Original Article

Changes in functional magnetic resonance imaging with *Yogic* meditation: A pilot study

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Abstract

Background: The neural substrates of *Yogic* meditation are not well understood. Meditation is theorized to be a conscious mental process that induces a set of complex physiological changes within the areas of the brain termed as the "relaxation response." **Aims and objective:** Pilot data of a functional magnetic resonance imaging (fMRI) study is presented to observe and understand the selective activations of designated brain regions during meditation. **Material and methods:** Four trained healthy Patanjali Yoga practitioners in their mid-60s participated in this prototype interventional study. A three-part 1-min block design alternating between meditation (test) and relaxation (control) phase with an imaginary visual fixation and auditory stimulation was used. **Result and observation:** The fMRI images revealed strong activation in the right prefrontal regions during the visual and auditory fixation meditation phases compared to no activations during the relaxation phase. A comparison between the visual and auditory fixations revealed shifts within the prefrontal and temporal regions. In addition, activation in occipital and temporal regions was observed during the meditation phase. Occipital lobe activation was more apparent during visual meditation phase. **Conclusion:** It is concluded that specific fMRI brain activations are observed during different forms of *Yogic* meditation (visual and auditory phases). Occipital and prefrontal activation could be modulating the known neurophysiological and biological effects of meditation.

Keywords: Brain, magnetic resonance imaging, meditation, *Patanjali*, *Yoga*

Introduction

Meditation is a mental discipline by which one attempts to get beyond the reflexive, "thinking" mind into a deeper state of relaxation or awareness and consciousness. It is usually based on ancient beliefs that make up the component of Eastern religions and has been practiced for over 5000 years. Many religions have developed their own method and technique of meditation that allows their adherents to arrive at a higher state of consciousness. Hinduism is known to be the first religion to put emphasis on meditation during spiritual and religious practices. The principal form of meditation in Hinduism is *Yoga*. *Yogic* meditation, puts an emphasis on both the physical body and the mind. It serves to engage oneself in a specific attention set. Within *Yogic* meditation, there are multiple sections – *Raja Yoga*, *Jnana Yoga*, *Hatha*, *Sutra Shabda, Bhakti* and *Japa*. The latter two are significant to this research. *Bhakti Yoga* uses a form of meditation that requires one to focus on an object of love or devotion. *Japa Yoga* calls for the practice of meditation which requires repeating a *Mantra* aloud or silently. Given that the various forms of *Yogic* meditation serve to engage oneself in a specific attention set, meditative styles can be classified into two types of extremes – mindfulness and concentrative.[1] Mindfulness practices involve allowing any thoughts, feelings or sensations to arise while maintaining a specific attention stance: awareness of the phenomenal field as an attentive and nonattached observer without judgment or analysis. *Zen*, *Vipashyana* and the Western adaptation to mindfulness meditation are some of the examples.[2] Concentrative meditations techniques involve focusing on a specific mental or sensory activity, a repeated sound, an imagined image or specific body sensations such as the breath. Examples include *Bhakti Yoga, Japa Yoga* and the *Buddhist Samatha* meditation, which focuses on the sensation of breath. Even these two types used to elicit specific states differ across

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practices, they both produce trait changes in self-experience: eliciting shift toward expanded experience of self not centered on the individual's body schema and mental contents.[3-6] Since both types of styles can have similar results, many meditative techniques lie somewhere on a continuum between the poles of these two general methods.[5,7,8]

Functional magnetic resonance imaging (fMRI) is the imaging modality that measures brain activity by detecting changes associated with blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled. When an area of the brain is in use, blood flow to that region also increases. This results in a corresponding local reduction in deoxyhemoglobin because the increase in blood flow occurs without an increase of similar magnitude in oxygen extraction.[9-12] Since deoxyhemoglobin is paramagnetic, it alters the T2-weighted magnetic resonance image signal.[13-19] Thus, deoxyhemoglobin is sometimes referred to as an endogenous contrast enhancing agent and serves as the source of the signal for fMRI. Using an appropriate imaging sequence, human cortical functions can be observed without the use of exogenous contrast enhancing agents on a clinical strength scanner.[20-24] Functional activity of the brain determined from the magnetic resonance signal has confirmed known anatomically distinct processing areas in the visual cortex,[15,18,24-26] the motor cortex[27,28] and Broca's area of speech and language related activities.[29,30] Furthermore, a rapidly emerging body of literature documents relate corresponding findings between fMRI and conventional electrophysiological techniques to localize specific functions of the human brain.[31-36] Consequently, the number of medical and research centers with fMRI capabilities and investigational programs continues to escalate. Overall, fMRI studies of those participating in meditation are on the cutting edge of research and will hopefully demonstrate why and how meditation is able to affect the brain and what those changes mean from a functional standpoint.

Methods

Four trained healthy Patanjali *Yoga* practitioners in their mid-60s participated in this prototype interventional study. A three-part 1-min block design alternating between relaxation phase (control condition), meditation phase with visual fixation and meditation phase with auditory stimulation was used to acquire ten contiguous 8-mm thick axial brain sections in a 1.5 Tesla MRI scanner was taken. The data were analyzed using a standard statistical parametric mapping software. Images were generated depicting contrast among various combinations of the three *Yoga* meditations. To establish a control period, the test participants were in a relaxation phase during the first part of the study. During the second part, the test participants achieved auditory stimulation by meditation on the sound AUM (Omm). During the last part, the test participants focused on visual meditation using beautiful scenery. fMRI scans were obtained during each phase to identify brain activity.

Results

Functional MRI images revealed significant activation in the right prefrontal regions of the brain during the visual and auditory fixation meditation phases compared to simple relaxation phase in all the participants. A comparison of visual and auditory fixations revealed shifts within the prefrontal and temporal regions of the brain depending on the fixation mode. Several other regions such as occipital and temporal regions of the brain were also activated during the visual and auditory meditation phases. The occipital lobe showed more activity during the visual meditation state [Figure 1].

Discussion

Meditation has been linked to a healthy living style, but the realm of evidence for neurological benefits has not been fully explored. Several modalities such as electroencephalography (EEG) have been used in the past to study localized brain activities during meditation. Although the beneficial effects of mediation have long been studied and documented, the scientific evidence has been lacking. The beneficial effects of *Yogic* meditation can be proved with the aid of modern technology and state of the art imaging techniques. Therefore, many scientists have resorted to brain scans to determine the effects of meditation. With the advent of fMRI real-time data on the effects of meditation on various centers of the brain that are critical in maintaining disease-free relaxed state can be obtained. Functional MRI is now a mature methodology to examine neural correlates of brain function. A large number of fMRI studies have been conducted to identify brain regions affected by meditation. Although the results are not consistent from study to study, fMRI generally shows increases in dorsolateral prefrontal cortex (DLPFC),[37,38] the anterior cingulate cortex (ACC) and left prefrontal cortex.[39] The increase in DLPFC has been associated with greater regulation of emotions by meditators.[40] Furthermore, the activated regions have been shown to vary between long and short term meditators with enhanced activity greater in the highly trained meditators suggesting that changes are actually due to mental training.[41] The prefrontal cortex is responsible for controlling the decision-making processes and is one of the last structures to develop in the human brain.[42] The pons modulates the autonomic functions by controlling functions such as heart rate and breathing rate. The cerebellum is generally involved with balance, coordination, spatial processing and cognition. A recent study has shown not only an increased activation in the anterior cingulate gyrus and dorsolateral prefrontal cortex but also an associated deactivation in pons and cerebellum.[43] Another fMRI study of *Kundalini Yoga* entailing a *Mantra* combined with heightened breath awareness showed increases in the putamen, midbrain, pregenual ACC and the hippocampal–parahippocampal formation, as well as areas within the frontal and parietal cortices. Further, with increased meditation time, there were robust activity increase in these areas.[44] A recent study investigating the depth of mental silence in long-term meditators and volume of different

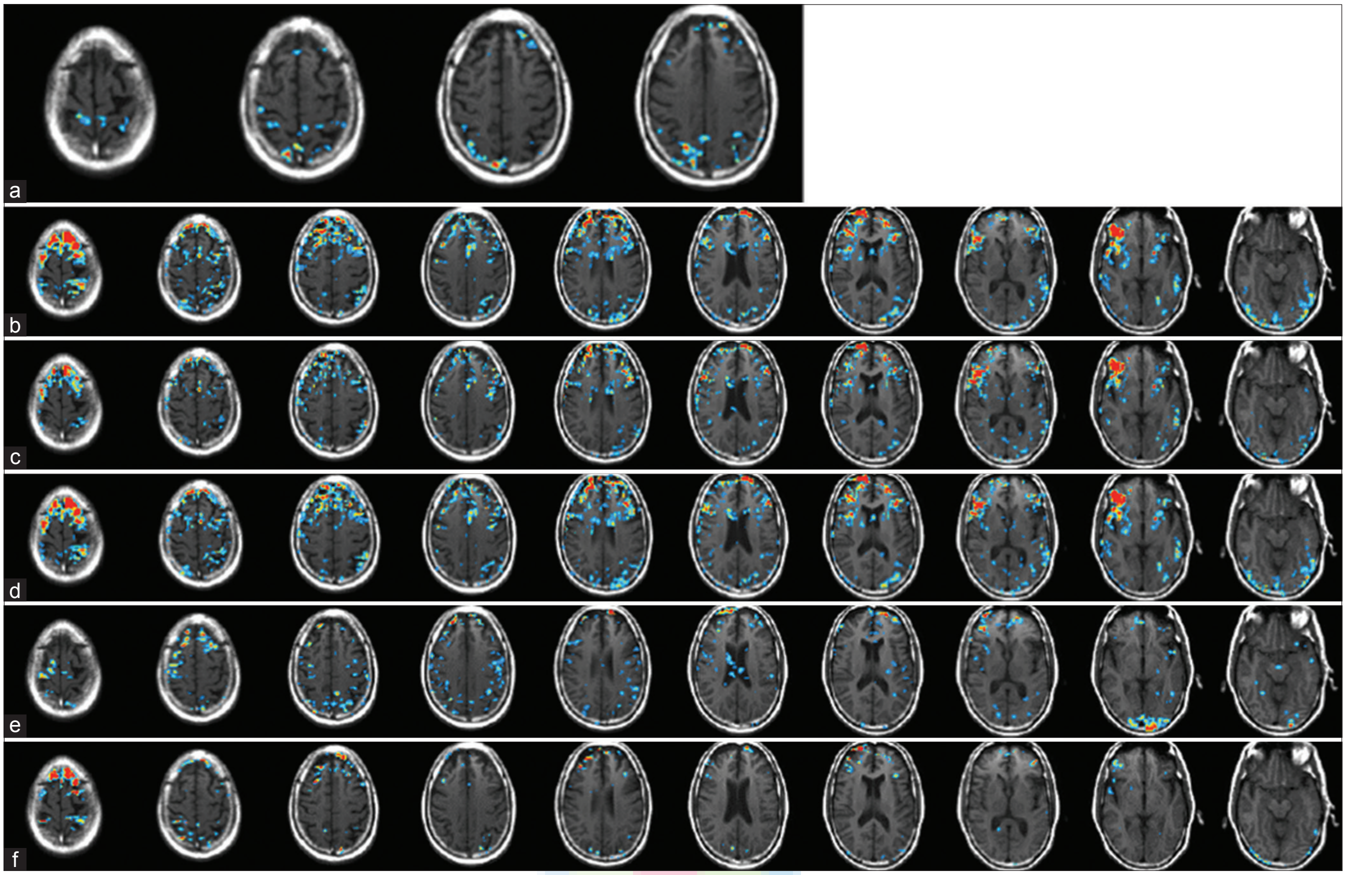

Figure 1: (a) Scan of relaxed state. (b) Scan of visual meditation state. (c) Scan of auditory meditation state. (d) Scan of average activity during the visual and auditory meditation states. (e) Scan of activity during the auditory meditation state which is not present during the visual meditation state. (f) Scan of activity during visual mediation state which is not present during the auditory meditation state

brain regions found positive correlation between gray matter volume in medial prefrontal cortex including rostral ACC and depth of mental silence. The depth mediation states were also associated with significantly increased functional capacity between medial prefrontal cortex and bilateral anterior insula/putamen. This is believed to play an important role in emotion regulation.[45] Hippocampus through its modulation of cortex is believed to play a pivotal role in intermediating the benefits of meditation.[46] Another important study analyzed hippocampal volumes in meditators and nonmeditators. This study indicated that the size of the left and right hippocampal volumes is larger in meditators than in controls, significantly so for the left hippocampus.[47] However, this particular study indicated greater activity in the right hemisphere of the brain versus the left during meditation. As a result, meditation might have different effects on the structure and activity of the brain. The study revealed significant activation in the right prefrontal regions of the brain during the visual and auditory-fixation meditation phases. The prefrontal cortex is a vital area of the brain that is associated with higher order brain functions such as concentration, decision-making and awareness. The selective activation of prefrontal cortex during meditation aids in stress free lifestyle. The decision-making capacity of the individuals improves dramatically and prevents wrongdoings. This in turn has a positive effect not only on the individual himself but also the society. Individuals are more focused in their tasks and able to concentrate better than their counterparts. The attention span improves intensely and they become more productive in day to day tasks. This creates a sense of awareness in the individual. They are able to plan their chores better and create a stress-free environment around them. This prefrontal cortex of the brain has also been implicated in modulating pain. With selective activation of prefrontal cortex, there is improved pain tolerance. Pain is currently one of the major factors that determine the quality of life of an individual. This not only affects the individual but also adversely affects the society. With meditation, one is able to modify the pain centers of the brain which conversely improves the quality of life. There is also seen a greater density of white matter and gray matter in areas of the brain responsible for processing and regulation of pain. Some studies have also reported positive correlation between the duration of *Yoga* and the volume of gray matter in the left insular cortex. Meditation is believed to reduce pain by increasing distraction capacity. The two main techniques that affect distraction capacity include focused attention and open monitoring. This study also demonstrated selective activation of temporal cortex and occipital cortex during various phases of meditation. This shows the level of coordination in the brain during meditation. It is a complex phenomenon involving various centers of the brain which are critical in maintaining relaxed state. These centers work in synchronization to maintain the emotional lability. The centers of stress that are activated as a result of pain are selectively reorganized with the help of meditation. This in turn results in boosting the emotional state of the mind and the body. This study tries to add to growing body of evidence regarding beneficial effects of *Yogic* meditation in boosting the emotional state of an individual.

Conclusion

A pilot study on four healthy meditators to observe the differences in brain activity during a relaxed state, an auditory mediation state and a visual meditation state was conducted. Functional MRI scans were performed during each phase and the results indicated an increase in the activity of the right prefrontal cortex during visual and auditory meditation states. In addition, an increase in the activity of the temporal and occipital regions was also observed during the meditation states. However, a larger study needs to be conducted for more conclusive results.

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Conflicts of interest

There are no conflicts of interest.

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