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EVENT-RELATED POTENTIAL CORRELATES OF MINDFULNESS MEDITATION COMPETENCE

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Abstract—*Objective:* This cross-sectional study evaluated event-related potentials (ERPs) across three groups: naïve, novice, and experienced meditators as potential physiological markers of mindfulness meditation competence. *Methods:* Electroencephalographic (EEG) data were collected during a target tone detection task and a Breath Counting task. The Breath Counting task served as the mindfulness meditation condition for the novice and experienced meditator groups. Participants were instructed to respond to target tones with a button press in the first task (Tones), and then ignore the primed tones while Breath Counting. The primary outcomes were ERP responses to target tones, namely the N2 and P3, as markers of stimulus discrimination and attention, respectively. *Results:* As expected, P3 amplitudes elicited by target tones were attenuated within groups during the Breath Counting task in comparison to the Tones task ($p < .001$). There was a task by group interaction for P3 ($p = .039$). Both meditator groups displayed greater change in peak-to-trough P3 amplitudes, with higher amplitudes during the Tones condition and more pronounced reductions in P3 amplitudes during the Breath Counting meditation task in comparison to the naïve group. *Conclusions:* Meditators had stronger P3 amplitude responses to target tones when instructed to attend to the tones, and a greater attenuation of P3 amplitudes when instructed to ignore the same tones during the Breath Counting task. This study introduces the idea of identifying ERP markers as a means of measuring mindfulness meditation competence, and results suggest this may be a valid approach. This information has the potential to improve mindfulness meditation interventions by allowing objective assessment of mindfulness meditation quality. Published by Elsevier Ltd. on behalf of IBRO.

Key words: meditation, mindfulness, event-related potentials, attention.

INTRODUCTION

Mindfulness meditation is an effective complementary medicine technique in the treatment of anxiety, depression, and chronic pain (Kabat-Zinn et al., 1992; Miller et al., 1995; Teasdale et al., 2000; Grossman et al., 2004; Zeidan et al., 2010; Chiesa and Serretti, 2010). However, much remains to be learned about the neurophysiological mechanisms underlying the benefits of mindfulness meditation (Ospina et al., 2007; Wahbeh et al., 2008), despite reported changes in electroencephalography (EEG) and magnetic resonance imaging (MRI) (Cahn and Polich, 2006; Chiesa and Serretti, 2010; Kilpatrick et al., 2011; Dickenson et al., 2013; Fox et al., 2014). A more straightforward EEG marker could enable researchers to more accurately assess the efficacy of mindfulness meditation trainings, as more and more meditation interventions are emerging. More accurate assessment would further elucidate the brain mechanisms in mindfulness meditation, assist in the development of effective dose in clinical trials, and facilitate mindfulness meditation training in the future.

Mindfulness meditation competence, for the purposes of this experiment, is delineated as the ability to attend to breathing while ignoring other stimuli. EEG is an appealing way to assess brain changes in meditation because it allows for brain activity to be inexpensively, noninvasively, and unobtrusively recorded. Considering that mindfulness meditation can improve aspects of cognition (Brefczynski-Lewis et al., 2007; Lutz et al., 2009), EEG may be of additional benefit since it can evaluate these changes.

The aim of this study was to identify an electrophysiological correlate of mindfulness meditation competence using event-related potentials (ERPs). To achieve this aim, we investigated brain changes with EEG during mindfulness meditation practice among participants with differing levels of experience: naïve, novice, and experienced.

Kabat-Zinn's (1994) definition of mindfulness is "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally." We examined the ERP correlates of "paying attention", not the motivational or emotional processes that accompany paying attention. We acknowledge that there are many definitions and components of mindfulness. In this particular experiment we are delineating the ability to keep awareness in the present moment because we were interested in developing a biomarker for the focused attention aspect of mindfulness. During mindfulness meditation practice and interventions such as mindfulness-based stress

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Abbreviations: ANOVA, analysis of variance; EEG, electroencephalography; ERPs, event-related potentials; FFT, Fast Fourier Transformation; MEDI, Meditation Depth Index; SSS, Stanford Sleepiness Scale.

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reduction and mindfulness-based cognitive therapy, participants both practice mindful attention to the present moment during daily living and cultivate concentrative meditational techniques. The Body Scan and Sitting Meditation, which are the two primary practices in the aforementioned secular interventions, are both concentrative techniques. Mindfulness meditation competence must be associated with a cognitive surrogate in order to be evaluated, and attention is an ideal marker given the results of past studies (Brefczynski-Lewis et al., 2007; Chan and Woollacott, 2007; Lutz et al., 2008; Chiesa et al., 2011). We used a Breath Counting task because non-meditators can do it and also because it has shown potential as an index of mindfulness (Levinson et al., 2014; Milz et al., 2014).

ERP components are predictable patterns of brain activity that occur in response to specific stimuli, and we expected two components in particular to display meditation experience-related differences during a quiet, potentially meditative state. The first was the P3, which generally indicates stronger attentional focus on a particular stimulus. We predicted that meditators would have greater attentional expertise, as observed in earlier work (Brefczynski-Lewis et al., 2007; Chan and Woollacott, 2007; Lutz et al., 2008; Chiesa et al., 2011). Thus we hypothesized that meditators would also have greater P3 amplitudes than non-meditators, as previously shown (Lutz et al., 2009). Differences in attentional focus and engagement have been previously observed between meditators and non-meditators (Cahn and Polich, 2009; Tang et al., 2009; Chiesa et al., 2011; Delgado-Pastor et al., 2013), although the relationship between meditation training and attentional priming effects remains unknown. We also predicted that P3 amplitudes would differ between experienced and novice meditators, expecting that participants with the most meditation experience would also have the most attentional control.

The second component of interest in this study was the N2, which is elicited by stimuli similar to those that elicit the P3, specifically those that involve greater task-related attention or novelty (Luck, 2014). The N2 is elicited in response to target tones in an oddball task. We hypothesized that N2 amplitudes in the Tones task would be greater in meditators due to meditation-related attentional training. Specifically, experienced meditators were expected to have the most pronounced difference from naïve participants while novices' performance would fall in the middle. To test these hypotheses, we compared the N2 and P3 components of experienced, novice, and naïve meditators during an odd-ball paradigm, initially while participants were instructed to attend to the target tones and then while they were told to ignore the tones and focus on their breathing. We were particularly interested in the effects of primed ERP responses to target tones during the Breath Counting task and how these responses differed from those in the Tones task.

EXPERIMENTAL PROCEDURES

Participants

Forty-two participants were recruited from the Portland metropolitan area utilizing internet-based, flyer, and word-of-mouth strategies. All underwent a 30-min telephone screening. Inclusion criteria for participants in all groups were as follows: (1) age 25–75 years; (2) good general past and present medical health; (3) stable on all medications for at least two months; and (4) cognitively intact, as determined by a score of $\geqslant$31 on the Telephone Interview for Cognitive Status (TICS) (Welsh et al., 1993). Exclusion criteria were as follows: (1) significant medical or neurological disorder/disease; (2) significant visual or hearing impairment; (3) medications that would affect outcome measures (e.g. benzodiazepines or neuroleptics); and (4) significant untreated depression, as determined by a score of $\geqslant$10 on the 10-item Center for Epidemiologic Studies Depression Scale (CESD-10) (Andresen et al., 1994).

The naïve, novice, and experienced groups were carefully defined, and each subject's telephone screening was thoroughly reviewed by the principal investigator. Information about lifetime hours of practice was collected via verbal self-report. Meditation was defined as any practice of attention training, in which one is intentionally working to improve his or her ability to pay attention to the present moment. Further details about the types of practice are described by group below. Mind–body movement practices were defined as any activity in which one is practicing attention training. Mind–body movement-based practices included yoga, tai chi, martial arts, qi gong, mindful eating, walking, running, and swimming. The practices included foci of attention and were reported to be breath, physical sensations, and sound. For participant characteristics, see Table 1.

The three groups were evaluated by specific criteria. Potential naïve subjects were excluded if they had taken a meditation or other mind–body movement class within the past two years or if they had a daily meditation practice of five minutes or longer in the past 30 days. Novice subjects were included if they had some formal training, meaning they attended classes that were described and approved by the principal investigator, practiced at least three days a week, and had $\leqslant$1000 h'

Table 1. Participant characteristics

	All participants (SD)	Non-meditators (SD)	Novice meditators (SD)	Experienced meditators (SD)
N	42	13	15	14
Age (*M*)	49 (13)	48 (11)	50 (13)	49 (15)
Female	62%	69%	73%	43%
Minority	24%	23%	27%	21%
Practice in years (*M*)	–	–	2.4 years (2.5)	22.6 years (13.2)

There were no significant demographic differences among groups.