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# Behavioral and Electrophysiological Evidence of Enhanced Performance Monitoring in Meditators

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**Abstract** Performance monitoring—the ability to monitor ongoing performance to detect and correct errors—is a core component of cognitive control. Impairments in performance monitoring have been associated with several psychiatric disorders, including attention deficit hyperactivity disorder and substance use disorder. Recent research indicates that the practice of meditation, as a mental training technique, may improve cognitive control. However, if and to what extent regular long-term meditation practice may enhance performance monitoring is currently unknown. The present study examined effects of meditation practice on behavioral and electrophysiological indices of performance monitoring. A group of meditators and an experience-matched active control group (non-meditator athletes) performed an Eriksen-Flanker task while their brain activity was recorded using electroencephalography (EEG).

Behaviorally, meditators made significantly fewer errors than controls on incongruent trials. EEG analyses revealed a general increase in the amplitude of two brain potentials associated with performance monitoring—the error negativity (Ne) or error-related negativity (ERN) and correct-related negativity (CRN)—in meditators compared to controls. These findings, which are indicative of enhanced performance monitoring in meditators, corroborate the idea that meditation could be a recommendable practice to train and improve cognitive control, specifically performance monitoring.

**Keywords** Meditation · Performance monitoring · Error-related negativity · Cognitive control · EEG

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## Introduction

Humans have the potential to adapt their behavior to continually changing conditions by learning from their experiences. The ability to monitor and evaluate performance is particularly indispensable for learning from errors and preventing them in the future (Hoffmann and Falkenstein 2012). Indeed, impairments in performance monitoring underlie inflexible and impulsive behavior (Ruchsow et al. 2005). Furthermore, deficits in performance monitoring have been related to substance use disorders (SUD) (Euser et al. 2013; Franken et al. 2007; Luijten et al. 2011, 2014), schizophrenia (Foti et al. 2016; Houthoofd et al. 2013; Kim et al. 2015; Perez et al. 2012; Rabella et al. 2016), psychopaths, and violent offenders (Brazil et al. 2009; Lievaart et al. 2015; Maurer et al. 2015; von Borries et al. 2010). Given the crucial role of performance monitoring in adaptive behavior, it is critical to determine which approaches might consistently enhance this core cognitive skill of the brain (Ridderinkhof et al. 2004). Meditation practice has been proposed as a particularly useful method for

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