



Review

Is meditation associated with altered brain structure? A systematic review and meta-analysis of morphometric neuroimaging in meditation practitioners



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ABSTRACT

Numerous studies have begun to address how the brain's gray and white matter may be shaped by meditation. This research is yet to be integrated, however, and two fundamental questions remain: Is meditation associated with altered brain structure? If so, what is the magnitude of these differences? To address these questions, we reviewed and meta-analyzed 123 brain morphology differences from 21 neuroimaging studies examining ~300 meditation practitioners. Anatomical likelihood estimation (ALE) meta-analysis found eight brain regions consistently altered in meditators, including areas key to meta-awareness (frontopolar cortex/BA 10), exteroceptive and interoceptive body awareness (sensory cortices and insula), memory consolidation and reconsolidation (hippocampus), self and emotion regulation (anterior and mid cingulate; orbitofrontal cortex), and intra- and interhemispheric communication (superior longitudinal fasciculus; corpus callosum). Effect size meta-analysis (calculating 132 effect sizes from 16 studies) suggests a global 'medium' effect size (Cohen's $d = 0.46$; $r = .19$). Publication bias and methodological limitations are strong concerns, however. Further research using rigorous methods is required to definitively link meditation practice to altered brain morphology.

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1. Introduction

A range of effects have been associated with long- and short-term training in the mental practices broadly referred to as

'meditation.' A few striking examples include enhancement of executive functions, such as attention (Jha et al., 2007), working memory (Jha et al., 2010), and introspection (Fox et al., 2012; Sze et al., 2010); improved immune function (Davidson

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