state of 'alertful rest' with facilitated cortical neural transmission and greater cortical neural synchrony. However, in the dhyana phase the changes were suggestive of 'alertful rest'. These obvious differences between the two meditation techniques have been detailed and discussed as possibly due to meditation on 'OM' being a concentrative type of meditation while BK meditation is mindfulness meditation technique.

There were also marked differences between the two meditation techniques when subjects were actively attending to or ignoring external stimuli. During the practice of 'OM' meditation when subjects actively attended to the external auditory stimuli, there was decrease in arousal whereas in the case of BK meditators there was no change. When the meditators were actively ignoring the external stimuli 'OM' meditators showed 'a state of alertful rest' and delay in cortical neural transmission while on BK meditators it actually produces 'a state of physiological arousal along with a delay in cortical neural transmission'.

Conclusion:

This study is the first attempt to examine the objectively recorded psychophysiological variables during the phases involved in the process of meditation described in ancient yoga texts. The findings have shown that the changes during the phases are different and also differ between meditational techniques. Also, the differences appear to fit in to the fairly well recognized descriptions of meditations of largely of two types i.e., 'Concentrative' and 'Mindfulness'.

Finally, the study also demonstrated psychophysiological responses to attending to or ignoring external stimuli different from one meditation technique to other, probably based on the processes involved. This knowledge may be mad use of in deciding which meditation technique may be most useful in enhancing the ability to 'shut out' external stimuli.

Implications of the study:

The study demonstrated that meditation (irrespective of the technique) produces a mental state characterized by alertness and deep physiological rest. This type of mental state is physiologically ideal to perform tasks, which require vigilance, without getting mentally stressed. This suggests an application of meditation for various tasks that require mental focusing.

Also, with regard to switching between 'attending to' and 'ignoring' an external auditory stimulus, while subjects were in meditation they were able to switch between states with less of physiological arousal compared to when they were not meditating. This suggests that the meditative state irrespective of the technique helps meditators to switch between attending to or to ignoring external stimuli. This has possible implications in the therapeutic management of conditions where persons may want to be able to ignore (at will) an external (or internal) stimulus, such as pain.

LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FUTURE WORK:

1. The study was conducted on male meditators for both 'OM' and 'BK' meditation. Additional information would be obtained by studying meditators of both genders, though this was not chosen, as the variable studied are known to vary with the cyclic phases of hormonal phases in females. A study including females would have to take this phasic fluctuation into account.

2. Auditory evoked potentials were used to see the changes at different levels induced by meditation. Others sensory modalities could also be used to study similar changes, especially since there is an interest to understand the effect of meditation to ignore pain sensation.

3. The study had one session each for meditation and non-meditation. Further studies could include repeat sessions to assess reproducibility of the result, although there is an inherent difficulty in getting experienced and co-operative subjects to participate in repeat sessions. This is of importance as each meditator has to be considered on an individual basis as their stage of practice and personal evolution probably be very individual.

4. This study assessed autonomic and respiratory variables, as well as long-latency auditory evoked potentials in two meditations (i.e., meditation on OM and Brahmakumaris Raja Yoga Meditation). These assessments gave useful insights into the physiological changes in meditative states (i.e., dharana and dhyana) at the level of autonomic functions, as well as primary, secondary auditory areas and mesencephalic – reticular activating system (RAS) (based on long-latency auditory evoked potentials).

Future studies could be planned to assess cognitive changes in meditation, for example using the auditory odd –ball paradigm to assess the P300. This would give useful information about the possible therapeutic benefits of meditation for neurocognitive disorders.

REFERENCES

- Chinmayananda, S. (1984). Mandukya Upanishad. Bombay: Sachin Publishers.
- Taimini, I.K. (1961). The science of yoga. Madras: The Theosophical Publishing House.

REPRINTS OF PAPERS PUBLISHED BY RESEARCHERS AT SVYASA ON BRAHMAKUMARIS RAJA YOGA MEDITATION

1. Naveen, K. V., and Telles, S. (2003). Sensory perception during sleep and meditation: common features and differences. Perceptual and Motor Skills, 96(3 Pt 1): 810-811.
2. Telles, S., and Desiraju, T. (1993). Autonomic changes in Brahmakumaris Raja Yoga Meditation. International Journal of Psychophysiology, 15(2): 147-152.

स्वामी विवेकानन्द योग अनुसंधान संस्थान
Swami Vivekananda Yoga Anusandhana Samsthana
A University, established under Section 3 of the UGC Act, 1956 vide
Notification No. F.9-45/2001-U.3 dated 08-05-2001 of the Government of India
No. 19, 'Eknath Bhavan', Gavipuram Circle, Kempegowda Nagar, Bangalore - 560 019.
Ph : 26612669 Telefax : 26608645
e-mail : svyasablr@yahoo.com website : www.vyasa.org

December 16, 2010

Kumari Ambika Didi,

Ishwariya Prajapitha Brahamakumari Raja Yoga Vishwa Vidyalaya,

Bengaluru

Re: Submission of a brief report on the study conducted on Brahamakumaris Raja Yoga meditators by the investigators from SVYASA.

Dear Ambika Didi,

It gives me immense pleasure to inform you that the study conducted at SVYASA evaluating BK meditators was a great success.

I am grateful to all the meditators and the management of Brahamakumari Raja Yoga Vishwa Vidyalaya, Bengaluru for their extended cooperation and help.

I am herewith attaching a brief summary of the work done for your referral.

Thanking you,

With kind regards,

Dr. Naveen K. V., Ph.D.,
Joint Director (Research),
SVYASA, Bengaluru

Donations qualify for tax exemption under section 80 G & 35(i)(ii) of Income Tax Act 1961

Functional Mapping of human brain during Meditation: An fMRI study

S.Khushu[1+], S.S. Kumaran[1], S.Telles[2], R.P. Tripathi[1], K.V. Naveen[2] and T.L. Mathew[1]
[1]NMR Research Centre, Institute of Nuclear Medicine & Allied Science, Lucknow Road, Delhi-110054, India.
[2]Vivekananda Kendra Yoga Research Foundation, Chamarajpet, Bangalore-560018, India.
[+]Author for correspondence:
e-mail: skhushu@hotmail.com, Phone: 91-11-23916741, 91-11-23926865, Fax: 91-11-23919509

Abstract

Functional magnetic resonance imaging (fMRI) using blood oxygenation level dependent (BOLD) contrast was used to map the active neural correlates during meditation (Brahma Kumaris Rajayoga Meditation) in eleven healthy, right-handed subjects who were practicing meditation for 3 years or more. Measurements consisted of five slices of gradient echo imaging (Magnetom Vision, Siemens, Erlangen) covering the frontoparietal and occipital lobe. The study was carried out in two sessions (of 30 measurements each) on consecutive days. In the first session, 18 measurements of meditation phase were preceded and followed by a period of random thinking (non-meditation), with 6 measurements each, with eyes open during the entire session. The second session consisted of random thinking for the entire duration. The heart rate exhibited significant increase ($p<0.02$) during the meditation phase. Z-score post processing showed bilateral activation in the prefrontal lobe extending laterally in four subjects and right frontal lobe activation in three subjects. Activation of left occipital lobe was observed in two subjects (>15 years of meditation experience). The neural substrates recruited during the process of meditation depend upon the experience and are explained in terms of directed attention, visual imagery and control of the autonomic nervous system.

Keywods: Meditation, BrahmaKumaris Rajayoga, fMRI, neuroimaging

Introduction

Cognitive neuroscience research has evolved rapidly over the past decade with the development of various neuroimaging techniques such as positron emission tomography (PET). functional magnetic resonance imaging (fMRI), magneto encephalography (MEG), electroencephalography (EEG) etc., which concurrently provide an integrated approach towards mapping the living brain in both space and time (1-9). Amongst these, PET and fMRI detect task-induced alterations in metabolic or vascular parameters such as regional cerebral blood flow (rCBO2).

Local physiological changes that accompany increased neuronal activation can be imaged using a susceptibility sensitive MR imaging method called blood oxygenation level dependent (BOLD) technique (10). Neurovascular coupling between the cerebral blood flow and oxygenation forms the basis of BOLD imaging, which uses deoxyhaemoglobin as the endogenous source of MR contrast. Increased metabolic demands following brain activity is over-compensated by an increase in regional cerebral blood flow resulting in an imbalance between oxygen supply and utilization. Oxyhaemoglobin is diamagnetic whereas deoxyhaemoglobin is paramagnetic, with slightly differing magnetic susceptibilities. This variation results in the increase of the effective transverse relaxation time ($T2^*$) and hence increased signal intensity in the local active neuronal tissue on $T2^*$ sensitive MR pulse sequence such as gradient echo (GE) or echo planar imaging (EPI) (11-13).

Meditation has been described as the 'Fourth major state of consciousness', characterized by a state of restful alertness. Exploration of the various autonomic and physiological correlated of meditation has revealed changes in the form of a reduction in oxygen consumption, an increase in skin resistance, a decrease in heart rate and an increase in the EEG alpha wave amplitude and regularity (14-16). The practice of meditation has also been associated with significant changes in perception, attention and cognition (17). Though meditation may be practiced through a variety of spiritual paths such as transcendental meditation, tantric yoga, zen technique etc. the final goal of all these techniques is to achieve an absolute state of consciousness, wherein one transcends the physical world, views reality with unencumbered clarity, or develops a metaphysical association with God (18-20). Performance of meditation thus, finally results in the achievement of a relaxed and quite mental state, devoid of any distractions (21). The set of integrated physiological responses induced by the practice of this technique is termed as the "relaxation response" (22). The origin of the 'meditative effect' produced in different types of meditation, appears to lie in the induction of a combination of three different neuro-physiological mechanisms viz. 'efferent attenuation', sensory attenuation' and 'cognitive restructuring' (23).

Electro-physiological studies have been able to provide objective evidence towards the presence of better sensory information processing following yoga. Presence of such an altered sensory perception is substantiated by observations on yogis in deep meditation, who showed an absence of alpha blocking in the EEG even when exposed to diverse stimuli such as visual, vibratory, thermal or sensory (24). Recordings of middle latency auditory evoked responses were taken in subjects with experience of meditation (ranging from 10 to 14 years) on a meaningful syllable (pronouncing OM). There was a shorter latency of a specific component (the Na wave, 14 to 18 msec), which corresponds to mesencephalic or diencephalic centers of the auditory pathway during meditation (16). comparisons were made with the preceding baseline state and with a non-meditation period, during which, subjects mentally repeated a neutral syllable ("one"). Another study (25) showed a shorter latency of a later component (the Nb wave, 35 to 65 ms) during the same meditation technique, in subjects who had between 5 to 20 years of experience of meditation. This suggested that in subjects with significant experience of meditation, there was better sensory information processing at the level of the dorsoposteromedial part of Heschl's gyrus (i.e. the primary auditory cortex). An increase in heart rate has been observed during the meditation session in 18 practitioners with 5-25 years of experience in the Brahmakumari Rajayoga form of meditation, as compared to both the preceding baseline period and the non-meditation period of control sessions (26). At the same time, performance of the form of meditation did not result in any significant change in other parameters such as respiratory rate, palmar galvanic skin resistance and finger plethysmogram amplitude.

Intra-individual changes have been observed in overall regional cerebral glucose metabolic responses (rCMRGlc) when meditation and non-meditation responses were compared on eight subjects practicing yoga mediation using PET (27). The ratios of frontal versus occipital rCMRGlc were significantly higher during meditation, compared to non-meditation (27). A PET study that compared four different forms of the 'Yoga Nidra' meditation revealed increased activations in the inferior frontal, fusiform, occipital and postcentral gyri for a pooled average of meditative states relative to the control condition (28). An analysis of the group-averaged data obtained in yet another study that used fMRI technique for mapping the relaxation response in a simple form of Kundalini meditation amongst 5 subjects revealed increased activations of neural structures involved in attention (frontal and parietal cortex) and arousal/autonomic control (pregenual anterior cingulate, amygdala, midbrain and hypothalamus) (29). Significant activation was also identified in the putamen, pre and postcentral gyri and hypothalamus/ parahippocampal formation, suggesting a possible role of these structures during meditation. Physiological monitoring in one subject during scanning revealed increased cardio-respiratory functions with an increase in heart rate during meditation, which returned to baseline at the end of meditation periods. A preliminary SPECT study on eight subjects experienced in Tibetan Buddhist meditation also reported an increased rCBF in cingulate gyrus, inferior and orbital frontal cortex. dorsolateral prefrontal cortex and thalamus with correlated decreased activity in the posterior parietal lobes (30). Observed activations were ascribed to the need for increased focused concentration, the experience of alteration in the sense of space and a general increase in cortical demands.

The aim of the present study was to use fMRI technique to map the neural substrates recruited during Brahmakumari Rajayoga meditation, which is different from other forms, and not based on Pranayama (concentration on breathing).

Materials & Methods
Subjects:

Eleven (10 male, 1 female) right-handed healthy volunteers between 32 and 65 years of age practicing Brahmakumari Rajayoga meditation were recruited. None of them had any neurological or psychiatric problems and were not under any medication for at least one month prior to the study. The study details were explained to them and written informed consent was obtained before the study. All these volunteers were practicing Brahmakumari Rajayoga meditation for at least three years and claimed the switching time for transition from normal consciousness to meditation state (in lying posture) between 30 sec to 5 minutes. All volunteers were studied in two sessions, i.e. a control and a meditation session, held at the same time on consecutive days. Each session consisted of a total of 30 measurements in ABCA paradigm, where A denotes six measurements in rest phase (or control phase) with random thinking, B had six measurements during the transition phase from rest to meditation (the time differs for different subjects) and C is the meditation phase of 12 measurements during which the subject was concentrating and focusing their attention on a series of meaningful positive thoughts. Verbal auditory instructions were given to begin and end the meditation process. The electrocardiogram of all the volunteers was monitored using three non-magnetic electrodes during the two sessions. After each session, the subjects were also interviewed for their subjective feelings, i.e. whether they were able to meditate as usual within the magnet and regarding the presence of any special experiences during meditation.

Brahmakumari Rajayoga Meditation:

The Brahmakumari Rajayoga meditation (BK) has spread from the organisation's headquarters at Mount Abu, Rajasthan (India) throughout the Indian subcontinent and to other countries. During meditation, the subjects sit in a comfortable position (lying posture for fMRI experiments), with their eyes open and gaze focused on a meaningful symbol. Meditation is carried out on the following thoughts… 'I am a soul, a conscient twinkling star, a point of light, radiating light in all directions… I will pass on this light, might, peace and bliss, which I am getting from thee, to all souls, in all directions…' Through the process of meditation, ultimately, one should be able to visualize mentally, a golden-red light call Brahman, which is omnipresent, according to their concepts. In it, one sees a brilliant and conscient point of light called the Supreme Father (God Shiva), radiating divine light, might, peace, bliss and love in all directions (31). Ultimately, this heightened consciousness enables one to feel relaxed, refreshed, purified, elevated and recharged.

Methods:

Images were acquired on a 1.5 Tesla whole body MRI system (Siemens, Magnetom Vision) using a circularly polarized head coil and 25mT/m actively shielded gradient system. High resolution, anatomical, flow sensitized para-axial images (5 to 7 slices) covering the fronto-parietal and occipital lobes were acquired using turbo gradient echo pulse sequence (TR = 450ms, TE =56ms; Flip angle = 40; Slice thickness = 3mm; Matrix 128x128; No of Meas = 30, Scan interval = 5sec) with a scan time of 59 sec/measurement. Figure 1 shows the position of the slices on the sagittal scout image. The in plane resolution was 1.64mm x 1.64mm with a total FOV of 210mm. Before acquiring the BOLD images, the magnetic field was shimmed to optimize the homogeneity of the magnetic field. The acquired image data was finally checked for any gross head motion following which they were taken for pixel wise calculation of the Z score. The activated pixels so calculated were superimposed onto the high-resolution anatomical images. To check reproducibility, two volunteers were repeated after a week with the same sequence and task paradigm.

Results

Heart rate was found to increase significantly ($p<0.02$) when instruction to start meditation was given to the volunteer, and it remained marginally high till the instruction for stopping meditation was given (Fig. 2b). In the control session, a constant (or a marginal declining) heart rate was observed in 5 out of 11 volunteers (Fig.2a). The data from two volunteers could not be included in the study, due to excessive head motion. An interview of the subjects and the monitoring of the heart rate during the fMRI sessions were used for the subjective assessment and to ascertain the degree of meditation attained by the volunteers.

Of the nine volunteers who confirmed to the experimental conditions, three volunteers exhibited right prefrontal lobe activation (34+5 pixels with mean intensity of 1884+288 au) during meditation (Fig.3a). Consistent but dominant bilateral activation (39+6 pixels with an average intensity of 1686+164 au) in the left prefrontal lobe was observed in four subjects during meditation (Fig. 3b). Small activation in the left parietal region was also observed in three out of these four volunteers. Two volunteers (>15years experience) showed very minimal activation in the left prefrontal cortex, but a prominent cluster of activation (120+17 pixels with average intensity of 1972+264 au) in the left occipital lobe (Fig. 3c). Figures 3 (d, e, f) show the results of the activation map during control sessions and figure 3 (a, b, c) shows the corresponding meditation sessions, respectively.

Discussion

The phenomenon of cognition consists of perception and its sequelae. Yoga and meditation are different ways of achieving a peaceful, calm, stress free mental state while going on to achieve an ultimate state of 'pure consciousness' and are considered to enhance human capabilities by relaxation. Though different types of meditation exist, the principles are similar, i.e., they involve the focusing of attention followed by an effortless expansive mental state ('dhyan' in Hindi). Thus, the initial stage of meditation involves focusing of thoughts and sustained attention. This is followed by inherent mental meditation while at rest or work, without posture restrictions. In Rajayoga, the subjects have alertness to external stimuli (which can be specified), without being disturbed by it. The switching time from normal (random thinking) to meditation state (and vice versa) decreases with experience and ranges from 30 second to a few minutes. The ultimate state of meditation is the heightened consciousness (visualization of a diffused golden-red light) in a few forms of meditation, resulting in the total relaxation of mind and body. This is observed only in advanced stages of meditation, and is not attained at will, even if the conditions are similar. A few experienced subjects achieve this state directly, bypassing other intermediate stages of meditation.

The significant decrease in the heart rate during the control session (Fig. 2a) and increase during the meditation sessions (Fig. 2b) agrees well with results of the previous study (26) on Rajayoga meditation. While decreased cardiorespiratory functions is observed normally in different forms of meditation, the increased heart rate is typical of the BK Rajayoga meditation (29). This could be due to the intense involvement and concentration required in BK Rajayoga meditation, when compared to other methods of meditation (26,29). Consistent increase in monitored heart rate during meditation could be indicative of cardio sympathetic activation, and may also point towards psycho-sympathetic arousal (26). Monitoring of other physiological parameters such as EEG, skin resistance, oxygen consumption etc. could not be performed in the present study.

The localized activation in the right prefrontal lobe (Fig. 3a) in three volunteers (having 3-5 years of experience) performing Rajayoga meditation may be attributed to attention/concentration and alertness, since right prefrontal cortex may be particularly important in visual-spatial and attention-demanding tasks (32, 33). In four volunteers (having experience 5-15 years), a bilateral prefrontal lobe activation extending laterally in the left hemisphere (Fig. 3c) may be suggestive of sustained attention and positive thoughts (34). Increased foci of activation in different parts of the frontal cortex have been observed during meditation by a SPECT study (30). Differential activity has been observed in dorsolateral and orbitofrontal cortex, anterior cingulate gyri, left temporal gyri, left inferior parietal lobule, striatal and thalamic regions, pons and cerebellar vermis and hemispheres, structures thought to support an executive attentional network during relaxation meditation or a simple form of meditation (28, 29). Though we have not attempted whole brain studies (concentrating on 7 slices covering frontal, parietal and occipital lobes), our results are in partial agreement with the observed neural activation patterns in the above mentioned reports, we observe focused activation in the right and left prefrontal lobe besides left parietal lobe. Some degree of bilateral activation observed in four subjects could be due to visual vigilance/sustained attention, as had been observed earlier (35).

The activation in the occipital lobe (Fig. 3e) in two most experienced subjects (>15 years) could be due to visual imagery. The subjects indicated that they could attain the ultimate stage and could visualize light, as revealed during the interview after the session. Hence this could be due to the 'pure consciousness state'.

The activation patterns observed in these volunteers, thus, seem to be related to their experience in meditation and dedication. The observed variations in results in our study compared to previous studies, could be attributed to differences in the type of meditation studied, steps adopted, duration of the session etc. along with other individual characteristics of the subject involved, such as overall commitment towards the practice, experience, lifestyle, etc.

More systematic studies with whole brain fMRI will go a long way in enhancing our understanding of the neurophysiological basis of different states of consciousness and possibly to identify neuronal pathways. A better understanding of the effects of meditation will also help in considering possible applications of this practice, for improvement of mental health and a concomitant reduction in stress level. This is especially relevant to personnel exposed to stressful situations.

Acknowledgements: The authors are grateful to Brahmakumari Rajayoga meditation volunteers and the centres from where they were recruited (especially, Siri fort & Shakti Nagar centres).

References:

Hamalainen M, Hari R, Illmoniemi R, Knuutila J and Lounasmaa O. Magnetoencephalography: Theory, Instrumentation and applications to non-invasive studies of the working human brain. Rev. Mod. Physics. 65: 413-498; 1993.

Petsche H, Etlinger SC and Filz O. Brain electrical measurements of bilingual speech management: an initial investigation. Electroenchphalogr Clin Neurophysiol. 86:385-394; 1993.

Kosslyn SM, Thompson WL and Alpert NM. Neural systems shared by visual imagery and visual perception: A PET study. Neuroimage. 6(4): 305-319; 1997.

Hillyard SA and Anllo-Vento L. Event-related brain potentials in the study of visual selective attention. Proc. Natl. Acad. Sci. USA. 95 (3):781-787; 1998.

Fletcher PC and Henson RNA. Frontal lobes and human memory-Insights from functional Neuroimaging. Brain. 124(5): 849-881; 2001.

Klein D. Zatorre RJ. Milner B and Zhao V. A cross-linguistic PET study of tone perception in mandarin Chinese and English speaker. Neuroimage. 13: 646-53; 2001.

Keller TA. Carpenter PA and Just MA. The Neural Bases of Sentence Comprehension: a fMRI Examination of Syntactic and Lexical Processing. Cereb. Cortex. 11:223-237; 2001.

Simon O, Mangin J-F, Cohen L, Le Bihan D and Dehaene S. Topographical layout of hand, eye, calculation and language – related areas in the human parietal lobe. Neuron. 33: 475-487; 2002.

© 2023 JETIR June 2023, Volume 10, Issue 6 www.jetir.org (ISSN-2349-5162)

JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

"Brahma kumaris raja yoga meditation in modern times: Addressing the current issues and applications"

Dr. Nagesh N.V.*[1]
Senior Professor cum Research Supervisor, Manipur International University, Manipur and CARE, India
*[1] Corresponding Author
#. 5, Om Shanthi Bhawan, Nallur Village, Chikmagalur Post, Chikmagalur-577101, Karnataka, India
Email: nag8108@gmail.com

ABSTRACT:
This comprehensive review article delves into the significance and potential influence of Brahma Kumaris Raja Yoga Meditation in the context of modern times, with a specific emphasis on its applications for personal and professional development. The article explores the multifaceted advantages of this practice, shedding light on how it can enhance various aspects of life. It highlights the remarkable benefits of Raja Yoga meditation, such as improved mental focus, enhanced emotional stability, heightened self-awareness, and a deeper sense of purpose and meaning.
Moreover, the review article acknowledges the growing body of scientific research that supports and validates the positive effects of Raja Yoga meditation. It delves into studies that demonstrate the impact of this practice on mental health, brain function, physical well-being, workplace productivity, and the process of ageing. By integrating scientific findings, the article underlines the credibility and efficacy of Raja Yoga meditation as a transformative tool.
Additionally, the article contemplates the future implications of Raja Yoga meditation. It envisions a society where the widespread adoption of this practice contributes to a more balanced, harmonious, and compassionate world. The potential societal outcomes include improved mental health on a larger scale, increased emotional well-being, enhanced productivity and creativity in various domains, and the fostering of meaningful connections and relationships among individuals.
Overall, this review article offers a thorough exploration of the relevance, benefits, and potential impact of Brahma Kumaris Raja Yoga Meditation in the modern era. It serves as a valuable resource for understanding the practical applications of this practice in personal growth, professional success, and the cultivation of a more fulfilling and harmonious society.

KEYWORDS: Raja Yoga meditation, Personal development, Professional development, scientific research, Future implications.

I. INTRODUCTION:

A review paper titled "Brahma Kumaris Raja Yoga Meditation in Modern Times: Addressing Current Issues and Applications" emerges within the vast realm of intellectual exploration. Its noble aim is to uncover the intricate complexities of the Brahma Kumaris organization, whose teachings are intertwined with the mystical practice of Raja Yoga meditation. Moreover, while shedding light on the latest scientific research regarding the benefits of Raja Yoga meditation, it fearlessly delves into the turbulent realm of criticism and controversy surrounding the organization.

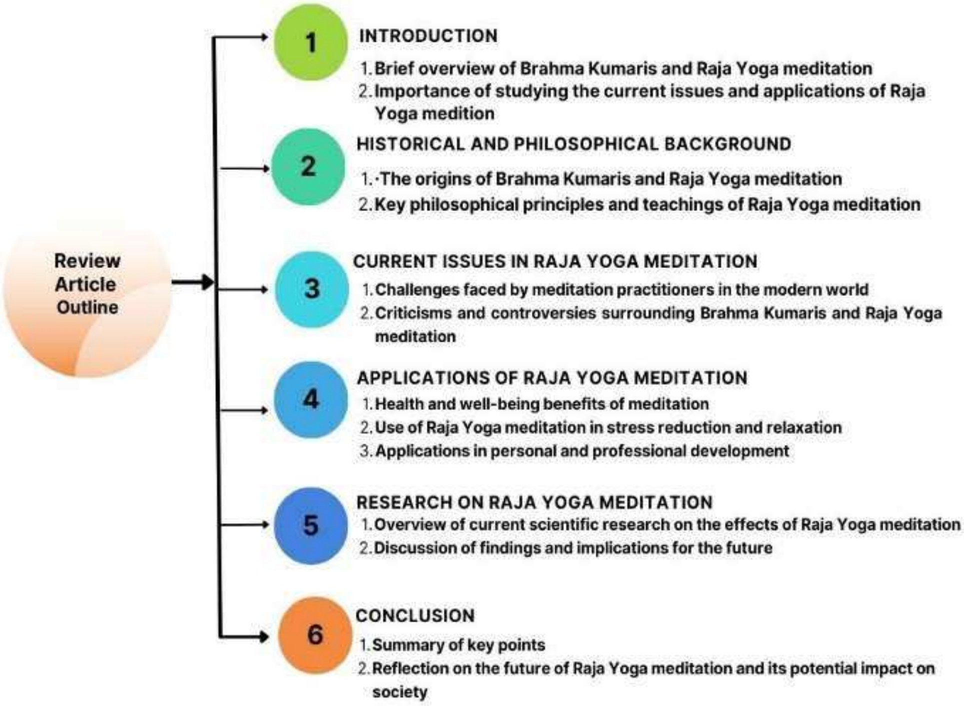


Fig-1: Outline of the Review article

To truly grasp the essence of the organization, its teachings, and the fundamental principles of Raja Yoga meditation, this review article transcends superficial understanding. It possesses the capacity to delve into the core of the matter, navigating through the treacherous waters of skepticism and disagreement while simultaneously illuminating the diverse applications and potential advantages of Raja Yoga meditation in our modern era.

This review article weaves together a rich tapestry of information sourced from various outlets, including published research papers, insightful books, doctoral dissertations, and the vast expanse of online literature. Like alchemists of knowledge, the authors skillfully combine these diverse strands, painstakingly creating a comprehensive panorama that offers profound insights into the Brahma Kumaris organization and the transformative potential of Raja Yoga meditation. Through their analysis, the mystical art of Raja Yoga is revealed as a catalyst for personal and professional growth, stress reduction, and the harmonization of emotional well-being.

However, this intellectual journey does not shy away from the turbulent terrain of criticism and contention. The article presents a beautifully balanced perspective on the teachings and practices of the Brahma Kumaris organization while sensitively acknowledging and navigating the intricacies of disagreement.

Ultimately, this review serves as a guiding light, casting its illuminating glow to raise awareness of Raja Yoga meditation and its immense potential benefits. It stands as an invaluable resource and beacon for individuals seeking to explore the profound depths of Raja Yoga meditation in our contemporary world. It embraces the puzzling interaction between puzzling ness and burstiness and acts as a crucial intellectual compass for anyone trying to understand the complexities of Raja Yoga meditation and its amazing applications in our ever-evolving environment.

1. A brief overview of Brahma Kumaris and Raja Yoga meditation

Step into the mystical realm of the Brahma Kumaris, a global spiritual movement born in the 1930s in India by the enigmatic figure of Dada Lekhraj Kripalani, also known as Brahma Baba. Since its inception, this movement has traversed boundaries, spanning a staggering 142 countries, with a particularly strong presence in India, the United States, and the United Kingdom. At the heart of Brahma Kumaris lies Raja Yoga meditation, a captivating practice that delves deep into the recesses of the mind and intellect. Raja Yoga meditation derives its power from the fundamental belief that the human mind possesses boundless potential, capable of unlocking inner serenity and profound satisfaction. Its essence lies in the tranquil act of sitting in silence, directing the mind towards a singular thought or concept, such as love or the profound realization of the self as a spiritual being. Through dedicated and consistent practice, Raja Yoga meditation unfurls a transformative journey, leading individuals to heightened self-awareness, enhanced concentration, and an inner sanctum of peace and fulfilment. Within the pages of this review article, we embark on an exploration of the contemporary facets and applications of Brahma Kumaris Raja Yoga meditation. Our odyssey commences by unravelling the historical tapestry and philosophical underpinnings of this profound practice. With an unwavering gaze, we delve into the current state of research surrounding Raja Yoga meditation, peering into the enigmatic depths of its effects and implications. The expedition continues as we navigate through the diverse domains in which this practice finds resonance, from its utilization in stress management and addiction recovery to its transformative impact on personal development. Finally, our voyage draws to a close with a contemplative discussion, examining the potential advantages and limitations of Raja Yoga meditation while charting the uncharted territories that await future exploration. Welcome to the realm of Brahma Kumaris and Raja Yoga meditation, where the mystical and practical converge, offering a gateway to new dimensions of understanding and self-discovery.

2. The importance of studying the current issues and applications of Raja Yoga meditation

Studying the current issues and applications of Brahma Kumaris Raja Yoga meditation holds significant importance, especially in today's world. As the demands and pressures of modern life continue to mount, more and more individuals are seeking refuge in meditation practices like Raja Yoga to navigate their challenges. However, along with the increasing popularity of meditation, various obstacles and barriers need to be addressed. Through the study of the current issues and applications of Raja Yoga meditation, we can gain a deeper understanding of the challenges and barriers faced by practitioners. This understanding allows us to identify contributing factors such as cultural differences, personal beliefs, and practical challenges. By recognizing these challenges, we can develop strategies to overcome them and assist practitioners in deriving maximum benefit from their meditation practice. Furthermore, delving into the current issues and applications of Raja Yoga meditation helps to comprehend its potential benefits. While meditation is commonly recognized for its role in stress reduction and relaxation, there is a growing body of evidence suggesting a range of additional health benefits. These include reducing symptoms of depression and anxiety, enhancing focus and attention, and promoting overall well-being. Additionally, studying the current issues and applications of Raja Yoga meditation enables us to explore its potential applications in various fields. Research has demonstrated its efficacy in improving performance in academic and professional settings, fostering creativity and innovation, and even mitigating the risk of burnout. In conclusion, studying the current issues and applications of Raja Yoga meditation is important as it equips us to overcome challenges, optimize the benefits of this practice, and explore its potential applications in diverse domains. Within the context of the review article titled "Brahma Kumaris Raja Yoga Meditation in Modern Times: Addressing the Current Issues and Applications," understanding these aspects becomes crucial in providing a comprehensive overview of the practice and its relevance in today's world.

3. Method

The methodology employed for the review article encompasses a comprehensive and meticulous approach to gathering pertinent information and gaining profound insights. The ensuing steps were undertaken:

1. Literature Search: An exhaustive and systematic exploration was conducted utilizing various academic databases, scholarly journals, doctoral dissertations, and reputable sources to identify pertinent articles, studies, and publications concerning Raja Yoga meditation in contemporary times. The search specifically targeted the current issues and applications associated with this practice.
2. Selection Criteria: With utmost care, articles and studies that aligned precisely with the scope and objectives of the review article were meticulously chosen. The criteria included factors such as relevance to the topic, credibility and reliability of the sources, and the presence of the most up-to-date information.
3. Data Extraction: Key findings, profound insights, and diverse perspectives from the selected articles were meticulously extracted and methodically organized based on coherent thematic categories. This facilitated a comprehensive analysis of the prevailing issues and applications of Raja Yoga meditation.
4. Analysis and Synthesis: The extracted data were subjected to rigorous scrutiny and critical analysis to discern recurrent patterns, discernible trends, and emergent perspectives. The interconnections and synergies between different sources and ideas were synthesized to engender a holistic and comprehensive understanding of the subject matter.
5. Framework Development: A meticulously structured framework was conceptualized and implemented to present the review article. This entailed comprehensive sections, including an engaging introduction that provided a comprehensive overview of the topic, a detailed discussion delving into the key principles and techniques of Raja Yoga meditation, an exploration of the current issues and applications, an examination of the emerging trends, and a visionary outlook encompassing future perspectives.
6. Conclusion and Implications: The review article culminated in a succinct yet comprehensive summary encapsulating the key points and implications derived from the meticulous analysis. Furthermore, it imparted insightful reflections regarding the immense potential impact of Raja Yoga meditation in modern times and proffered thought-provoking avenues for further research and exploration.

The utilization of this rigorous methodology in the review article ensures an exhaustive, evidence-based, and in-depth exploration of the current issues and applications of Brahma Kumaris Raja Yoga meditation in modern times.

4. Selection Criteria:

The study selection criteria for the review article encompassed specific inclusion and exclusion criteria. Inclusion criteria involved articles and studies directly related to Brahma Kumaris Raja Yoga meditation, published in reputable sources, and discussing emerging trends such as technological integration, mental and emotional well-being, and the practice’s popularity among younger generations. Future perspectives were also considered, including the potential for technology integration, the role in promoting global peace, and collaborations with other organizations. Exclusion criteria focused on articles unrelated to Brahma Kumaris Raja Yoga meditation, non-English or unreliable publications, and content lacking discussion on emerging trends or future perspectives, and outdated or irrelevant sources. These criteria facilitated a focused and comprehensive analysis of relevant literature, ensuring a thorough exploration of contemporary issues and applications of Raja Yoga meditation.

5. Search Strategies:

The search strategies employed for this review article encompassed the following several steps:

a) General Search Engines: Initial searches were conducted using popular search engines like Google Scholar, PubMed, Medline, and Scopus. Keywords such as "Brahma Kumaris Raja Yoga," "meditation," "yoga," "spirituality," "mindfulness," "mental health," and "well-being" were used to identify relevant articles, books, and sources.

b) Authoritative Sources: Emphasis was placed on consulting authoritative sources, including academic journals, books, and government websites that provide reliable information on Brahma Kumaris Raja Yoga meditation. Recommended journals such as the International Journal of Yoga, the Journal of Religion and Health, and Complementary Therapies in Medicine were specifically searched.

c) Brahma Kumaris' Official Website: The official websites of Brahma Kumaris were explored to gather information about the history, philosophy, and practice of Raja Yoga meditation directly from the source.

d) Specialized Databases: Specialized databases like PsycINFO, CINAHL, and AltHealthWatch were utilized to uncover articles and studies specifically related to the mental and physical health benefits of meditation, with a focus on Raja Yoga.

e) Reference Review: The reference lists of relevant articles, dissertations, and books were carefully reviewed to identify additional sources about Brahma Kumaris Raja Yoga meditation, ensuring a comprehensive approach to the literature review.
f) Social Media and Online Communities: Active engagement with online communities centered on meditation and spirituality, including Facebook groups, Telegram groups, and WhatsApp groups, was undertaken to connect with like-minded individuals and subject matter experts in the field, potentially uncovering valuable insights and resources.
By employing these diverse search strategies, the review article aimed to gather a wide range of reliable and relevant information on Brahma Kumaris Raja Yoga meditation to address the current issues and applications comprehensively.

6. Data Extraction Limitations:

While conducting data extraction for the review article "Brahma Kumaris Raja Yoga Meditation in Modern Times: Addressing the Current Issues and Applications," certain limitations were encountered. These limitations include:
1. Language Bias: The data extraction process focused primarily on articles written in English. As a result, valuable insights and research published in other languages may have been missed, leading to a potential language bias in the analysis.
2. Publication Bias: The inclusion criteria were designed to select research articles, review articles, and meta-analyses published between 2010 and 2023. This timeframe and selection criteria may introduce a publication bias, as relevant studies published before 2010 or after 2023, or those published in different formats, such as books or conference proceedings, may have been excluded.
3. Search Terms and Databases: Although a comprehensive search was conducted using various databases such as Scopus, PubMed, Google Scholar, and PsycINFO, the effectiveness of the search terms used and the databases selected may have influenced the breadth and depth of the extracted data. Some relevant articles or sources may have been inadvertently excluded due to the limitations of the search strategy.
4. Accessibility of Sources: The data extraction process relied on the availability and accessibility of the selected articles and sources. Restricted access to certain publications or the limited availability of full-text articles may have impacted the inclusiveness of the extracted data.
Despite these limitations, the data extraction process aimed to capture a broad range of relevant articles and sources to address the current issues and applications of Brahma Kumaris Raja Yoga meditation, its emerging trends, future perspectives, and its mental and physical health benefits within the defined parameters and available resources.

7. Results:

Details of the inclusion and exclusion criteria for the study are depicted in the following flow chart.

Fig-2: Flow Chart of Articles selection asper PRISMA

The review article followed a systematic approach to conducting the review process. The search and selection process, adhering to the PRISMA guidelines, involved multiple steps. Initially, a thorough search was conducted using electronic databases, manual searching, and other sources, resulting in 80 potentially relevant studies. Through the screening stage, 56 studies were excluded based on a review of titles and abstracts. The full-text screening stage further assessed 24 studies in more detail, leading to the exclusion of 8 studies. In the eligibility stage, a final assessment of the remaining studies was performed, resulting in 16 studies meeting the inclusion criteria for the review. The subsequent stage involved data extraction and synthesis, where relevant data from the included studies were extracted and findings synthesized to conclude. Finally, the results presentation, summary of findings, discussion, and conclusion stages were carried out to ensure a clear and transparent reporting method for the systematic review.

II. HISTORICAL AND PHILOSOPHICAL BACKGROUND

The discussion in this section was conducted using the following two primary headings:

A) The origins of Brahma Kumaris and Raja Yoga meditation

Brahma Kumaris is a spiritual organization that was established in Hyderabad, Sindh (present-day Pakistan), in 1936 by Dada Lekhraj Kripalani, also known as Brahma Baba. The organization’s headquarters are located in Mount Abu, Rajasthan, India. The name "Brahma Kumaris" signifies "daughters of Brahma" and highlights the organization’s emphasis on women's empowerment.

© 2023 JETIR June 2023, Volume 10, Issue 6 www.jetir.org (ISSN-2349-5162)

Raja Yoga meditation holds a significant place in the teachings and practices of Brahma Kumaris. Its origins can be traced back to ancient India, where it was one of the six orthodox schools of Hindu philosophy. "Raja Yoga" translates to "royal union" in Sanskrit, signifying the union of the individual self (Jivatma) with the divine self (Paramatma).

Brahma Baba was inspired to introduce Raja Yoga meditation through the Brahma Kumaris organization as a means of personal transformation and spiritual growth. The practice involves focusing the mind on the self and ultimately on the divine to attain a state of inner peace, clarity, and understanding.

According to Brahma Kumaris' teachings, Raja Yoga meditation assists individuals in overcoming negative thought patterns and emotions, nurturing virtues such as love, peace, and compassion, and developing a profound sense of self-awareness and connection with the divine. It is considered a tool for personal and collective transformation, contributing to the betterment of the world.

Over time, Brahma Kumaris and Raja Yoga meditation have expanded into a global movement, with centers and practitioners in over 142 countries. The organization has broadened its scope beyond personal spiritual growth to encompass initiatives related to environmental sustainability, women's empowerment, and interfaith dialogue.

In summary, the roots of Brahma Kumaris and Raja Yoga meditation can be traced back to India's ancient spiritual traditions and were brought to the modern world by Brahma Baba in the 1930s. Presently, the practice is recognized worldwide as a means for personal and collective transformation and continues to evolve to address contemporary issues and applications.

B) Key philosophical principles and teachings of Raja Yoga meditation

The three primary captions below were used to describe this heading.

1) The principles of Raja Yoga can be summarized as follows:

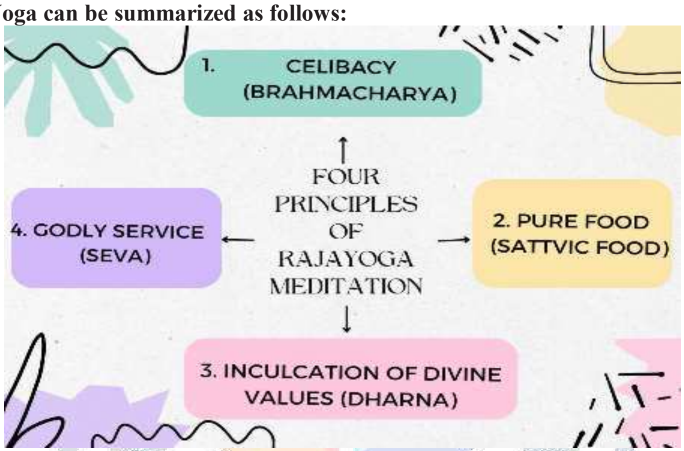


Fig-3: The Core Principles of Rajayoga Meditation

1. Celibacy (Brahmacharya): Celibacy in Raja Yoga refers to abstaining from sexual activity. It is believed that redirecting sexual energy towards spiritual growth and self-realization is beneficial. Celibacy involves more than physical abstinence; it also entails maintaining purity in thoughts, words, and actions.
2. Pure food (Sattvic diet): Raja Yoga emphasizes the importance of consuming a pure and sattvic diet. This diet consists of fresh, light, and easily digestible foods like including fruits, vegetables, grains, nuts, and dairy products prepared in the remembrance of Supreme Soul. The principle behind this is that our food choices affect our consciousness and our ability to concentrate and meditate.
3. Inculcation of divine values (Dharna): Dharna is the practice of cultivating virtues such as love, compassion, truthfulness, and non-violence. These virtues are considered innate qualities of the soul and are essential for spiritual growth. Developing a positive and virtuous mind-set aligned with spiritual principles is emphasized.
4. Company of God (Satsang): Satsang refers to associating with spiritually elevated individuals or seeking the company of truth. Being in the presence of such individuals is believed to positively influence one's consciousness and aid in spiritual progress. The importance of connecting with like-minded people on a spiritual path and learning from their experiences is emphasized.

In summary, the four principles of Raja Yoga—celibacy, pure food, inculcation of divine values, and the company of God (Satsang)—are intended to guide individuals towards a life of purity, virtue, and spiritual progress. These principles are considered essential for achieving self-realization and recognizing one's true nature as a spiritual being.

2) Raja Yoga meditation, as practiced by the Brahma Kumaris, revolves around four core subjects, which serve as the pillars of this spiritual practice:

Fig-4: The Main Teachings of Brahma Kumaris Raja yoga Meditation

1. Knowledge (Gyan): Knowledge holds utmost importance as the foundational pillar of Raja Yoga meditation. The Brahma Kumaris emphasize the significance of acquiring spiritual knowledge and developing a profound understanding of one's true essence, the world, and the divine. This knowledge is believed to be vital for personal transformation and the expansion of one's spiritual journey.
2. Meditation (Yog): Meditation stands as the second pillar of Raja Yoga meditation. It involves the training of the mind to achieve focus and inner tranquilly. Through consistent meditation practice, individuals can gain mastery over their thoughts and emotions, fostering a deeper connection with their inner selves and the divine presence.
3. Conduct (Dharna): Conduct represents the third pillar that forms the essence of Raja Yoga meditation. It encompasses the way we interact with the world and the choices we make in our daily lives. Practitioners of Raja Yoga are encouraged to embody virtues such as love, peace, and compassion, allowing these qualities to permeate their actions. By doing so, they create a positive impact not only on their own lives but also on the world around them.
4. Godly Service (Seva): Godly service serves as the fourth pillar of Raja Yoga meditation. It involves selflessly giving back to the world through acts of kindness and service. Practitioners are inspired to utilize their unique skills and talents to contribute positively to society and extend their benevolence to others.

These four pillars collectively provide the solid foundation of Raja Yoga meditation. Practitioners strive to integrate these principles into their daily lives, paving the way for a more meaningful and fulfilling existence.

Please note that Raja Yoga meditation, as taught by the Brahma Kumaris, is primarily rooted in the pursuit of spiritual growth, self-realization, and the harmonious development of the self.

3) Raja Yoga meditation, taught by the Brahma Kumaris, is based on profound philosophical principles rooted in the ancient wisdom of India. These principles aim to guide individuals in their quest for spiritual realization and self-transformation. Let's explore a few of these principles:

a) Self-realization: At the core of Raja Yoga meditation is the aspiration to attain self-realization, understanding the true nature of oneself. According to this philosophy, the authentic self is a spiritual entity separate from the physical body and mind. Through meditation and other spiritual practices, individuals can directly connect with their true selves, unlocking inner peace, joy, and contentment.

b) Karma and reincarnation: Raja Yoga meditation emphasizes the idea that actions have consequences, shaping future lives. It teaches that the soul is immortal and undergoes a cycle of reincarnation for spiritual growth and enlightenment.

c) Non-violence and compassion: Raja Yoga meditation highlights the importance of non-violence and compassion towards all living beings, including animals and nature. Practitioners are encouraged to cultivate empathy and compassion, extending them to all forms of life.

d) Spiritual values: Raja Yoga meditation promotes spiritual values such as truthfulness, purity, self-discipline, and devotion. These values serve as a foundation for spiritual growth and self-transformation, fostered through regular meditation and other spiritual practices.

e) Meditation and self-reflection: Central to Raja Yoga meditation is the practice of meditation and self-reflection, considered vital for spiritual evolution and self-realization. Through consistent engagement in meditation and introspection, individuals can develop a heightened awareness of their true selves, transcending the limitations of the ego and the mind.

f) Raja Yoga meditation weaves together these philosophical principles and teachings to facilitate spiritual realization and self-transformation. By nurturing spiritual values, embracing meditation and self-reflection, and embodying compassion for all beings, practitioners embark on a profound journey towards inner peace, happiness, and fulfilment.

Please note that Raja Yoga meditation, as taught by the Brahma Kumaris, is deeply focused on spiritual growth, self-discovery, and the harmonious development of the self.

III. CURRENT ISSUES IN RAJA YOGA MEDITATION

Two main sub headings were used to cover this topic, and they are listed below:

A) Challenges faced by practitioners in the modern world

In the modern world, practitioners of Raja Yoga meditation encounter unique challenges that require a fresh perspective on the practice. These challenges stem from the demands of work and family, as well as the influence of technology and social media.

Finding time for regular meditation practice is a primary challenge faced by practitioners today. With busy schedules and numerous commitments, setting aside dedicated time for meditation can be daunting. Moreover, the fast-paced nature of modern life makes it difficult to achieve the necessary focus and presence of the mind during meditation, hindering the attainment of inner peace and concentration.

The pervasive presence of technology and social media also presents a challenge. Constant connectivity to devices and the constant influx of information can hinder individuals from disconnecting and being fully present at the moment. This constant stimulation makes it hard to quiet the mind and engage in the practice of Raja Yoga meditation effectively. Additionally, the content consumed on these platforms can negatively impact mental and emotional well-being, further hindering inner peace and harmony.

Maintaining a healthy lifestyle can also prove challenging for practitioners. The principles of celibacy and pure food advocated in Brahma Kumaris Raja Yoga may clash with the availability of unhealthy food options and the prevalence of sexual imagery in the media.

Lastly, finding a supportive community of fellow practitioners can be a challenge in the modern world. The company of like-minded individuals, known as Satsang, plays a crucial role in maintaining motivation and connection to the principles and teachings of Raja Yoga. However, amidst the fast-paced nature of life today, finding the time and space for such connections can be difficult.

In summary, practitioners of Raja Yoga meditation face numerous and complex challenges in the modern world. Nonetheless, by acknowledging and addressing these challenges, practitioners can continue to derive the physical, mental, and spiritual benefits that this ancient practice offers.

B) Criticisms and controversies surrounding Brahma Kumaris and Raja Yoga meditation

Brahma Kumaris and Raja Yoga meditation have faced criticism and controversy over the years, giving rise to various concerns. Here are some of the main criticisms and controversies:

1. Cult Accusations: One of the main criticisms is that Brahma Kumaris is considered a cult. Critics claim that the organization exerts excessive control over its members and that they are manipulated to follow its teachings. Former members have accused the organization of using mind-control techniques. However, Brahma Kumaris denies these allegations, asserting that it is a spiritual movement focused on self-transformation and personal growth.
2. Misogyny: Another criticism is that Brahma Kumaris is viewed as a misogynistic organization that discriminates against women. Critics argue that its teachings promote patriarchal values and favor men. In response, the organization highlights that women hold leadership positions and promote gender equality.
3. Financial Exploitation: Some critics accuse the Brahma Kumaris of exploiting their members financially. They claim that the organization pressures members to donate money and lacks transparency in financial matters. The organization refutes these claims, emphasizing its non-profit nature and reliance on donations for its activities.
4. Medical Advice: Critics allege that Brahma Kumaris provides medical advice unsupported by scientific evidence. They argue that the organization promotes ineffective alternative therapies for treating illnesses. Brahma Kumaris maintains that it does not offer medical advice and encourages members to seek appropriate medical treatment.
5. Alleged Psychic Abilities: Critics accuse Brahma Kumaris of endorsing psychic abilities and clairvoyance without scientific basis. They argue that the organization promotes the belief that members can communicate with spirits, potentially endangering vulnerable individuals. Brahma Kumaris clarifies that it does not endorse psychic abilities, instead emphasizing spiritual growth and self-transformation.

In conclusion, while Brahma Kumaris and Raja Yoga meditation have faced criticism and controversy, the organization asserts its role as a spiritual movement promoting self-transformation and personal growth. It is important to acknowledge and address valid concerns and criticisms while recognizing the positive impact the organization has had on the lives of many individuals.

IV. APPLICATIONS OF RAJA YOGA MEDITATION

The three key captions below served as the discussion points for this section.

A) Health and well-being benefits of Raja yoga meditation

Raja Yoga meditation is a form of meditation that has been scientifically shown to offer numerous health benefits. Let's explore some of these benefits:

Fig-5: Health and well-being benefits of Raja yoga Meditation

1. Stress Reduction: Regular practice of Raja Yoga meditation can effectively reduce stress and anxiety levels. By engaging in this meditation technique, individuals experience a deep sense of relaxation and well-being.
2. Improved Mental Health: Raja Yoga meditation has proven to be beneficial in managing symptoms of depression, anxiety, and other mental health conditions. It contributes to an improved mood and overall mental well-being.
3. Better Sleep: Incorporating Raja Yoga meditation into one's routine can lead to better quality and quantity of sleep. This practice promotes relaxation, helping individuals achieve restful and rejuvenating sleep.
4. Increased Focus and Concentration: Raja Yoga meditation enhances focus, concentration, and cognitive function. Practitioners experience improved mental clarity, heightened attention, and enhanced memory.
5. Improved Immune Function: Engaging in Raja Yoga meditation has been found to enhance immune function. By reducing stress and inducing a state of relaxation, it supports a healthy immune system, leading to improved overall health and a reduced risk of illness.
6. Reduced Pain: Raja Yoga meditation has shown promise in reducing chronic pain. By alleviating stress and stimulating the body's natural pain-relieving hormones, it can provide relief for individuals suffering from persistent pain.
7. Increased Emotional Intelligence: Regular practice of Raja Yoga meditation can enhance emotional intelligence, enabling individuals to better understand and manage their emotions. This can lead to improved relationships and an overall sense of well-being.
8. Improved Self-awareness: Raja Yoga meditation facilitates self-awareness, allowing individuals to gain a deeper understanding of their thoughts, feelings, and behaviors. This self-awareness fosters personal growth and development.

In summary, Raja Yoga meditation offers a wide range of health and well-being benefits, including stress reduction, improved mental health, better sleep, increased focus and concentration, enhanced immune function, pain reduction, increased emotional intelligence, and improved self-awareness. By incorporating this simple and accessible practice into daily life, individuals can experience improved quality of life and overall well-being.

B) Use of Raja Yoga meditation in stress reduction and relaxation

1. Raja Yoga meditation has proven to be an effective method for reducing stress and promoting relaxation in individuals. Stress is a prevalent issue that can impact both physical and mental well-being, but the practice of Raja Yoga meditation offers a valuable approach to alleviating its effects.
2. Raja Yoga meditation involves directing the mind's attention to a single focal point, such as a mantra or visualization. By doing so, practitioners can quiet their thoughts and attain a state of deep relaxation. This state of relaxation has significant health benefits, including stress reduction.
3. Scientific studies have demonstrated that regular practice of Raja Yoga meditation can lead to a decrease in cortisol levels, a hormone associated with stress. By reducing cortisol, Raja Yoga meditation enables individuals to experience a greater sense of calmness and tranquilly, even in demanding circumstances.
4. Moreover, Raja Yoga meditation encompasses other advantages for overall health. It has been found to lower blood pressure and diminish the risk of heart disease. Additionally, this practice enhances immune system functioning, bolstering the body's ability to ward off infections and illnesses.
5. Raja Yoga meditation serves as a complementary therapy for various health conditions. It has exhibited efficacy in alleviating symptoms of anxiety, depression, and insomnia. Furthermore, it can be utilized in managing chronic pain, including headaches and back pain.
6. To summarize, Raja Yoga meditation is a powerful technique for stress reduction and relaxation. By quieting the mind and focusing on a chosen object or concept, practitioners can achieve a profound state of relaxation that yields numerous health benefits. With regular practice, Raja Yoga meditation empowers individuals to cultivate a sense

C) Applications in personal and professional Growth

1) Personal Growth: Raja Yoga Meditation, specifically the Brahma Kumaris approach, holds significant applications in personal development, encompassing various aspects of an individual's life. Here, I will outline six specific applications of Brahma Kumaris Raja Yoga Meditation to personal growth:

Fig-6: Application of Raja yoga Meditation in Personal development

1. Improved mental focus and clarity: Raja Yoga Meditation necessitates releasing distracting thoughts and embracing silence, leading to a clearer mind and enhanced focus. This sharpened mental clarity can greatly benefit personal development.
2. Greater sense of peace and calmness: Consistent practice of Raja Yoga Meditation cultivates a profound sense of peace and calmness within individuals. This inner tranquilly serves as a valuable resource for managing daily stress and anxiety.
3. Increased self-awareness and introspection: Raja Yoga Meditation emphasizes self-mastery and self-sovereignty, prompting individuals to develop a deeper understanding of themselves. This heightened self-awareness and introspection facilitate personal growth and development.
4. Greater sense of purpose and meaning: Raja Yoga Meditation encourages the study of spiritual knowledge, enabling individuals to discover a greater sense of purpose and meaning in life. This newfound clarity of purpose aids personal development.
5. Improved emotional stability: Regular engagement in Raja Yoga Meditation contributes to improved emotional stability and enhanced control over one's emotions. This emotional stability proves beneficial in personal relationships and social interactions.
6. Promotes self-mastery and self-sovereignty: The ultimate objective of Raja Yoga Meditation is to attain self-mastery and self-sovereignty. This pursuit empowers individuals to achieve their personal goals and aspirations.

Incorporating Brahma Kumaris Raja Yoga Meditation into personal development endeavors can lead to enhanced mental focus, a greater sense of peace, heightened self-awareness, emotional stability, a deeper sense of purpose, and the realization of personal potential. By integrating these applications into one's life, individuals can embark on a transformative journey of self-discovery and growth.

2) Professional Growth: Raja Yoga Meditation holds immense potential in the realm of professional development, offering a wide range of applications that can significantly enhance various aspects of one's professional life. Here, I will explore seven key applications of Raja Yoga Meditation in the context of professional growth:

Fig-7: Application of Raja yoga Meditation in Professional growth

1. Personal Effectiveness: Through the practice of Raja Yoga Meditation, professionals can cultivate a positive attitude, improve concentration, and enhance their ability to focus. This leads to better decision-making and the capacity to respond effectively to challenging situations.
2. Improved Communication Skills: Raja Yoga Meditation teaches practitioners the art of deep listening and responding with calmness, enabling them to develop clear, concise, and accurate communication skills.

3. Leadership Qualities: By engaging in Raja Yoga meditation, individuals can nurture leadership qualities within themselves. With a calm and centered mind, they can make informed decisions and inspire their teams to achieve shared objectives.
4. Work-Life Balance: Raja Yoga Meditation serves as a powerful tool to reduce stress, anxiety, and tension. This allows professionals to detach from work-related pressures and maintain a healthy work-life balance, focusing on their personal lives with renewed energy and mindfulness.
5. Increased Creativity: Raja Yoga Meditation promotes a state of calm and focused awareness, fostering heightened creativity and innovation in professional settings. It opens the doorway to fresh ideas and approaches.
6. Improved Relationships: Through Raja Yoga Meditation, individuals develop greater empathy, compassion, and understanding towards others. This cultivates stronger and more harmonious relationships in both personal and professional domains.
7. Greater Sense of Purpose: Raja Yoga Meditation facilitates the development of a profound sense of purpose in life. By aligning personal and professional goals with their inner values, professionals can pursue their ambitions with clarity and dedication.

Furthermore, Raja Yoga Meditation enhances professionals' problem-solving abilities, decision-making skills, and overall well-being, contributing to a fulfilling and successful professional life. By nurturing self-awareness, emotional stability, and positive thinking patterns, individuals can not only excel in their careers but also lead satisfying and balanced life.

In summary, Raja Yoga Meditation offers powerful applications for professional development. By incorporating this practice into their lives, professionals can unlock their full potential, achieve success, and maintain physical, emotional, and mental well-being.

V. RESEARCH ON RAJA YOGA MEDITATION

Fig-8: Current Scientific research on Raja yoga Meditation

Under this heading, the following two significant subtopics were covered:

A) Overview of current scientific research on the effects of Raja Yoga meditation

Ongoing scientific research is actively exploring the effects of Raja Yoga meditation across various domains, shedding light on its potential benefits for mental health, physical health, and cognitive function. Several notable areas of ongoing research include:
1. Mental Health: Researchers are investigating the potential therapeutic benefits of Raja Yoga meditation for individuals with mental health conditions such as depression, anxiety, and post-traumatic stress disorder (PTSD). For example, a randomized controlled trial is currently underway to assess the effectiveness of Raja Yoga meditation in alleviating symptoms of depression and anxiety among cancer survivors.
2. Brain Function: Ongoing research aims to uncover the impact of Raja Yoga meditation on brain function and structure. Scientists employ techniques like functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) to observe changes in brain activity and connectivity resulting from Raja Yoga meditation practice.
3. Physical Health: Researchers are exploring the potential benefits of Raja Yoga meditation for various physical health conditions, including hypertension, chronic pain, and diabetes. A randomized controlled trial is presently examining the effects of Raja Yoga meditation on blood pressure levels in individuals with hypertension.
4. Workplace Productivity: Ongoing research investigates the potential advantages of Raja Yoga meditation in enhancing workplace productivity and performance. For instance, a randomized controlled trial is currently assessing the effects of Raja Yoga meditation on stress, burnout, and job satisfaction among healthcare workers.
5. Ageing: Researchers are exploring the potential benefits of Raja Yoga meditation for cognitive function and overall well-being in older adults. A randomized controlled trial is currently underway to examine the effects of Raja Yoga meditation on cognitive function and brain structure in healthy older individuals.

These ongoing scientific investigations are invaluable in providing deeper insights into the potential benefits of Raja Yoga meditation for mental and physical health, cognitive function, and overall well-being. As research progresses, we can expect to gain a more comprehensive understanding of the profound effects that Raja Yoga meditation may have on various aspects of human health and functioning.

B) Discussion of findings and implications for the future

1. Scientific research findings on Raja Yoga meditation indicate its positive impact on various aspects of health and well-being, encompassing stress reduction, cognitive enhancement, emotional regulation, and physical health improvement. These findings hold profound implications for the future, influencing both individuals and society at large.

2. At the individual level, practicing Raja Yoga meditation serves as a valuable tool for stress management and mental health enhancement, consequently leading to an elevated quality of life. The cognitive improvements attained through this practice translate into practical benefits in everyday life, such as heightened focus and productivity in professional and educational settings. Furthermore, the physical health advantages of Raja Yoga meditation contribute to reduced healthcare expenses and an enhanced quality of life in later stages.
3. On a broader scale, the widespread adoption of Raja Yoga meditation holds implications for public health and well-being. Mitigating stress and anxiety among individuals can result in diminished healthcare costs and amplified productivity within the workforce. Moreover, the cognitive advancements associated with Raja Yoga meditation have the potential to influence educational programs and workplace training initiatives, yielding far-reaching benefits.
4. Additionally, the potential of Raja Yoga meditation to foster neuroplasticity and enhance brain function holds promise for the treatment of diverse neurological and mental health conditions. While further research in this domain remains necessary, the potential benefits are highly encouraging.
5. In conclusion, scientific research findings underscore the significant advantages of Raja Yoga meditation for both individuals and society as a whole. Continued research endeavors are required to fully comprehend the underlying mechanisms fueling these effects and formulate effective strategies for promoting the widespread adoption of Raja Yoga meditation across various settings.

VI. CONCLUSION

This was discussed under the following two subheadings.

A) Summary of key points

The review article titled "Brahma Kumaris Raja Yoga Meditation in Modern Times: Addressing the Current Issues and Applications" presents a comprehensive exploration of the relevance and potential impact of Raja Yoga meditation in today's society. The key points discussed in the various pre-paragraphs can be summarized as follows:
1. Understanding Raja Yoga Meditation: The article introduces Raja Yoga meditation as a spiritual practice that promotes self-mastery and self-sovereignty through meditation and spiritual knowledge. It emphasizes the multifaceted benefits of this practice, including improved mental focus, emotional stability, self-awareness, and a greater sense of purpose.
2. Applications in Personal Development: The article highlights the applications of Raja Yoga meditation in personal development. It discusses how regular practice can improve mental focus and clarity, foster peace and calmness, enhance self-awareness and introspection, and promote emotional stability and a greater sense of purpose. It emphasizes the potential for self-mastery and self-sovereignty, leading to personal growth and the achievement of goals.
3. Applications in Professional Development: The article explores the applications of Raja Yoga meditation in the realm of professional development. It highlights how this practice can enhance personal effectiveness, communication skills, leadership qualities, work-life balance, creativity, and relationships. It emphasizes the potential for improved well-being, productivity, and satisfaction in professional endeavors.
4. Scientific Research on Raja Yoga Meditation: The article acknowledges ongoing scientific research on the effects of Raja Yoga meditation. It highlights studies examining its impact on mental health, brain function, physical health, workplace productivity, and ageing. It suggests that the findings indicate positive effects, including stress reduction, improved cognitive function, and enhanced overall well-being.
5. Reflection on the Future and Potential Impact: The article prompts reflection on the future of Raja Yoga meditation and its potential impact on society. It suggests that the practice holds growing relevance in addressing modern challenges and has the potential to shape individual lives, enhance social interactions, promote collective well-being, and integrate science and spirituality. It envisions a future where Raja Yoga meditation plays a central role in individual and societal well-being.
In conclusion, the review article engenders within us a tantalizing vision—a vista wherein Raja Yoga meditation occupies a seminal role in both individual and societal well-being. Embracing this transformative practice possesses the power to sculpt a world that reverberates with equilibrium, harmonious coexistence, and compassion—wherein individuals flourish and synergistically contribute to the collective welfare.

B) Reflection on the future of Raja Yoga meditation and its potential impact on society

The thought-provoking review article prompts deep reflection on the future trajectory of Raja Yoga meditation and its profound societal impact. As we embark on this introspective journey, a multitude of intriguing insights come to the fore:
1. Growing Relevance: In our fast-paced modern world plagued by stress, mental health challenges, and a sense of disconnection, Raja Yoga meditation assumes an increasingly vital role. Its ability to address these contemporary dilemmas positions it as an invaluable tool for individuals seeking solace, holistic well-being, and personal growth.
2. Transforming Lives: Raja Yoga meditation holds tantalizing potential to profoundly transform the lives of its practitioners. Through this practice, individuals can cultivate deep self-awareness, strengthen emotional resilience, and foster a profoundly positive mind-set. As more people embrace this transformation, it ripples through families, communities, and workplaces, catalyzing a cascade of positive change.
3. Enhancing Social Interactions: Rooted in empathy, compassion, and understanding, Raja Yoga meditation becomes a catalyst for enriched social interactions and the nurturing of harmonious relationships. By embodying these noble qualities, individuals become agents of positive change, contributing to a more compassionate and interconnected society.
4. Promoting Collective Well-Being: The prospects of Raja Yoga meditation hold tremendous promise for revolutionizing societal well-being. As individuals experience reduced stress, improved mental health, and enhanced emotional regulation, a collective shift occurs—a tapestry of greater social harmony, increased productivity, and an overall atmosphere of happiness.
5. Integrating Science and Spirituality: As scientific research increasingly validates the profound effects of Raja Yoga meditation, the fusion of science and spirituality becomes imperative. Collaborative efforts among researchers, practitioners, and institutions have the potential to delve into the underlying mechanisms, strengthen the evidence base, and promote wider acceptance of Raja Yoga meditation as an invaluable practice.
In conclusion, the review article highlights the wide-ranging applications and potential benefits of Raja Yoga meditation for personal and professional development. It acknowledges ongoing scientific research, contemplates future implications, and envisions a society where this practice contributes to a balanced, harmonious, and compassionate world.

VII. **Sources of support**: Nil

VIII. **Conflict of interest**: There are no conflicts of interest.

IX. REFERENCES:-

[1] Ramsay, T., Smith, W., and Manderson, L. (2012) Brahma Kumaris: Purity and the Globalisation of Faith in: Manderson, L.,Smith, W., and Tomlinson, M. (eds.) Flows of Faith, Springer, Dordrecht https://doi.org/10.1007/978-94-007-2932-2_4

[2] Olson, C. (2013), July 8 Understanding the Brahma Kumaris by Frank Whaling .The Journal of Hindu Studies, 6(2), 237–238, https://doi.org/10.1093/jhs/hit021

[3] Gupta, K., & Indu, 2022. Raj Yoga Meditation as a Pivotal Pillar of Holistic Health: A Mini Review International Journal of Creative Research Thoughts (IJCRT), 10 (5) Retrieved from https://www.ijcrt.org/papers/IJCRT220539.pdf

[4] Newcombe, Suzanne, and Steidinger, Silke 2021. Brahma Kumaris World Spiritual University (BKWSU) CenSAMM

[5] Baruah, D. (2013), Concept of Raja Yoga and Its Practical Utility, Social Science Researcher, 2.2, 39–55

[6] Shaha, R., & Gupta, S. (2018) Role of Raj yoga meditation as a psychotherapy for various physical and mental illnesses and well-being. Indian Journal of Positive Psychology, 9(01). https://doi.org/10.15614/ijpp.v9i01.11753

[7] Babu, M. G. R., Kadavigere, R., Koteshwara, P., Sathian, B., & Rai, K. S. 2020. Raj yoga meditation induces grey matter volume changes in regions that process reward and happiness. Scientific Reports, 10(1), 16177 PMID: 32999361. DOI: 10.1038/s41598-020-73221-x.

[8] Vieten C, Wahbeh H, Cahn BR, MacLean K, Estrada M, Mills P, et al. (2018) Future directions in meditation research: recommendations for expanding the field of contemplative science PLoS ONE 13(11): e0205740. https://doi.org/10.1371/journal.pone.0205740

[9] Singh, P., & Kumar, P. (2022). Meditation: A Correlational Study between Subjective Well-being and Quality of Sleep among Raj yoga Meditators. International Journal of Indian Psychology*, 10(4),* 206-212. DIP: 18.01.023.20221004, DOI: 10.2 521 5/1 00 4. 023

[10] Awasthi, B. (2012). Issues and Perspectives in Meditation Research: In Search of a Definition. *Frontiers in Psychology*, *3*. https://doi.org/10.3389/fpsyg.2012.00613

[11] Sahu, A., and Dubey, S.P. (2015), Rajyoga Meditation and Effects: A Comprehensive Review, International Journal of Engineering Development and Research, 3 (4), 1. Retrieved from https://www.ijedr.org/papers/IJEDR1504174.pdf

[12] Shah, R., Shah, P. P., Shah, B. B., & Makwana, V. 2015. Enhancement in the emotional intelligence level of students through practising Raj yoga meditation. IOSR Journal of Humanities and Social Science (IOSR-JHSS), 20(5), 44–53. DOI: 10.9790/0837-20524453

[13] Shaha, R., & Gupta, S. (2018), April 6. Role of Rajyoga meditation as a psychotherapy for various physical and mental illnesses and well-being. Indian Journal of Positive Psychology, *9*(01). https://doi.org/10.15614/ijpp.v9i01.11753

[14] M.G., R.B., S.E., S.Rai, K.S., 2013. Efficacy of Raja yoga Meditation on Positive Thinking: An Index for Self-Satisfaction and Happiness in Life, *J* Clin of Diagn Res. *7*(10), 2265–2267

[15] Anjali Singh, Dr. Suman Bala Sharma, Amandeep Kaur, et al., 2019. Effectiveness of "Raj Yoga Meditation" for holistic healing in addicted patients: A quasi-experimental study International Journal of Advanced Research and Review, 4(11), 28–36.

[16] Nawale, A. Y., K. S. L., Nath, S., & Muralidharan, S. 2022. A Systematic Review of the Effectiveness of Rajyoga Meditation on Chronic Tension-Type Headache Journal of Pharmaceutical Negative Results, 13(1), 1622–1628 doi:10.47750/pnr.2022.13.S01.193[17]Brahma Kumaris World Spiritual University, Retrieved from https://www.brahmakumaris.org

[17] Brahma Kumaris World Spiritual University, Retrieved from https://www.brahmakumaris.org

[18] Brahma Kumaris, retrieved from Brahmakumaris.com

[19] https://www.brahmakumaris.us/what-is-raja-yoga-meditation.html

[20] Raja yoga meditation Retrieved from https://bkarticles.home.blog/wisdom

[21] Brahma Kumaris Raja Yoga Meditation Retrieved from https://www.bkgoogle.org

[22] http://brahmakumarisresearch.org/meditation

[23] Brahma Kumaris news retrieved from https://bk.ooo/

© 2023 JETIR June 2023, Volume 10, Issue 6 www.jetir.org (ISSN-2349-5162)

X. AUTHOR BIOGRAPHY

Dr. Nagesh N.V. is a highly regarded senior professor and research supervisor who holds a prominent position at Manipur International University in Manipur, India, as well as CARE India. With a comprehensive background spanning both academia and industry, Dr. Nagesh has accumulated valuable experience. He has an impressive teaching tenure of over five years and previously served as the Senior Deputy Director at Karnataka Milk Federation Limited in Bangalore for 17 years. This combination of academic and industry experience has allowed him to develop a diverse skill set and profound knowledge in his field.

Dr. Nagesh holds a Ph.D. in commerce and management, which further enhances his credibility and expertise. Currently, he is actively involved in research supervision at JJTU in Rajasthan and serves as a project guide at Annamalai University in Tamil Nadu. His primary passion is advancing his field and nurturing the next generation of researchers. Dr. Nagesh is dedicated to providing guidance and support to aspiring researchers, empowering them to excel in their research endeavours.

Spiritual Applications Research Centre
(SpARC Wing), Brahma Kumaris,
Academy for Better World, Post Box. 66,
GyanSarovar, Mount Abu – 307501, Rajasthan, India.

Cell #: +91-9772844861, +91-7976610376,
email:sparcwing@bkivv.org, bksparc@gmail.com