International Journal of Psychophysiology 81 (2011) 198–202

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Comparison of coherence, amplitude, and eLORETA patterns during Transcendental Meditation and TM-Sidhi practice

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ARTICLE INFO

Article history:
Received 14 October 2010
Received in revised form 18 May 2011
Accepted 20 June 2011
Available online 2 July 2011

Keywords:
TM technique
TM-Sidhi program
Coherence
eLORETA
Word recognition
Meditation
Alpha
Frontal theta
Transcendental Meditation
Sanyama

ABSTRACT

This random-assignment study compared coherence, amplitude, and eLORETA patterns during practice of the Transcendental Meditation (TM) and the TM-Sidhi programs. The TM technique involves systematic transcending of contents of experience to a state of pure consciousness. The TM-Sidhi program involves *sanyama*—the simultaneous experience of *dhārānā* (fixity), *dhyāna* (transcending) and *samādhi* (pure consciousness). Thirty-two channel EEG was recorded from experienced TM subjects randomly assigned to two consecutive 10-min TM sessions or to a 10-min TM session followed by 10-min TM-Sidhi practice. Compared to TM practice, TM-Sidhi practice was characterized by higher frontal alpha1 and beta1 amplitudes, and eLORETA-identified sources of alpha1 EEG in right-hemisphere object recognition areas including the right parahippocampus gyrus, right fusiform gyrus, lingual gyrus, and inferior and medial temporal cortices. These cortical areas are involved in specific/holistic representation of words. The observed brain patterns support the descriptions of sanyama as including both specificity (sutras or verses), as suggested by higher frontal beta1 EEG amplitude and by eLORETA sources in right-hemisphere object-recognition areas, and holistic experience (pure consciousness) as suggested by higher frontal alpha1 EEG amplitude. These EEG patterns fit the complex description of sanyama.

1. Introduction

Research has described two features of consciousness: the *level* of consciousness (graded levels of being awake or asleep), and the *contents* of consciousness (inner thoughts, feelings, and perception of outer objects) (Koch and Tsuchiya, 2007; Tsuchiya and Adolphs, 2007). These two features of consciousness are intertwined during ordinary waking experiences. Consequently, most scientists beginning with William James concluded that consciousness cannot be experienced without an object (James, 1890/1951; Natsoulas, 1997). However, these two features of consciousness can be separated during meditation practices, allowing exploration of conscious contents and levels of consciousness.

Three meditation categories have been described that are distinguished by cognitive processes and EEG patterns (Travis and Shear, 2010). The first two categories, Focused Attention and Open Monitoring, include both *contents* of consciousness and *levels* of consciousness. In Focused Attention meditations, the *level* of consciousness is intertwined with *contents*—the object of sustained focus completely fills awareness. In Open Monitoring meditations, the *level* of consciousness begins to be separated (mindful) from changing *contents*, objects of experience such as body states, thoughts, feelings or breath. The third category, Automatic Self-Transcending, includes meditations designed to transcend the procedures of the meditation. These techniques minimize the *contents* of consciousness and so allow exploration of *levels* of consciousness devoid of content.

The Transcendental Meditation™ (TM™) technique is in the third category of meditations. TM practice is a process of transcending, which involves appreciating a mantra at "finer" levels in which the mantra becomes increasingly secondary in experience and ultimately disappears, while self-awareness becomes more primary (Maharishi Mahesh Yogi, 1969; Travis and Pearson, 2000). This state is described as "pure consciousness" in which consciousness is open to itself (Maharishi Mahesh Yogi, 1994). TM practice has been characterized by 1) EEG patterns—higher frontal and central alpha power (Banquet, 1973; Dillbeck and Bronson, 1981; Hebert et al., 2005; Travis and Wallace, 1999), and higher frontal alpha coherence (Dillbeck and Bronson, 1981; Gaylord et al., 1989; Levine, 1976; Travis and Arenander, 2006; Travis et al.; Travis et al., 2000); 2) physiological patterns—lower breath rate, lower skin conductance and lower plasma lactate (Dillbeck and Orme-Johnson, 1987); 3) MEG patterns—source localization of MEG activity in medial prefrontal and anterior cingulate cortices (Yamamoto et al., 2006); 4) eLORETA source localization—sources of alpha1 activity in midline frontal and parietal cortices that are part of the default mode network (Travis et al., 2010); and 5) patterns of cerebral metabolic rate in a pilot PET study—higher frontal and parietal activity and lower thalamic activity, compared to eyes-closed rest (Newberg et al., 2006).

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doi:10.1016/j.ijpsycho.2011.06.011

While TM practice has been extensively investigated, no studies have compared brain patterns during TM with those during the advanced TM program, the TM-Sidhi program. The TM technique involves transcending; in contrast, the TM-Sidhi program involves *sanyama*—the simultaneous processes of *dhārānā* (fixity), *dhyāna* (transcending) and *samādhi* (pure consciousness) (Maharishi Mahesh Yogi, 1978). (The TM-Sidhi program is described in more detail below in the procedure.) Since TM-Sidhi practice involves both changing objects of attention (*dhārānā*), transcending (*dhyāna*), and the experience of pure consciousness (*samādhi*) then, compared to TM practice, one might expect heightened alpha1 activity characteristic of Automatic Self-Transcending and heightened beta1 activity characteristic of active processing, during TM-Sidhi practice.

This random-assignment study compared EEG amplitude and coherence during Transcendental Meditation and TM-Sidhi practice in theta2 through gamma frequency bands. It also investigated eLORETA patterns during these two practices. eLORETA was developed at the KEY Institute for Brain-Mind Research at the University of Zurich (Pascual-Marqui et al., 1994) to compute the 3-D intracerebral distribution of sources of scalp-recorded electrical potentials (Pascual-Marqui, 2002). Two refinements of this method have been released: first, sLORETA (standardized Low Resolution Electromagnetic Tomography), which uses standardized current density to calculate intracerebral generators, and recently eLORETA (exact Low Resolution Electromagnetic Tomography), which does not require standardization for correct localization (Pascual-Marqui, 2002, 2007). Both sLORETA and eLORETA are argued to have low resolution but zero localization error even in the presence of measurement and biological noise (Pascual-Marqui, 2007). The current implementations of sLORETA and eLORETA use a realistic head model calculated by Fuchs et al. (2002), and electrode coordinates provided by Jurcak et al. (2007).

The hypothesis tested in this study was that compared to TM practice, TM-Sidhi practice would be characterized by higher levels of alpha1 and beta1 amplitude and coherence. No predictions were made about eLORETA sources, since only one paper has reported results from eLORETA during TM practice.

2. Material and methods

2.1. Subjects

Twenty-six subjects volunteered to participate in this study – 12 men and 14 women – average age 49.0 ± 14.5 years, who had been practicing the TM technique for 25.6 ± 11.6 years and the TM-Sidhi program for 19.4 ± 10.8 years. Subjects were randomly assigned to practice TM for two consecutive 10-min sessions (TM-Only Group), or to practice TM for 10 min followed by 10-min practice of the TM-Sidhi program (TM-Sidhi Group). We used a between-design, because TM-Sidhi practice always follows TM practice. Thus, it would not have been appropriate to use a within design with counterbalanced TM and TM-Sidhi sessions.

2.2. Procedure

Subjects came in individually for their EEG measurement in the early afternoon. Thirty-two EEG active-sensors were applied according to the 10/10 system using the BIOSEMI ActiveTwo amplifier and acquisition software (www.biosemi.com). Potentials at the left and right ear lobes were also measured for calculating an averaged-ears reference offline. EEG was recorded for two ten-minute periods and stored for analysis off line.

2.3. Meditation practices

2.3.1. The Transcendental Meditation technique

The TM practice is a mental procedure practiced for 20 min sitting with eyes-closed. During TM, one allows the attention to experience "finer" levels of a mantra—the mantra becomes increasingly secondary in experience and self-awareness becomes increasingly primary (Maharishi Mahesh Yogi, 1969; Travis and Pearson, 2000). In the process of transcending, attention moves from the ordinary thinking level to the least excited state of consciousness— consciousness without content, called pure consciousness (Maharishi Mahesh Yogi, 1969; Travis and Pearson, 2000).

Unlike most mantra meditations, the mantras used in TM practice are used for their sound value and not for any possible meanings. Also, unlike most mantra meditations, TM is not a process of concentration—keeping the mantra in awareness or continued mental rehearsal of the mantra. Rather, TM is a process of automatic transcending (see (Travis et al., 2010; Travis and Shear, 2010) and (Cahn and Polich, 2006) for a discussion of the concept of automatic transcending).

2.3.2. The TM-Sidhi program

The TM-Sidhi program was developed by Maharishi Mahesh Yogi from the Yoga Sutras of Patanjali. It is learned after many months of TM practice. While TM practice is a process of transcending, the TM-Sidhi practice involves the procedure of *sanyama*—the simultaneous processes of *dhārānā* (fixity on a sutra or phrase), *dhyāna* (transcending on that sutra) and *samādhi* (pure consciousness) (Maharishi Mahesh Yogi, 1978). Patanjali, the author of the Yoga Sutras predicted effects of practicing sanyama on different sutras or phrases. The TM-Sidhi practice includes a subset of these sutras. TM-Sidhi program is intended to connect aspects of the individual personality, such as senses, intuition, and emotions, with pure consciousness.

2.4. Data selection

The first 30-sec artifact-free periods were selected within the first minute of the TM and the TM-Sidhi sessions. Previous research reports that brain patterns in the first minute of TM practice are similar to those in the middle and end of the TM session (Travis and Wallace, 1999). Thus, brain patterns in the beginning of these sessions should be representative of brain patterns during each practices.

2.5. Data analyses

The data were analyzed with Brain Vision Analyzer. The 30-sec artifact-free data were re-referenced to averaged left and right ears, to compare with previous TM research, digitally filtered in a 2.0–50 Hz band pass filter with a 48 dB roll off, and fast Fourier transformed in 2-s epochs, using a Hanning window with 10% onset and offset. EEG amplitude was calculated from 2.0 to 50 Hz at the 32 recording sites. Coherence, the absolute value of the cross-correlation function in the frequency domain, was calculated for the 496 possible combination pairs of 32 recording sites.

2.5.1. Amplitude analysis

Brain Vision Analyzer can output either peak-to-peak amplitude ($\mathrm{sqrt}(\mathrm{real}^2 + \mathrm{imaginary}^2)$) or power ($\mathrm{real}^2 + \mathrm{imaginary}^2$) values from the FFT. This paper reports amplitude values, since they are more normally distributed—skewness was between 1 and −1for amplitudes in all frequency bands. Amplitude estimates were grouped into seven frontal (AF3, F3, FC1, Fz, AF4, F4, FC2) and seven parietal (PO3, P3, CP1, Pz, P4, CP2, PO4) spatial averages and averaged into six frequency bands—theta2 (5–7.5 Hz), alpha1 (8–10 Hz), alpha2 (10.5–12.5 Hz), beta1 (16–20 Hz), beta2 (20.5–30 Hz), and gamma bands (30.5–50 Hz). Changes in frontal and parietal power have been most often reported in the literature during TM practice.

2.5.2. Coherence analysis

Coherence estimates were averaged into two spatial averages: seven frontal coherence pairs (AF3–AF4, F3–F4, FC1–FC2, AF3–F3, AF4–F4, AF4–FC2, AF3–FC1), and six anterior-posterior coherence pairs (AF3–P3,