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Monitoring the Neural Activity of the State of Mental Silence While Practicing *Sahaja* Yoga Meditation

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Abstract

Objective: To identify the neural correlates of the state of mental silence as experienced through *Sahaja* yoga meditation.
Design: Nineteen experienced meditators underwent functional magnetic resonance imaging during three short consecutive meditation periods, contrasted with a control relaxation condition.
Results: Relative to baseline, at the beginning of the meditation sessions there was a significant increase of activation in bilateral inferior frontal and temporal regions. Activation became progressively more reduced with deeper meditation stages and in the last meditation session it became localized to the right inferior frontal cortex/ right insula and right middle/superior temporal cortex. Furthermore, right inferior frontal activation was directly associated with the subjective depth of the mental silence experience.
Conclusions: Meditators appear to pass through an initial intense neural self-control process necessary to silence their mind. After this they experience relatively reduced brain activation concomitant with the deepening of the state of mental silence over right inferior frontal cortex, probably reflecting an effortless process of attentional contemplation associated with this state.

Introduction

MEDITATION IS AN UMBRELLA TERM that includes many different techniques likely to be mediated by different regions and patterns of brain activation.[1–4] The main objective, common to most meditation techniques, is to reduce the thinking process.[1–4] This reduction appears to be associated with personal growth, increased compassion, empathy, sociability, and benefits to physical and mental health.[1–5]

The state of mental silence (SMS)[6] experienced in *Sahaja* yoga meditation (SYM) is attainable in several different ways, all of which converge on the central principle that when the attention is focused on the fontanelle area on top of the head in the absolute present moment, rather than events of the past or future, thinking activity ceases and SMS is established, even though one is fully alert and in control of one's faculties. At first, this cessation of mental activity is short-lived, but with practice, it can be drawn out into a continuous enjoyable experience.[6]

SMS has been associated with benefits to physical and mental health in the normal population.[7–9] Furthermore, SYM has shown therapeutic benefits for several disorders, including depression,[10] anxiety,[8] asthma,[11] epilepsy,[12] attention-deficit/hyperactivity disorder,[13] and work stress.[8]

To our knowledge, SMS experienced in SYM has so far been investigated only through use of electroencephalography (EEG),[14,15] which showed increased theta and alpha activity over fronto-central brain regions. Frontal theta activity is associated with sustained attention,[16] while increased frontal alpha activity is thought to reflect a reduction in brain regions that mediate mental effort and external attention.[14]

However, EEG has poor spatial resolution. The purpose of this study was therefore to use the better-resolved technique of functional magnetic resonance imaging (fMRI) to more thoroughly investigate the precise neurofunctional correlates of SMS in a within-subject design with experts in SYM.

Materials and Methods

Participants

Participants were 19 right-handed healthy experts in SYM (11 women and 8 men), aged 29–68 years (mean age ± standard deviation, 46.6 ± 9.5 years), with no physical or mental illness. Volunteers had 3–24 years' experience in

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SYM (mean, 11.8 ± 7.4 years), and the average time spent per meditation was 43.2 ± 21.2 minutes, with 13.6 ± 2.0 sessions per week (approximately two meditations per day).

All participants consented to voluntarily participate. The Ethics Committee of the University of La Laguna approved this study.

Task

The paradigm consisted of four registered conditions. In the control condition (2 minutes) meditators, with their eyes closed, focused their attention on breathing and belly-breathing movements, being relaxed, and not worrying about thoughts. Conditions 2–4 were consecutive meditation conditions.

For the meditation in the MRI scanner, practitioners were instructed to practice SYM in the same way as they do regularly at home. This involves mainly focusing the attention on the fontanelle area on top of the head while trying to be in the present moment, inhibiting thoughts with the goal of achieving SMS.

Before each registered condition, participants opened their eyes to watch a 20-second fixation cross before the control condition and, for the next three stages, the image of the founder of SYM for 20 seconds before each meditation condition. During these 20-second nonregistered events, participants were instructed about the following condition via the microphone.

Other meditation techniques, such as mindfulness meditation, that do not pursue mental silence focus the attention on breathing.[17] Therefore, this control condition was purposely chosen to differentiate SMS in SYM from these other techniques that would be equivalent to our control condition.

To facilitate the meditative process, this study sought to emulate the volunteers' meditation at home by using two strategies: (1) As in Beauregard and Paquette's study,[18] there was no alternation between meditation and control blocks, and the control condition was presented only at the beginning of the paradigm to avoid the deterioration or disruption of the meditation/SMS by intercalated control blocks. (2) Indian classical music was played during the meditation conditions because it facilitates the interoceptive attention needed in meditation[19,20] and it helps prevent distraction by the scanner noise. To prevent volunteers from entering into SMS during the control conditions, no music was played in that condition.

Data acquisition and analysis

Functional images of the whole brain were obtained on a 3T MRI scanner, using an echo-planar imaging gradient-echo sequence and an 8-channel head coil; imaging variables were as follows: repetition time/echo time/flip angle of 2000 ms/21 ms/90^o, matrix size of 64×64 pixels, 24 slices, 4×4-mm in-plane resolution, spacing between slices of 5 mm. Data were pre-processed and analyzed by using Statistical Parametric Mapping, SPM5 (Wellcome Trust Centre for Neuroimaging, London United Kingdom).

A general linear model was implemented for every participant (first level), and the results were computed as a group (second-level). Four regressors were created by modelling the blood oxygen level–dependent response to each stimulus condition. The conditions modelled in the design matrix were as follows: Control, Meditation 1, Meditation 2, and Meditation 3 (Control, Med1, Med2, Med3). The contrast of interest computed were as follows: Med1 > Control, Med2 > Control, Med3 > Control, and Med1,2,3 (average of all meditations) > Control. Group analysis was performed by using the random-effect approach with a one-sample t test. Analyses were thresholded at a level of $p < 0.001$, with cluster size larger than 50 voxels (voxel size, $2 \times 2 \times 2$ mm). Because the application of corrections for multiple comparisons in SPM has been criticized as being overly conservative, resulting in type II errors,[21] results are reported with $p < 0.001$, uncorrected.

An SPM random-effects group analysis was performed by entering individual first-level t contrasts for each of the four conditions into a within-subject one-way analysis of variance (ANOVA) ($p < 0.001$, uncorrected).

In addition, to test whether there were significant differences between the three meditation conditions for activated regions, repeated-measures ANOVAs were performed on the voxel numbers for each of the regions that were activated across all three meditation sessions.

After the experiment, meditators completed questionnaires on demographic information, their experience with SYM at home, and their subjective assessment of the quality of the three meditations inside the MRI scanner.

To directly correlate resulting brain activations with the depth of the SMS, a second-level SPM regression analysis was conducted using the individual results of the Med3 > Control contrast (where 95% of meditators reported the best SMS) as input images and the subjective depth of SMS at Meditation3 (reported in the questionnaire) as a covariate.

Results

On the questionnaire on the quality of the SMS in the scanner relative to their home experience, 7 of 19 meditators (37%) reported that the SMS reached inside the scanner was better than their average SMS at home, 2 (11%) reported it to be similar, and 10 (52%) reported it to be worse. When assessing the quality of the three meditations inside the scanner against each other, 95% (18 of 19 meditators) reported that they went deeper in their SMS, with the best SMS at Med3; only 1 participant (5%) reported deterioration in SMS at Meditation3.

The following clusters were significant for the three meditation conditions relative to the control condition (Table 1, Fig. 1): Med1: bilateral medial and inferior frontal cortex, right anterior cingulate cortex (ACC), right anterior insula, left inferior frontal cortex (IFC), and bilateral middle/superior temporal lobe (MTL/STL); Med2: bilateral IFC, right ACC, right anterior insula and bilateral MTL/STL; Med 3: right IFC (rIFC) reaching into anterior insula and right MTL/STL; Med1,2,3 (average): rIFC/middle frontal cortex reaching into ACC and anterior insula, left IFC, bilateral MTL/STL.

One way ANOVA with 4 conditions (Control, Med1, Med2, Med3) showed a significant effect of condition in 4 right-hemispheric clusters: three were located in rIFC (BA 45/46), reaching into medial frontal lobe including ACC and deep into the anterior insula. The most ventral cluster also reached into the head of the caudate and the most dorsal

Table 1. Brain Activations Registered During Meditation Conditions Relative to Control Conditions

Contrast and brain areas	*Brodmann areas (from high to low activations)*	*MNI coordinates: peak (x;y;z)*	*Volume (mm^3)*	*Cluster* p-*value*
Med1 > Control				
Left superior/middle/transverse temporal, insula	22, 41, 21, 42, 39, 40, 13, 6	−60; −26; 6	11,528	<0.001
Right superior/middle temporal	22, 21, 39, 41, 40, 42	66; −36; 6	7824	<0.001
Right superior/middle inferior frontal, ACC	9, 10, 32, 46	22; 50; 6	5920	0.002
Left middle/inferior frontal	6, 47, 46	−42; 32; 2	2632	0.031
Med2 > Control				
Right middle/inferior frontal, ACC, insula	9, 45, 46, 44, 24, 13, 32, 10	32; 30; 34	10,144	<0.001
Left superior temporal	22, 21, 40	−48; −50; 8	4632	0.013
Right middle/superior temporal	21, 22, 38	64; −22; −6	3376	0.049
Left inferior frontal	45, 47, 44	−48; 14; 6	608	0.542
Med3 > Control				
Right middle/superior temporal	21, 22	62; −14; −12	2032	0.084
Right insula, inferior frontal	13, 45	32; 32; 8	1632	0.137
Med123 > Control				
Right middle/inferior frontal, ACC, insula	9, 45, 46, 13, 32, 44, 10	30; 32; 8	12,680	<0.001
Left superior/middle temporal, posterior insula	39, 22, 21, 13, 40, 37	−62; −52; 16	12,504	<0.001
Right middle/superior temporal	21, 22, 40,39	64; −44; −2	8312	<0.001
Left insula, inferior frontal	13, 45, 47, 22	−42; 30; 4	5608	0.002

No area decreased activation in meditations relative to the control conditions.

MNI, Montreal Neurologic Institute; Med1, meditation condition 1; Med2, meditation condition 2; Med3, meditation condition 3; Med123, average of all meditations; ACC, anterior cingulate.

cluster reached into precentral gyrus (BA 9/6); the forth cluster was in MTL/STL(BA 21/22).

Repeated-measures ANOVAs on the voxel numbers for each of the regions that were activated across all three meditation sessions showed a significant effect for meditation condition for each region (F [df = 2,74] = 8.03; $p < 0.001$). Post hoc analyses showed that this was due to increased voxel numbers in each region for Med1 relative to Med2 and Med3, which also differed between each other (Med2 > Med3).

The second-level SPM regression analysis using the individual results of the Med3 > Control contrast as input images and the subjective depth of SMS reported by each meditator at Med3 as a covariate showed that the two clusters observed at Med3 > Control were altered when compared with the second-level non-covaried results of Med3 > Control (Table 1): The rIFC/insula activation cluster increased in volume by 57.4% and the cluster p-value decreased by 54.8%, while the right MTL/STL activation cluster was reduced in volume by 24.1% and the p-value increased by 29.1%.

This suggests that when meditators who reported deeper SMS have more weight in the second-level analysis, the rIFC/insula cluster becomes reinforced in volume and significance

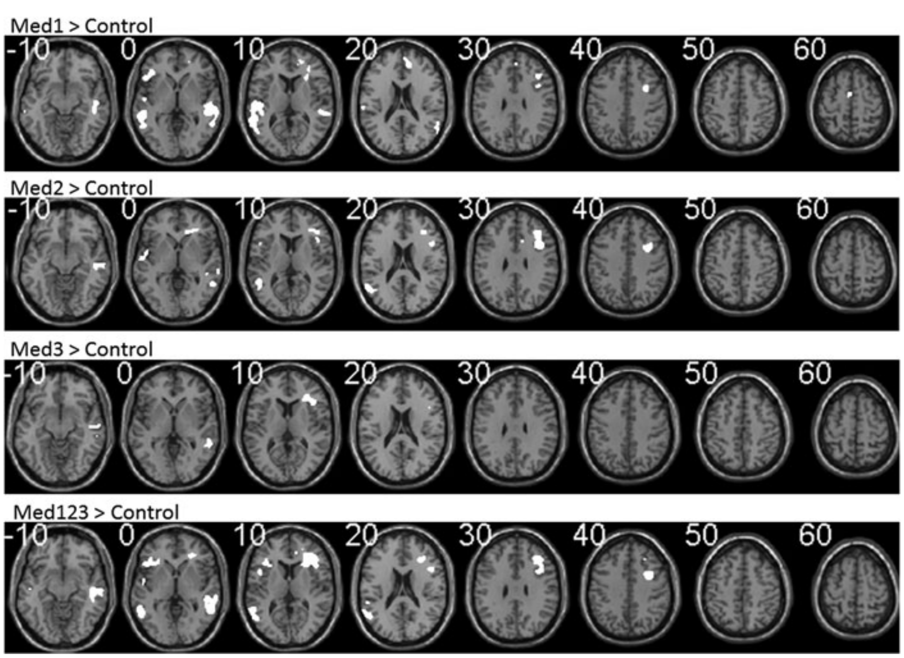

FIG. 1. Horizontal magnetic resonance imaging slices showing brain activations for main contrasts. Med1, meditation condition 1; Med2, meditation condition 2; Med3, meditation condition 3; Med123, average of three meditation conditions.

while the right MTL/STL activation weakens in total volume and p-value. This finding indicates that rIFC, but not STL activation, is directly associated with the depth of SMS.

No activation was observed for Control > Meditation conditions.

Discussion

During SMS, relative to the control condition of focusing on breathing, experts in SYM showed significantly increased activation in bilateral but predominantly right hemispheric clusters of rIFC/insula, ACC, and MTL/STL. Furthermore, the extent of activation relative to the control condition appeared to diminish progressively with later, deeper meditation stages so that activation in the third meditation stage remained only over rIFC/insula and right MTL/STL, suggesting a more restricted, presumably more focused activation. Furthermore, the depth of SMS was directly associated with the rIFC/insula activation, suggesting that this area is mediating the state of SMS.

Right IFC activation during meditation, which was associated with the subjective depth of SMS, probably reflects the inhibitory self-control process needed to reach and sustain SMS: First, sustained attention, which is mediated by right ventral frontal attention networks together with superior temporal and inferior parietal cortices,[17,22,23] is necessary to focalize and keep the attention on the present moment. In addition, an inhibitory process, known to be mediated by rIFC and ACC[24] of rejecting unwanted or distracting thoughts, is necessary to achieve SMS.

The activation clusters in rIFC in Med3 were significantly reduced and only about 7% of the total active volume of Med1, suggesting that SMS may be associated with an initial increase in effortful attention and cognitive control regions. However, these increases are then diminished at the later stages of the process of reaching SMS, similar to the findings of Brefczynski-Lewis et al.[17] This argument is coherent with the first-person subjective data[25] about the experience inside the scanner and the general praxis of SYM and SMS.

The predominance of activation over this rIFC region of attention and self-control may be an important characteristic of this form of meditation and SMS, which was also observed in the EEG experiments of SYM.[14,26]

The rIFC also reached into the anterior insula, which mediates interoceptive attention needed in SMS.[27] Interestingly, structural imaging studies have shown a slowing down in the normal age-related thinning process of rIFC and anterior insula in long-term practitioners of Buddhist meditation,[28] which may possibly be a long-term outcome of the here observed acute neuroplastic effects of meditation on this region.

The regression analysis reinforced the role of rIFC/insula as the key area mediating SMS because it was directly associated with the subjective depth of SMS.

During Med1, there was also bilateral superior and middle temporal activation, which became restricted to the right MTL/STL at Med3. Temporal lobe activation has been associated with the mystical experience of meditation.[18,29] An alternative explanation, however, could be the uncontrolled confound of auditory processing in the meditation session, where Indian classical music was played to facilitate the interoceptive attention needed in meditation and to prevent distractions caused by the scanner noise. Our additional regression analysis between Med3 > control and the subjective report of depth of SMS in fact showed that the right temporal cluster was statistically reduced in size and probability by more than 25%, suggesting that this activation may not have been associated with the mental silence per se but with the music confound.

Conclusion

This study of SYM compared with a control condition of breathing activity shows that meditators appear to pass through an initial intense self-control process necessary to silence their mind that activates bilateral frontal and temporal areas, after which they gradually experiment relatively reduced brain activation focused on the rIFC/ insula. Furthermore, this was directly associated with the subjective depth of SMS. Right IFC/insula activation therefore probably reflects an effortless process of attentional contemplation associated with SMS.

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Author Disclosure Statement

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