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Effects of Transcendental Meditation practice on brain functioning and stress reactivity in college students

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ABSTRACT

This randomized controlled trial investigated effects of Transcendental Meditation (TM) practice on Brain Integration Scale scores (broadband frontal coherence, power ratios, and preparatory brain responses), electrodermal habituation to 85-dB tones, sleepiness, heart rate, respiratory sinus arrhythmia, and P300 latencies in 50 college students. After pretest, students were randomly assigned to learn TM immediately or learn after the 10-week posttest. There were no significant pretest group differences. A MANOVA of students with complete data ($N=38$) yielded significant group vs treatment interactions for Brain Integration Scale scores, sleepiness, and habituation rates (all $p<.007$). Post hoc analyses revealed significant increases in Brain Integration Scale scores for Immediate-start students but decreases in Delayed-start students; significant reductions in sleepiness in Immediate-start students with no change in Delayed-start students; and no changes in habituation rates in Immediate-start students, but significant increases in Delayed-start students. These data support the value of TM practice for college students.

1. Introduction

Experience-related cortical plasticity was first identified during critical periods of development (von Senden, 1960; Hubel and Weisel, 1977), but now has been reported across the lifespan (Donoghue, 1995; Elbert et al., 1995; Buonomano and Merzenich, 1998; Merzenich, 1998; Maguire et al., 2006). Cortical plasticity explains learning (LeDoux, 2002; Zull, 2002). Synaptic connections are strengthened when students learn new facts, skills, and procedures (Mochizuki-Kawai et al., 2006).

Other experiences in college—high pressure, interrupted sleep, and alcohol and drug use—also leave their mark on brain functioning and behavior (Arnedt et al., 2005; Zeigler et al., 2005). Under high stress, the brain "downshifts" to a stimulus/response mode (Caine and Caine, 1991). Stress results in elevated sympathetic reactivity (Weekes et al., 2006), which can interrupt sleep causing excessive daytime sleepiness (Buboltz et al., 2001; Moo-Estrella et al., 2005) and cognitive deteriorations (Lee et al., 2003). High psychosocial stress causes brain regions involved in memory and emotions, such as the hippocampus, amygdala, and prefrontal cortex, to undergo structural remodeling, with the result that memory is impaired and anxiety and aggression are increased (McEwen, 1998, 2006a,b).

The stress response is a normal response to prepare for emergency situations. However, if the system is not allowed to recover from stressful experiences, then the body becomes sensitized to stress (McEwen, 2004). The stress response may not turn off or it may get triggered by mild experiences (McEwen, 2006a,b).

Transcendental Meditation®[1] practice is reported to decrease effects of previous stressful experiences and to help an individual function better in stressful situations. Transcendental Meditation practice is characterized by 1) lower sympathetic tone (Dillbeck and Orme-Johnson, 1987); 2) higher parasympathetic tone, as reflected in amplitude of the high frequency component of heart rate variability, also called respiratory sinus arrhythmia (Travis, 2001); and 3) higher levels of frontal EEG alpha coherence (8–12 Hz) (Dillbeck and Bronson, 1981; Gaylord et al., 1989; Travis, 2002; Travis et al., 2002) and frontal-parietal phase synchrony (Hebert et al., 2005). Simultaneous recording of EEG and MEG during Transcendental Meditation practice found that higher frontal and central scalp recorded alpha EEG activity is associated with MEG source location in medial frontal and anterior cingulate cortices (Yamamoto et al., 2006).

These physiological changes during Transcendental Meditation practice are associated with improvements in psychological functioning.

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A matched longitudinal study reported increases in Cattell Culture Fair IQ scores in college students after two years Transcendental Meditation practice (Cranson et al., 1991), and a random assignment longitudinal study reported increases in multiple measures of intelligence—Cattell Culture Fair IQ, practical intelligence, creativity, field independence and inspection time—after one year Transcendental Meditation practice (So and Orme-Johnson, 2001). A matched design reported greater flexibility in concept learning in college students (Dillbeck, 1982) and faster P300 latency in elderly participants (Goddard, 1989). A meta-analysis of 141 studies reported larger effect sizes for reduction of anxiety through Transcendental Meditation practice compared to other traditional meditation and clinical relaxation responses (Eppley et al., 1989). Another meta-analysis of 101 studies reported larger effect sizes for increases in self-actualization with Transcendental Meditation practice (Alexander et al., 1991).

Transcendental Meditation practice is also reported to result in improved health. A series of randomized controlled trials on the effects Transcendental Meditation practice on prevention and treatment of cardiac heart disease in multi-ethnic groups reported reductions in hypertension, atherosclerosis, left ventricular mass, and CHD morbidity and mortality in high-risk multi-ethnic populations practicing the Transcendental Meditation program, compared to controls (Schneider et al., 1995; Alexander et al., 1996; Castillo-Richmond et al., 2000).

Transcendental Meditation (TM) practice also changes brain patterns during challenging cognitive tasks after the meditation session. Nine brain measures including broadband inter- and intrahemispheric coherence (alpha: 8–12 Hz, beta: 12.5–20 Hz, and gamma: 20.5–50 Hz), broadband absolute and relative power, power ratios (alpha/beta and alpha/gamma), and cortical preparatory responses (contingent negative variation) were derived from EEG recorded during simple and choice reaction time tasks in 17 non-TM, 17 short-term (7.1 yrs TM) and 17 long-term TM participants (24.2 yrs TM). Of these nine brain measures, three measures were entered in a multiple discriminate analysis of group differences: 1) higher broadband frontal (F3–F4) coherence (alpha, beta, and gamma), 2) higher alpha/beta absolute power ratios, and 3) better match between task demands and brain preparatory response (Travis et al., 2000, 2002; Travis, 2002). These empirically identified measures were converted to z-scores and combined to form a scale. This scale was called a “Brain Integration Scale” (Travis et al., 2002).

The Brain Integration Scale derived its name from the long-term TM participants in this research, who reported the permanent integration of deep meditation experiences with waking, sleeping and dreaming states. Also, this name was chosen because EEG frontal coherence, which was the first variable entered in the multiple discriminate analysis, reflects structural and functional connectivity between brain areas (Thatcher et al., 1986). Brain Integration Scale scores in these participants positively correlated with emotional stability, moral reasoning, and inner directedness, and negatively correlated with anxiety (Travis et al., 2004). Also, Brain Integration Scale scores were significantly higher in top-level managers compared to middle-level managers (Travis et al., in press). Thus, the Brain Integration Scale appears to tap brain patterns important for success in life.

Reported effects of Transcendental Meditation practice on psychological and physiological functioning could be beneficial for students and help them manage the stressful experiences of college. The current study uses a random-assignment clinical-trial design with pretest and 10-week posttest to investigate effects of Transcendental Meditation practice on brain functioning, autonomic reactivity, heart rate, sleepiness, and speed of processing. The study hypotheses were that participants randomly assigned to learn the Transcendental Meditation technique, compared to wait-listed controls, would 1) increase in Brain Integration Scale scores; 2) increase in parasympathetic tone as measured by the amplitude of respiratory sinus arrhythmia during paced breathing; 3) decrease in sympathetic reactivity as measured by faster habituation rates to an 85-dB tone; 4) decrease in heart rate; 5) decrease in sleepiness levels as measured by Epworth Sleepiness Scale; and 6) have faster brain response times, as measured by shorter P300 latencies to novel stimuli.

2. Method

2.1. Study design

Pretest data were recorded from 50 students at the beginning of the Spring 2006 term. The students responded to signs advertising the research and came to introductory meetings that explained the study. At these meetings, students volunteered to be part of the EEG section of this study. Following baseline recordings, students were randomly assigned, using computer randomization, to either Immediate-start or Delayed-start in Transcendental Meditation instruction. The posttest occurred 10-weeks before final's week at the end of spring term. This was a time of maximum stress for the students. The IRB approved the study before beginning recruitment for the study.

The initial design for this study included only the pretest and 10-week posttest. Subsequently, an additional year of funding was obtained. Following the 14-week summer vacation, the Delay-start participants learned the TM technique, at the beginning of the Fall term, and both Immediate-start and Delayed-start participants meditated throughout the Fall term. A second posttest was conducted at the end of the Fall term. However, only 36% of the Immediate-start participants and 60% of the Delayed-start participants were available for the second posttest at the end of the Fall term. Many study participants missed the second posttest because they were out of the area on college-related internships. Due to the high attrition, it is difficult to make reliable inferences from the second posttest data. Thus, only data from the pretest and first posttest will be reported in this paper.

2.2. Subjects

This EEG research was a sub-study of research investigating effects of the Transcendental Meditation program on brain functioning, cognitive development, and health in 298 college students in the Washington, D.C. area. The inclusion criteria for entering this study were: 1) being an undergraduate or graduate student, 2) being in school through May 2006 (the study began January 2006), and 3) having blood pressure less than 140/90 mm Hg. During the first six weeks of recruitment for the larger study, students were offered the opportunity to participate in this neurophysiological sub-study. Fifty students (13 males and 37 females; average age = 22.4 ± 8.0 years) volunteered to participate in this part of the study. Forty-four were white; five were Asians; and one was Hispanic. These 50 students included 45 students attending American University, and one each attending George Washington University, George Mason University, Walden College, Marymount University, or Johns Hopkins University.

2.3. Procedure

Students came individually for their EEG recording. After completing consent and demographic forms, individuals answered the items on the Epworth Sleepiness Scale, while electrodes were applied. 1) 32 Ag/AgCl sensors were applied in the 10–10 system with sensors on the left and right earlobe for re-referencing offline. While coherence estimates are inflated by an averaged-ears reference (Fein et al., 1988; Travis, 1994), this confound would be the same in both groups and during the three recordings sessions, and so would not mask possible group differences. The average-ear reference will also allow comparison with other TM studies, which used averaged-ear references. 2) A Ag/AgCl sensor was applied on the left wrist to measure heart rate