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fMRI during Transcendental Meditation practice

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ABSTRACT

This study used a within group design to investigate blood flow patterns (fMRI) in 16 long-term practitioners of Transcendental Meditation (mean practice: 34.3 years with each having over 36,000 h of meditation practice). During Transcendental Meditation practice, blood flow patterns were significantly higher in executive and attention areas (anterior cingulate and dorsolateral prefrontal cortices) and significantly lower in arousal areas (pons and cerebellum). This pattern supports the understanding that Transcendental Meditation practice requires minimal effort. During Transcendental Meditation, the attentional system was active (heightened blood flow in anterior cingulate and dorsolateral prefrontal cortices) in an automatic manner—decreased blood flow in the pons and cerebellum. This pattern of heightened blood flow in attentional areas and decreased blood flow in arousal areas has not been reported during other meditation practices. Future research should investigate blood flow patterns in different meditation practices in the same study.

1. Introduction

Meditation practices have been placed into three categories according to their EEG patterns, which reflect the procedures used in each practice (Travis & Shear, 2010). One category, *Focused Attention*, includes meditation practices that keep the attention focused on a specific experience and not allowing the mind to move. Meditation practices in this category may focus on the head or heart, on the breath, on a thought or on a feeling. These practices are associated with increase gamma EEG power and coherence (Claire Braboszcz, Cahn, Levy, Fernandez, & Delorme, 2017; Hauswald, Ubelacker, Leske, & Weisz, 2015; Lutz, Slagter, Dunne, & Davidson, 2008). A second category, *Open Monitoring*, includes meditation practices that involve dispassionate observation or nonreactive monitoring of changing breath, thoughts, feelings, or bodily sensations (Goleman, 1996; Kabat-Zinn, 1990). These practices are associated with increases in theta, alpha and beta bands (Ahani et al., 2013). A third category, *Automatic Self-Transcending*, includes meditations that transcend the steps of meditation practice—they begin with thinking and end with "Being" or wakefulness without customary mental and emotional content (Travis, 2014; Travis & Parim, 2017; Travis & Pearson, 2000). Meditation practices in this category are associated with alpha1 (8–10 Hz) EEG (Travis et al., 2010; Travis & Shear, 2010).

The procedures used in meditation procedures are also reflected in the pattern of activation of an intrinsic brain network, the default mode network. Activation in the default mode network is lower during goal-directed behaviors requiring executive control (Gusnard, Raichle, & Raichle, 2001; Raichle et al., 2001; Raichle & Snyder, 2007), and higher during daydreaming and mind wandering (Baird et al., 2012), during self-referential mental activity (Kelley et al., 2002; Vogeley et al., 2001) and during tasks involving self-projection (Kelley et al., 2002; Vogeley et al., 2001). Most meditation practices—Mindfulness Meditation, Focused Attention, Loving-Kindness, and Choiceless Awareness—lead to deactivation of the default mode network (Brewer et al., 2011; Simon & Engstrom, 2015). Deactivation of the default mode network during these meditation practices is consistent with the understanding that these meditations are goal-oriented practices that involve directing of attention or mental content. In contrast, default mode network activity is reported to remain high during a meditation that is in the Automatic Self-Transcending category, Transcendental Meditation (Travis et al., 2010; Travis & Parim, 2017). High activation of the default mode network during Transcendental Meditation practice suggests that this meditation involves minimal attentional control.

Transcendental Meditation involves easily thinking a mantra. The mantras used in Transcendental Meditation are not labels for objects or experiences—they are not words that describe feelings or experiences. Rather, the mantras used during Transcendental Meditation practice are simply sounds that facilitate transcending—take the attention from active thinking levels with distinct changing mental content to "finer" levels in which the sound of the mantra becomes secondary in

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experience and ultimately the mantra disappears and self-awareness is primary (Maharishi Mahesh Yogi, 1969; Travis & Pearson, 2000). The process of transcending during Transcendental Meditation is said to be and so transcending can happen with minimal control of attention (Travis & Parim, 2017).

Neural imaging studies have investigated meditations in the first two categories of meditation practices (Ivanovski & Malhi, 2007; Lou, Nowak, & Kjaer, 2005; Marchand, 2014; Pagnoni, Cekic, & Guo, 2008; Tang, Rothbart, & Posner, 2012). No research has reported neural imaging during Transcendental Meditation practice.

This study explored blood flow patterns in experienced Transcendental Meditation practitioners. Blood flow patterns (fMRI) during eyes-closed rest were compared to those during Transcendental Meditation practice.

2. Materials and method

2.1. Subjects

Sixteen women participated in the study. They were an average age of 60.2 ± 8.2 years, and had been practicing Transcendental Meditation for 34.3 ± 9.4 years, which translates to more than 36,000 h of meditation practice. None of the subjects were claustrophobic, or had metal in or on their bodies (dental fillings were allowed). Subjects with extensive years of TM practice were chosen because their long history of meditation might enable them to meditate successfully in the fMRI environment.

Participants were screened for psychopathology, and were free from head injuries or medications that would affect the neural imaging. All participants refrained from caffeine and/or cigarette use for at least two hours before the fMRI scan. Participants were interviewed after the fMRI recording to probe the impact of the recording on their meditation experience.

2.2. Procedure

The images were recorded at the *Applied fMRI Institute* in San Diego, CA. Subjects responded to posters in the Transcendental Meditation centers around San Diego. They came to an information meeting at the local Transcendental Meditation centers to find out more details about the study. After the meeting, they filled out demographic forms, consent forms and scheduled a time to have their fMRI recorded. The protocol and procedures met the ethical standards set by the Institutional Review Board, those of the American Psychological Association, and the Helsinki Declaration of 1975.

After the fMRI recording, the subjects were interviewed concerning their meditation experiences during the recording. This was to probe whether the scanner environment interfered with the meditation experience—namely, the subjects would meditate lying down with their head immobilized along with 100 dB noise.

2.3. Data acquisition

Data acquisition began with a 12 min structural, anatomical scan. Participants were instructed to close their eyes, relax and remain as still as possible during the anatomical scan. Then data were acquired during eyes closed resting peacefully (1 min), during counting the pulses in the scanner (1 min)—this is reported elsewhere, and during Transcendental Meditation practice (10 min uninterrupted).

Images were acquired on a 3 T Siemens Trio Scanner (Bandettini, Wong, Hinks, Tikofsky, & Hyde, 1992). A five-minute magnetization prepared, rapid-acquisition gradient echo image (MPRAGE) was acquired for anatomic overlays of functional data and spatial normalization (T1 MN1 Template). BOLD imaging used a 33-slice whole-brain, single-shot gradient echo (GE) echo-planar (EPI) sequence (TR/TE = 2000/25 ms, FOV = 240 mm, matrix = 64 × 64, slice thickness/gap = 4/0 mm). This sequence delivers a nominal voxel resolution of 3 × 3 × 3 mm.

2.4. Data analysis

Brain Voyager QX 2.1.2 was used for this study's preprocessing, analysis, and visualization of functional magnetic resonance imaging data. Prior to statistical processing, all data were normalized to Talairach coordinates (Talairach & Tournoux, 1988). Images were slice time-corrected, motion-corrected to the median image using sinc-interpolation, and were high-pass filtered (100 s). A group averaged VMR mask created within Brain Voyager was used to anatomically align all participants. Brain Voyager was used to group statistical parametric maps of voxel based morphometry during the two conditions. For each subject, contrasts comparing meditation to eyes closed was performed, producing statistical parametric maps of the t-statistic at each voxel using a threshold of $p < .05$ and cluster size > 20 voxels, to minimize the risk of false positive findings.

3. Results

The exit interview yielded valuable information for future studies. First, all 16 subjects reported “deep restfulness” during the meditation session in the fMRI environment. Eight of the 16 subjects experienced “bliss” (deep inner fulfillment and happiness) and “clear transcending” during the fMRI recording. Five reported that their meditation experience was “not as deep” as usual, but was “relaxing” and “effortless.” All TM participants reported that the noise of the scanner was a distraction at first, but not in the latter part of the meditation and as a whole was not a barrier to the meditation.

3.1. Comparison of neural activation

There were significant condition differences in activation levels. The meditation condition was distinguished by higher wide spread activation in bilateral anterior cingulate gyrus (BA 24 and 32) and bilateral dorsolateral prefrontal cortices (BA 46) and areas of deactivation in the pons and cerebellum. Fig. 1 below shows areas of significant activation (orange) and deactivation (blue) that met the threshold of $p < .05$ (corrected) and cluster size ≥20 voxels.

4. Discussion

Activation of the anterior cingulate gyrus and dorsolateral prefrontal cortex have been reported during other meditation practices (Manna et al., 2010; Grant, Courtemanche, & Rainville, 2011). These studies of other meditations, however, do not report decreases in the pons and cerebellum.

4.1. What might be the significance of deactivation in the pons and cerebellum?

The pons is the seat of autonomic motor neurons and so modulates overall arousal as well as governing breath rate and heart rate. A straightforward interpretation of lower blood flow in the pons is that fewer mental and physical resources are being recruited and used during Transcendental Meditation practice.

The cerebellum is generally understood as governing muscle tone, balance and coordination of motor movements. However, neuroimaging and clinical studies indicate that the cerebellum is also involved in modulating spatial, motor and executive processing, working memory, and social cognition (Andreasen & Pierson, 2008; Van Overwalle, Baetens, Mariën, & Vandekerckhove, 2014).

The cerebellum and prefrontal work together. The prefrontal cortex underlie executive control processes, the cerebellum modulates the speed, variability, and automaticity of information processing

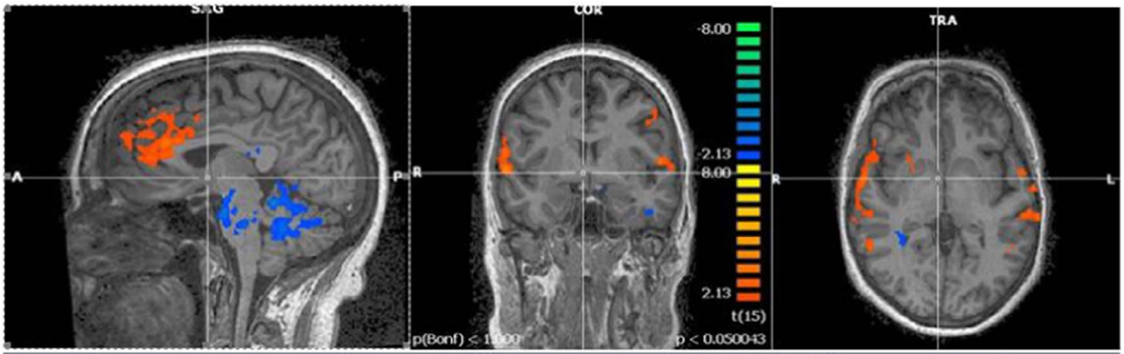

Fig. 1. Significant areas of activation during transcendental meditation practice compared to eyes-closed rest. Areas of activation (orange) included anterior cingulate gyrus and dorsolateral prefrontal cortex and areas of deactivation (blue) included the pons and cerebellum. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

operations (Hogan, 2004). The pre-frontal cortex and cerebellum are the last structures to develop (Allman, McLaughlin, & Hakeem, 1993). Age related declines are seen in both the pre-frontal cortex and cerebellum: grey and white matter density decline in frontal and cerebellar structures with age and grey and white matter densities are correlated with general intelligence in elderly subjects (Hogan et al., 2011). Thus, these two brain structures are linked developmentally and functionally.

Decreased pons and cerebellar activity could reflect reduced cognitive control and reduced executive processing overall during Transcendental Meditation practice. This conclusion from the current fMRI study, echoes the finding from a study reporting default mode network activation. DMN activation is reported to remain high during Transcendental Meditation practice, suggesting low cognitive and attentional control during this practice (Travis & Parim, 2017).

4.2. Can attention be focused without effort?

Cognitive control ranges from focused, conscious control of mental content to spontaneous, undirected mind wandering. Transcendental Meditation practice permits such undirected movement of the mind. This movement is not directed by the experiencer, or subject, but it is pulled by the inherent nature of the object of experience. In the case of transcending during Transcendental Meditation this is the experience of silent, expanded levels of awareness (Maharishi Mahesh Yogi, 1969; Travis & Parim, 2017).

Mind wandering has been investigated using iphone technology in 2250 people. Subjects were randomly texted throughout the day, and asked to answer a happiness-question, an activity-question and a mind wandering-question. Mind wandering with positive emotions was rated at the same level of positive emotional tone as the average of all other tasks, and mind wandering with neutral and negative emotions was rated progressively more negative. This led to the conclusion that a "wandering mind is an unhappy mind" (Killingsworth & Gilbert, 2010) (pg 932). However, follow up research reported that when the object of mind-wandering was rated as being highly interesting, it was associated with more positive emotional tone than when the person was simply on-task (Franklin et al., 2013).

When you are interested in a task, your attention naturally remains on the task for long periods of time. When the object of focus is more attractive, you don't need to exert effort for the mind to continue to experience it. The mind is drawn to it because of its inherent appeal. We have the common experience when someone mentions our name, we naturally turn our attention to that conversation. The shifting of attention from our current experience to hearing our name happened automatically. Continuing to listen to the new conversation also happened automatically—it was not a conscious decision. The attention is drawn by your interest in the conversation.

The shifting of the mind to more attractive experiences is the explanation for how the mind transcends during Transcendental Meditation practice (see Travis & Parim, 2017). When one learns Transcendental Meditation a trained teacher systematically leads you to the experience of inner silence, tranquility, peace, and transcendence. Once having had that experience, the attention readily takes that inward direction when one sits to meditate. The attention is guided by the inherent pleasure of inner transcendence, rather than through cognitive evaluation and control.

This could explain the blood flow patterns seen in this study. There was heightened blood flow in the anterior cingulate and dorsolateral prefrontal cortex. The brain was continuing to engage in a specific experience. However, this process required minimal control; the blood flow was lower in the pons and cerebellum.

5. Conclusion

The pattern of blood flow seen in these expert practitioners of Transcendental Meditation has not been reported during other meditation techniques. While higher frontal blood flow is often reported during meditation practices, these studies do not report reduced blood flow in the pons and cerebellum. Future comparison research is needed to compare neural imaging patterns during different meditation practices to more fully understand the nature of different meditation practices and how different practices lead to different effects in brain functioning.

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