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Meditation and auditory attention: An ERP study of meditators and non-meditators

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ABSTRACT

The findings of a study by Cahn and Polich (2009) suggests that there is an effect of a meditative state on three event-related potential (ERP) brain markers of "low-level" auditory attention (i.e., acoustic representations in sensory memory) in expert meditators: the N1, the P2, and the P3a. The current study built on these findings by examining trait and state effects of meditation on the passive auditory mismatch negativity (MMN), N1, and P2 ERPs. We found that the MMN was significantly larger in meditators than non-meditators regardless of whether they were meditating or not (a trait effect), and that N1 amplitude was significantly attenuated during meditation in non-meditators but not expert meditators (an interaction between trait and state). These outcomes suggest that low-level attention is superior in long-term meditators in general. In contrast, low-level attention is reduced in non-meditators when they are asked to meditate for the first time, possibly due to auditory fatigue or cognitive overload.

1. Introduction

Meditation has been described as the intentional regulation of attention (Kabat-Zinn, 1982), and specific instructions for the intentional regulation of attention form the basis of many styles of meditative practice (e.g., concentration on the breath; Tang & Posner, 2009; Tang et al., 2015). Given the central role that attention appears to play in meditation, it is interesting that a meta-analysis about the effects of meditation on behavioural variables concluded that meditation has only a moderate effect on measures of attention. However, this effect was measured across different meditation techniques (Sedlmeier et al., 2012), and the meta-analysis did not differentiate the effects of meditation on different "levels" of attention, such as early "low-level" processes of attention (e.g., the storage of stimulus features in the sensory memory) and "high-level" attention processes (e.g., complex attention skills, such as the ability to respond to multiple simultaneous streams of information). This raises the question of whether meditation has different effects on different types of attention that average together to produce a moderate effect on attention. The aim of the current study was to investigate the effect of meditation on one specific type of attention. We investigated low-level attention using event-related potentials (ERPs), which allows the measurement of attention during meditation without interrupting a meditator's practice.

An ERP is an average electrical potential generated by groups of neurons in response to a particular event or stimulus (e.g., a musical tone, a written word, a spoken word, a face). ERPs can be measured under "passive" conditions (i.e., an individual is not required to pay attention to a particular task or stimulus) or under active conditions (i.e., an individual is asked to attend to a stimulus or task). Passive and active ERPs are represented by waveforms that comprise a series of positive and negative peaks. These peaks are named according to their position in that series (e.g., P1 is the first positive peak and N1 is the first negative peak; see Fig. 1(a–d) for an example) or according to their timing (e.g., the N100 is a negative peak that occurs approximately 100 ms in the waveform, P200 is a positive peak that occurs at around 200 ms in the waveform).

Several studies have compared meditators' and non-meditators' passive and active ERPs to various stimuli after a period of meditation (e.g., Banquet & Lesévre, 1980; Sarang & Telles, 2006; Travis & Miskov, 1994). This includes two studies that focused on "low-level" auditory attention (i.e., storage of acoustic features in the sensory memory; Cahn et al., 2013; Delgado-Pastor et al., 2014). However, to our knowledge, only two studies have used ERPs to measure low-level attention in meditators during meditation (Cahn & Polich, 2009; Atchley et al., 2016).

Cahn and Polich (2009) tested 16 Vipassana meditators during meditation and non-meditation conditions for their passive auditory ERPs (N1, P2, P3a at midline frontal (Fz), central (Cz), and parietal (Pz)

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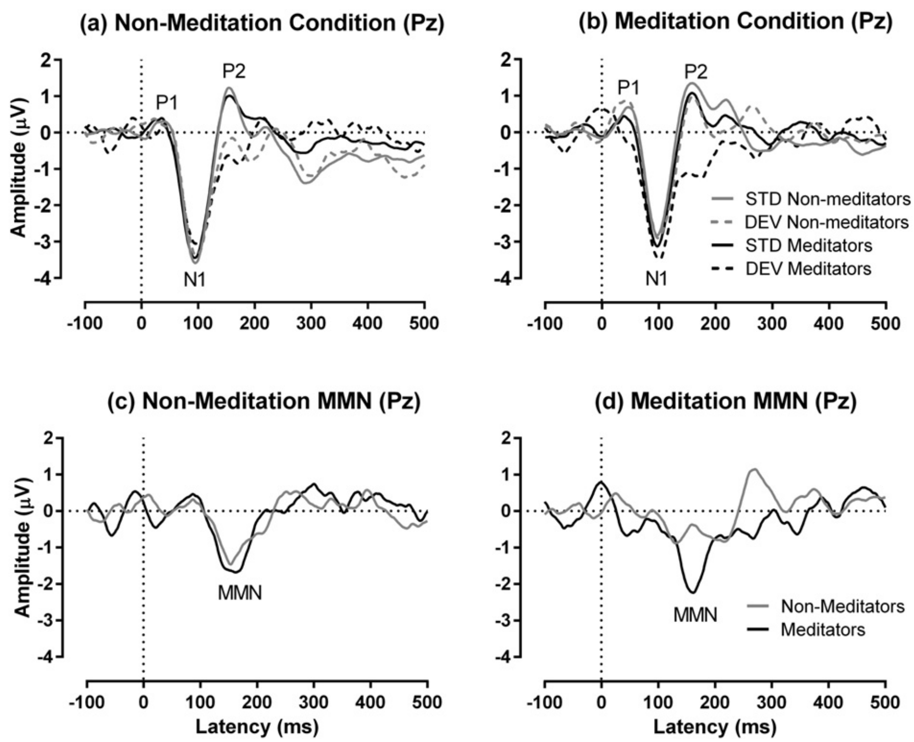

Fig. 1. a–d Examples and results for positive and negative peaks across conditions.

scalp sites) to three types of sounds: a frequent 500-Hz tone ("standard", 80% of tones), an infrequent 1000-Hz tone ("deviant", 10%) and an infrequent white noise ("distractor", 10%). The passive auditory N1 and P2 ERPs are thought to reflect the early processing of acoustic features of a stimulus and early automatic orienting of attention (Alcaini et al., 1994; Näätänen & Picton, 1987) while the P3a is thought to reflect attentional engagement (Polich, 2007). Cahn and Polich found that meditation reduced the N1, the P2, and the P3a to deviants and/or distractors - but not to standards. They concluded that meditation reduces automatic reactivity and processing of task-irrelevant attention-demanding stimuli.

The outcomes of Cahn and Polich's study are interesting because they suggest that meditation may have an effect on low-level auditory attention. However, the strength of this suggestion is obscured by two methodological factors. First, half of the participants were asked to meditate before the mind-wandering task, raising the possibility of meditation "after-effects" confounding the non-meditation control phase.[1] Second, there was no control group of non-meditators in the study, making it impossible to discern whether an effect of meditation on low-level attention-related reactivity was specific to expert meditators (i.e., an effect of "trait" that is only present in meditators), is specific to meditation (i.e., an effect of "state" that is present whenever anyone meditates), or resulted from an interaction between both trait and state (i.e., is only present in meditators during meditation).

A recent study by Atchley et al. (2016) addressed these two issues using three groups: non-meditators, novice meditators (under 1000 hours of practice within the last 2.5 years), and long-term meditators (over 4000 hours of practice). These groups were tested for their N2 and P3 ERPs firstly during a non-meditation condition (i.e., they were asked to count the deviant sounds in an oddball task) and then during a meditation condition (i.e., they were asked to ignore sounds in an oddball task in while breath counting). Compared to non-meditators, the meditators (i.e., novice and long-term meditators pooled together) had larger N2 and P3 responses during non-meditation (when the sounds were attended) and smaller N2 and P3 responses during meditation (when the sounds were ignored). In addition, there were greater differences in N2 and P3 amplitudes elicited by the meditation and non-mediation conditions compared to the non-meditators. The authors interpreted these findings as evidence for greater attention control in meditators.

The combined findings of Atchley et al. (2016) and Cahn and Polich (2009) support the idea that meditation may have trait and state effects on low-level auditory attention-related skills indexed by the N1, P2, and P2 ERPs. The aim of the current study was to expand build upon these findings by testing if meditation has trait or state effects on yet another ERP that indexes low-level auditory attention - the mismatch negativity (MMN). The auditory MMN is hypothesised to reflect an automatic auditory change detection mechanism that activates a shift in the focus of attention (Escera et al., 1998; Escera et al., 2003; though cf Garrido et al., 2009; Jääskeläinen et al., 2004). The MMN is calculated by subtracting a passive ERP to a frequent standard stimulus to a passive ERP to a rare deviant stimulus. The resulting "difference" waveform typically shows a negativity that peaks at around 200 ms in adults that is maximal at fronto-central scalp sites but is also observed at parietal scalp sites (for example see Näätänen et al., 2007). It is generally thought that the MMN is generated by neurons in temporal and pre-frontal brain regions (Garrido et al., 2009).

No study has compared the auditory MMN in meditators and non-meditators during meditation. However, one study has found that meditators had a larger average MMN after Sudarshan Kriya Yoga than non-meditators who did a relaxation session (Srinivasan & Baijal, 2007). While this study did include a control group of non-meditators, it confounded the comparison of meditators and non-meditators by applying different conditions to each group (yoga for the experimental group and relaxation for controls).

With the knowledge of the findings and limitations of the studies by Cahn and Polich (2009), Srinivasan and Baijal (2007), and Atchley et al. (2016) in mind, the current study aims to explore the effect of meditation on low-level attention by comparing the MMN ERP of expert

[1] For example, across different meditation traditions, breath counting is the fundamental basis but mind wandering is factored into the meditation (e.g., Zen). An integral part of the meditation practice is to notice 'the thought that arises' or the 'mind that is wondering', and to come back the breath or the koan.