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Meditation (Vipassana) and the P3a event-related brain potential

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ABSTRACT

A three-stimulus auditory oddball series was presented to experienced Vipassana meditators during meditation and a control thought period to elicit event-related brain potentials (ERPs) in the two different mental states. The stimuli consisted of a frequent standard tone (500 Hz), an infrequent oddball tone (1000 Hz), and an infrequent distracter (white noise), with all stimuli passively presented through headphones and no task imposed. The strongest meditation compared to control state effects occurred for the distracter stimuli: N1 amplitude from the distracter was reduced frontally during meditation; P2 amplitude from both the distracter and oddball stimuli were somewhat reduced during meditation; P3a amplitude from the distracter was reduced during meditation. The meditation-induced reduction in P3a amplitude was strongest in participants reporting more hours of daily meditation practice and was not evident in participants reporting drowsiness during their experimental meditative session. The findings suggest that meditation state can decrease the amplitude of neurophysiologic processes that subserve attentional engagement elicited by unexpected and distracting stimuli. Consistent with the aim of Vipassana meditation to reduce cognitive and emotional reactivity, the state effect of reduced P3a amplitude to distracting stimuli reflects decreased automated reactivity and evaluative processing of task irrelevant attention-demanding stimuli.

1. Introduction

The neuroelectric (EEG) effects of meditation on brain activity are as yet not well characterized. There is no consensus as to whether evoked sensory and elicited cognitive event-related potentials (ERPs) are altered systematically from long hours dedicated meditators devote to their practice (Cahn and Polich, 2006). Some meditation effects of increased attention-related activations have been reported for changes in P300 amplitude (Banquet and Lesévre, 1980; Murthy et al., 1997; Sarang and Telles, 2006), contingent negative variation (CNV) amplitude (Travis et al., 2000; Travis et al., 2002), and frontal midline theta power (Aftanas and Golocheikine, 2001; Hebert and Lehmann, 1977). Meditation is most readily conceived as a set of diverse and specific methods of distinct attentional engagement and recent reports have begun to focus specifically on measures of attentional engagement during (state) and from (trait) meditation (Brefczynski-Lewis et al., 2007; Holzel et al., 2007; Jha et al., 2007; Pagnoni and Cekic, 2007; Raz and Buhle, 2006; Slagter et al., 2007; Srinivasan and Baijal, 2007).

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The goal of present study was to assess the state effects of meditation in experienced Vipassana meditators (average 13 years of daily meditation practice) using stimulus conditions indexing neurophysiologic processing underlying perception and attentional engagement. A passive three-stimulus auditory oddball task was employed as it did not require participants to disengage from meditation practice to produce a behavioral response, simultaneously allows for characterization of the sensory aspects of audition via the N1/P2 components, and assays attentional engagement via the P3a potential elicited by the distracter stimulus (Combs and Polich, 2006; Polich, 2007). As the primary goal was to characterize neurocognitive meditation effects, a within-subject meditation vs. control cognitive task paradigm was employed.

1.1. Vipassana meditation

Vipassana meditation is a traditional Buddhist practice that involves focusing on present-moment sensory awareness within an equanimous and non-reactive mental set. This tradition has served as the foundation for the development of contemporary "mindfulness" meditation techniques that are being used clinically (Davidson, 2003; Kabat-Zinn, 1982, 2003). Development of greater awareness of and non-reactivity to intero- and exteroceptive sensory stimuli during formal Vipassana/mindfulness meditation is hypothesized to enhance self-awareness such that selective adaptive responding is facilitated at the expense of automated non-adaptive reactions, thereby promoting more successful management of stressful life situations (Hart, 1987; Lutz et al., 2007; Segal et al., 2002). Vipassana practitioners of the Theravadin Vipassana tradition as taught by S. N. Goenka (Hart, 1987) were assayed. This practice emphasizes deep attentional absorption in subtle somatosensory awareness and associated self-monitoring without mental reactivity to such sensory experience. It was expected that meditation state effects would reflect a decrease in automated cognitive reactivity to the infrequent distracter stimuli of the auditory three-stimulus paradigm.

The neural loci of Vipassana/mindfulness meditation effects are of key empirical and theoretical import. A study using fMRI demonstrated that experienced Vipassana meditators during meditation evinced higher levels of hemodynamic activity in rostral anterior cingulate cortex and medial prefrontal cortex relative to novice meditators (Holzel et al., 2007). Moreover, experienced meditators in the mindfulness-based traditions have consistently demonstrated higher levels of attention-related activity in prefrontal areas. This outcome is consistent with findings that selective attentional control is increased in meditative practice partly through the recruitment of prefrontal cortical activity (Baerentsen, 2001; Cahn and Polich, 2006; Lazar et al., 2003; Ritskes et al., 2003). Following a three-month intensive Vipassana meditation retreat, practitioners but not control participants demonstrated P300 amplitude decreases to the initial stimulus during the attentional blink paradigm suggesting enhanced attentional engagement to the full stimulus train (Slagter et al., 2007). Furthermore, several investigations of mindfulness meditation practice have reported increased functioning of attentional measures such as executive attention (Chan and Woollacott, 2007; Tang et al., 2007; Wenk-Sormaz, 2005), visual sensitivity (Brown et al., 1984a,b; Brown, 2007), as well as endogenous orienting and exogenous alerting-related functions (Jha et al., 2007).

These attention-related meditation effects may stem from physical changes induced in Vipassana meditators, who have increased cortical thickness in regions related to auditory, visual, somatosensory, and interoceptive processing (Lazar et al., 2005). The strongest of these effects have been observed in the right anterior insula, an area related to bodily attention and increased visceral awareness (Craig, 2002, 2003; Critchley et al., 2004). That meditative practice was the cause for these changes in cortical thickness is not definitive, as cross-sectional rather than longitudinal samples were assessed. However, the cortical thickness of the meditation vs. control young participant groups was similar and implies that meditation practice may have slowed the age-related thinning of the insular and prefrontal cortical areas. Assessment of Zen meditators compared to controls yielded similar findings (Pagnoni and Cekic, 2007). The absence of age-related gray matter loss was especially prominent in the putamen and was accompanied by improved sustained attentional functioning in the meditator group as assessed by a rapid visual processing sustained attention. Thus, Vipassana meditation appears to be associated with differences in attentional deployment, brain function, and cortical structures that may underlie meditation's long-term effects of decreased emotional reactivity, increased well-being and compassion, and reported changes in self-experience (Goleman, 1996; Wallace, 1999) and scientific (Astin, 1997; Farb et al., 2007; Travis et al., 2004; Wallace and Shapiro, 2006).

1.2. Meditation and ERPs

The earliest studies on the effects of meditation on neuroelectric activity associated with stimulus processing were concerned with alpha blocking. Assessment of concentrative Yogic practices indicated that during meditation some highly experienced experts did not demonstrate the characteristic alpha blocking to auditory clicks or aversive stimuli such as placing the hands in cold water (Anand, 1961; Wenger and Bagchi, 1961). The results suggested that practitioners during meditation may be able to tune the relevant neural attentional networks such that brain activity is not activated to the same extent by stimulation. Studies of Japanese Zen monks, schooled in a tradition with similarity to the mindfulness-focus of Vipassana, indicated that with regularly repetitive auditory stimulation the normal habituation of alpha blocking was not observed in meditation masters compared to novices (Hirai, 1974; Kasamatsu and Hirai, 1966). This lack of habituation was thought to indicate that long-term meditation was associated with a "de-automization" of sensory and cognitive processing such that successive auditory stimuli were perceived as fresh. Later studies further indicated that alpha power was less disrupted in meditation than control states during presentation of loud aversive stimuli (Lehrer et al., 1980) and "name calling" (Kinoshita, 1975). Thus, meditation may lead to neurophysiologic states that are less reactive to stimulus-driven automated processing.

Cognitive ERPs have been used to assess meditation states and traits, with the P300 elicited to characterize attention and memory processing (Cahn and Polich, 2006). P3a is hypothesized to index frontal neural activity produced by stimulus-driven attention mechanisms, whereas the P3b indexes temporal–parietal activity reflecting resource allocation that contributes subsequent memory processing (Polich, 2007). An early study found shorter response times and increased N1 and P2 as well as P3b amplitudes to visual stimuli after a period of meditation in experienced yoga meditators compared to component amplitude decreases after a period of rest in non-meditators (Banquet and Lesévre, 1980). However, a subsequent investigation obtained no systematic effects of yoga, TM, or Zen meditation on any component from auditory stimuli, although post-hoc analyses of the TM and yoga groups demonstrated increased N1 component amplitudes towards the beginning of the stimulus train (Becker and Shapiro, 1981). A series of reports using Transcendental Meditation participants suggested that increased length of meditation practice was associated with decreased P3b latencies (Cranson et al., 1990; Goddard, 1989, 1992), and that decreased P3b latencies were observed after meditation but not rest periods (Travis and Miskov, 1994). Depressed and dysthymic individuals evinced improved clinical status that occurred with increases in P3b amplitude from an auditory oddball task after a period of concentrative meditation training (Murthy et al., 1997). P3b amplitudes from auditory stimuli were increased after a session of concentrative meditation (Sarang and Telles, 2006). Using an attentional blink paradigm that manipulates fundamental sensory responsivity to visual stimuli demonstrated that after an intensive Vipassana meditation retreat, meditators showed a decrease in visual P3b amplitude to the T1 stimulus and concomitant increase in T2 target detection, reflecting more efficient attentional processing (Slagter et al., 2007). In sum, the P300 component may be modulated by meditative practice, although whether such findings are consistent across subjects or specific to different sensory domains and particular meditative practices is as yet unclear as is the relative impact on P3a compared to P3b.

1.3. Present study

Although these findings suggest that meditation appears to influence brain function, systematic evaluation of meditation state in comparison to comparable but not meditative thought conditions in long-term practitioners is needed (Lutz et al., 2008). The present study assayed ERP effects between a meditation and control state using an equal length mental control state through the injunction to let the mind wander freely through non-emotional thoughts and memories. This control task was chosen to induce a state particularly contrasted with the purposeful engagement of attention involved in meditation. Further, this state was designed to mimic a mind-wandering state thought to have good ecologic validity to a common mode of cognitive engagement in normal everyday life (Smallwood and Schooler, 2006).