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Research Paper

The Effect of Mindfulness and Neurological Changes

Dr. Amruta Ashok Magar[1]*

ABSTRACT

Research over the past two decades broadly supports the claim that mindfulness meditation practiced widely for the reduction of stress and promotion of health exerts beneficial effects on physical and mental health, and cognitive performance. Recent neuroimaging studies have begun to uncover the brain areas and networks that mediate these positive effects. However, the underlying neural mechanisms remain unclear, and it is apparent that more methodologically rigorous studies are required if we are to gain a full understanding of the neuronal and molecular bases of the changes in the brain that accompany mindfulness meditation.

Keywords: *Mindfulness, Meditation, Neurological changes*

Meditation can be defined as a form of mental training that aims to improve an individual's core psychological capacities, such as attentional and emotional self-regulation. Meditation encompasses a family of complex practices that include mindfulness meditation, mantra meditation, yoga, tai chi and chi gong1. Of these practices, mindfulness meditation — often described as non-judgmental attention to present-moment experiences has received most attention in neuroscience research over the past two decades. Although meditation research is in its infancy, a number of studies have investigated changes in brain activation (at rest and during specific tasks) that are associated with the practice of, or that follow, training in mindfulness meditation. These studies have reported changes in multiple aspects of mental function in beginner and advanced meditators, healthy individuals and patient populations.

Challenges in meditation research Findings on the effects of meditation on the brain are often reported enthusiastically by the media and used by clinicians and educators to inform their work. However, most of the findings have not yet been replicated. Many researchers are enthusiastic meditators themselves. Although their insider perspective may be valuable for a deep understanding of meditation, these researchers must ensure that they take a critical view of study outcomes. In fact, for meditation studies there is a relatively strong bias towards the publication of positive or significant results, as was shown in a meta-analysis.

[1]Post -doctoral research fellow (ICSSR, Delhi), Department of psychology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad (M.S.), India.
*Corresponding Author

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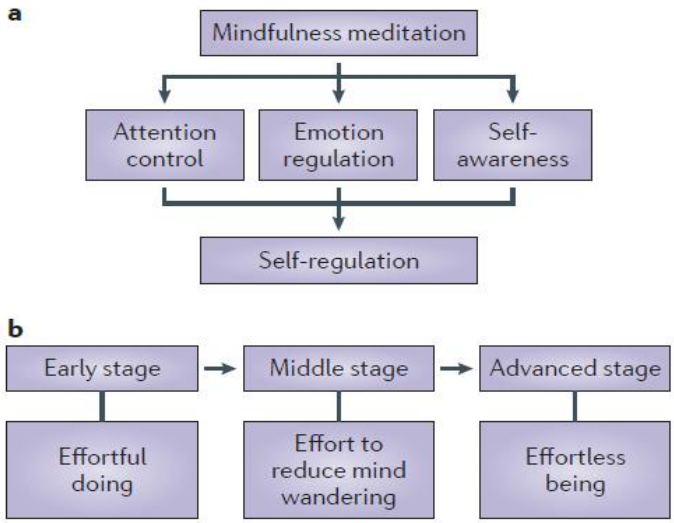
Mindfulness meditation

Different styles and forms of meditation are found in almost all cultures and religions. Mindfulness meditation originally stems from Buddhist meditation traditions3. Since the 1990s, mindfulness meditation has been applied to multiple mental and physical health conditions, and has received much attention in psychological research. In current clinical and research contexts, mindfulness meditation is typically described as non-judgmental attention to experiences in the present moment. This definition encompasses the Buddhist concepts of mindfulness and equanimity and describes practices that require both the regulation of attention (in order to maintain the focus on immediate experiences, such as thoughts, emotions, body posture and sensations) and the ability to approach one's experiences with openness and acceptance. Mindfulness meditation can be subdivided into methods involving focused attention and those involving open monitoring of present-moment experience.



The mindfulness practices that have been the subject of neuroscientific research comprise a broad range of methods and techniques, including Buddhist meditation traditions, such as Vipassana meditation, Dzogchen and Zen, as well as mindfulness-based approaches such as integrative body–mind training (IBMT), mindfulness-based stress reduction (MBSR) and clinical interventions based on MBSR. Both MBSR and IBMT have adopted mindfulness practices from the Buddhist traditions and aim to develop moment-to-moment, non-judgmental awareness through various techniques. IBMT has been categorized in the literature as open-monitoring mindfulness meditation, whereas MBSR includes both focused attention and open-monitoring practices8.It has been suggested that mindfulness meditation includes at least three components that interact closely to constitute a process of enhanced self-regulation: enhanced attention control, improved emotion regulation and altered self-awareness (diminished self-referential processing and enhanced body awareness) (see the figure, part a). Mindfulness meditation can be roughly divided into three different stages of practice — early, middle (intermediate) and advanced that involve different amounts of effort.

A number of cross-sectional studies revealed differences in brain structure and function associated with meditation (see below). Although these differences may constitute training-induced effects, a cross-sectional study design precludes causal attribution: it is possible that there are pre-existing differences in the brains of meditators, which might be linked to their interest in meditation, personality or temperament. Although correlational studies have

attempted to discover whether more meditation experience is related to larger changes in brain structure or function, such correlations still cannot prove that meditation practice has caused the changes because it is possible that individuals with these particular brain characteristics may be drawn to longer meditation practice. More recent research has used longitudinal designs, which compare data from one or more groups at several time points and ideally include a (preferably active) control condition and random assignment to conditions. In meditation research, longitudinal studies are still relatively rare. Among those studies, some have investigated the effects of mindfulness training over just a few days, whereas others have investigated programs of 1 to 3 months. Some of these studies have revealed changes in behavior, brain structure and function. A lack of similar changes in the control group suggests that meditation has caused the observed changes, especially when other potentially confounding variables are controlled for properly.

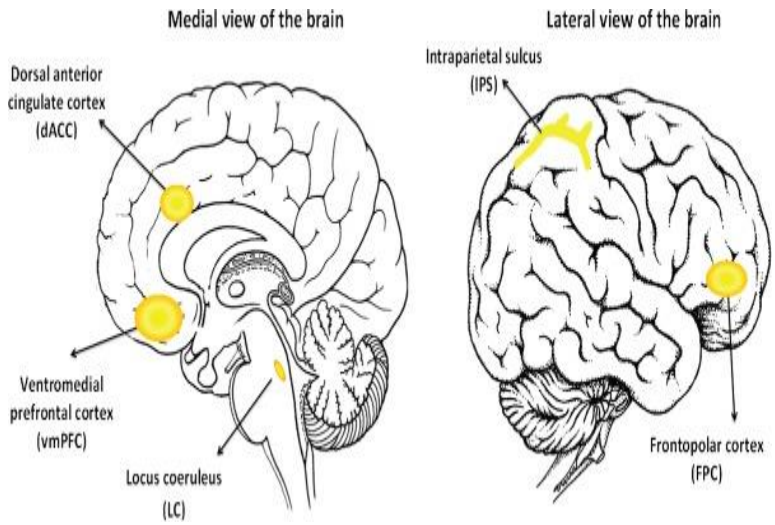
Changes in brain structure in the past decade, 21 studies have investigated alterations in brain morphometry related to mindfulness meditation. These studies varied in regard to the exact mindfulness meditation tradition under investigation, and multiple measurements have been used to investigate effects on both grey and white matter. Studies have captured cortical thickness, grey-matter volume and/or density, fractional anisotropy and axial and radial diffusivity. These studies have also used different research designs. Most have made cross-sectional comparisons between experienced meditators and controls; however, a few recent studies have investigated longitudinal changes in novice practitioners. Some further studies have investigated correlations between brain changes and other variables related to mindfulness practice, such as stress reduction, emotion regulation or increased well-being. Most studies include small sample sizes of between 10 and 34 subjects per group. Because the studies vary in regard to study design, measurement and type of mindfulness meditation, it is not surprising that the locations of reported effects are diverse and cover multiple regions in the brain. Effects reported by individual studies have been found in multiple brain regions, including the cerebral cortex, subcortical grey and white matter, brain stem and cerebellum, suggesting that the effects of meditation might involve large-scale brain networks. This is not surprising because mindfulness practice involves multiple aspects of mental function that use multiple complex interactive networks in the brain. An activation likelihood estimation meta-analysis, which also included studies from traditions other than mind-fullness meditation, was conducted to investigate which regions were consistently altered in meditators across studies17. The findings demonstrated a global medium effect size, and eight brain regions were found to be consistently altered in meditators: the front polar cortex, which the authors suggest might be related to enhanced meta-awareness following meditation practice; the sensory cortices and insula, areas that have been related to body awareness; the hippocampus, a region that has been related to memory processes; the anterior cingulate cortex (ACC), mid-cingulate cortex and orbitofrontal cortex, areas known to be related to self and emotion regulation; and the superior longitudinal fasciculus and corpus callosum, areas involved in intra- and inter-hemispherical communication.

Mindfulness and attention

Many meditation traditions emphasize the necessity to cultivate attention regulation early in the practice. A sufficient degree of attentional control is required to stay engaged in meditation, and meditators often report improved attention control as an effect of repeated practice. Multiple studies have experimentally investigated such effects.

Components of attention:- Attention is often subdivided into three different components: alerting (readiness in preparation for an impending stimulus, which includes tonic effects

that result from spending time on a task (vigilance) and phasic effects that are due to brain changes induced by warning signals or targets); orienting (the selection of specific information from multiple sensory stimuli); and conflict monitoring (monitoring and resolution of conflict between computations in different neural areas, also referred to as executive attention). Other distinctions between types of attention refer to combinations of these three components. For example, sustained attention refers to the sense of vigilance during long continued tasks and may involve both tonic alerting and orienting, whereas selective attention may involve either orienting (when a stimulus is present) or executive function (when stored information is involved).



Brain regions involved in the components of mindfulness meditation. Schematic view of some of the brain regions involved in attention control (the anterior cingulate cortex and the striatum), emotion regulation (multiple prefrontal regions, limbic regions and the striatum) and self-awareness (the insula, medial prefrontal cortex and posterior cingulate cortex and presumes).

Performance in these three basic domains can be measured with the attention network test (ANT). This test uses as a target an arrow pointing left or right. The target is surrounded by flankers, and subtracting reaction times to congruent stimuli (that is, those on the side of the screen indicated by the arrow) from reaction times to incongruent stimuli produces a measure of the time to resolve conflict. The inclusion of cues that indicate when or where the target will occur allows the measurement of alerting and orienting. These measures are used to performance task that measured aspects of tonic alertness, but did show some improvement in orienting 22. We do not know whether the differences in the findings of these studies are due to the type of training, type of control or other subtle factors. A systematic review that compiled the findings of these studies (as well as the effects on other measures of cognition) concluded that early phases of mindfulness meditation might be associated with improvements in conflict monitoring and orienting, whereas later phases might be mainly associated with improved alerting. It is currently still unclear how different meditation practices differentially affect the specific attentional components. In addition, the length of practice needs to be defined more consistently in future research.

Effects of mindfulness meditation on emotion regulation

Improvements in emotion regulation associated with mindfulness meditation have been investigated through various approaches, including experimental studies, self-reporting studies, measurement of peripheral physiology and neuroimaging. These studies have

reported various positive effects of mindfulness meditation on emotional processing, such as a reduction in emotional interference by unpleasant stimuli87, decreased physiological reactivity and facilitated return to emotional baseline after response to a stressor film88, and decreased self-reported difficulties in emotion regulation. Consequently, low-erred intensity and frequency of negative affect and improved positive mood states are reported to be associated with mindfulness meditation.

Mindfulness and self-awareness

According to Buddhist philosophy, the identification with a static concept of 'self' cause's psychological distress. Dis-identification from such a static self-concept result in the freedom to experience a more genuine way of being. Through enhanced meta-awareness (making awareness itself an object of attention), mindfulness meditation is thought to facilitate a detachment from identification with the self as a static entity and a tendency to identify with the phenomenon of 'experiencing' itself is said to emerge. Currently, empirical research into this area is only just emerging and the few interpretations of connections between neuroimaging findings and self-reported data which we will summarize briefly below are suggestive at best. Self-referential processing. Altered self-representation has been investigated with questionnaire studies. Early studies reported mindfulness training to be associated with a more positive self-representation, higher self-esteem, higher acceptance of oneself and styles of self-concept that are typically associated with less-severe pathological symptoms. Meditators have also been shown to score higher than non-meditators on a scale that measures non-attachment: a construct that is based on insight into the constructed and impermanent nature of mental representations. Although such concepts are not easy to capture in experimental and neuroscientific studies, findings from a few recent studies seem to suggest that brain structures supporting self-referential processing might be affected by mindfulness meditation.

Mindfulness and stress

Stress reduction might be a potential mediator of the effects of mindfulness practice on neural function. Mindfulness meditation has been shown to reduce stress; this is most consistently documented in self-reported data. A review of mindfulness-based stress reduction (MBSR) studies showed a non-specific effect on stress reduction, which is similar to that of standard relaxation training134. However, findings in studies that have examined biomarkers of stress, such as cortisol levels, are less consistent: changes in cortisol levels have been found in association with mindfulness training in some studies but not in others. The brain is a target for stress and stress-related hormones. It undergoes functional and structural remodeling in response to stress in a manner that is adaptive under normal circumstances but can lead to damage when stress is excessive. Evidence suggests that vulnerability to stress-induced brain plasticity is prominent in the prefrontal cortex (PFC), hippocampus, amygdala and other areas associated with fear-related memories and self-regulatory behaviors. The interactions between these brain regions determine whether life experiences lead to successful adaptation or maladaptation and impaired mental and physical health. A study has shown that chronic stress induces less flexibility in attention shifting in the rodent and human adult. This was paralleled by a reduction in apical dendritic barbarization in rodent medial PFC (specifically, in the anterior cingulate cortex) and fewer feed forward PFC connections in humans under stress, effects that recovered when the stressor was removed174. This suggests that the effects of chronic psychosocial stress on PFC function and connectivity are plastic and can change quickly as a function of mental state174. Studies have also shown that moderate to severe stress seems to increase the

volume of the amygdala but reduce the volume of the PFC and hippocampus. Mindfulness training, however, has been shown to enhance grey-matter density in the hippocampus.

Mindfulness meditation as exposure therapy

Exposure therapy aims for patients to extinguish a fear response and instead to acquire a sense of safety in the presence of a formerly feared stimulus by exposing them to that stimulus and preventing the usual response164. Mindfulness meditation resembles an exposure situation because practitioners 'turn towards their emotional experience', bring acceptance to bodily and affective responses, and refrain from engaging in internal reactivity towards it. Research on fear conditioning has helped to identify a network of brain regions that are crucial for the extinction of conditioned fear responses and the retention of extinction165. This network includes the ventromedial prefrontal cortex (vmPFC), which is important for a successful recall of the extinction; the hippocampus, which is related to signaling the extinguished context (contextual safety); and the amygdala, which has a crucial role during the acquisition and expression of conditioned fear167 and is thought to be down regulated by the PFC and the hippocampus. Activation in the PFC (subgenera anterior cingulate cortex) is primarily linked to the expression of fear learning during a delayed test of extinction and is critical for the retention of extinction.

Clinical application

Self-regulation deficits are associated with diverse behavioral problems and mental disorders, such as increased risk of school failure, attention deficit disorder, anxiety, depression and drug abuse. Convergent findings indicate that mindfulness meditation could ameliorate negative outcomes resulting from deficits in self-regulation and could consequently help patient populations suffering from diseases and behavioral abnormalities. Several clinical trials have explored the effects of mindfulness meditation on disorders such as depression 154, generalized anxiety 26, addictions 155, attention deficit disorders 156 and others 42, and have begun to establish the efficiency of mindfulness practice for these conditions. Only a few recent studies, however, have investigated the neuroplasticity changes underlying these beneficial effects of mindfulness in clinical populations. Although these studies are promising, future work needs to replicate and expand the emerging findings to optimally tailor interventions for clinical application.

CONCLUSION

Interest in the psychological and neuroscientific investigation of mindfulness meditation has increased markedly over the past two decades. As is relatively common in a new field of research, studies suffer from low methodological quality and present with speculative post-hoc inter-predations. Knowledge of the mechanisms that underlie the effects of meditation is therefore still in its infancy. However, there is emerging evidence that mindfulness meditation might cause neuroplasticity changes in the structure and function of brain regions involved in regulation of attention, emotion and self-awareness. Further research needs to use longitudinal, randomized and actively con-trolled research designs and larger sample sizes to advance the understanding of the mechanisms of mindfulness meditation in regard to the interactions of complex brain networks, and needs to connect neuroscientific findings with behavioral data. If supported by rigorous research studies, the practice of mindfulness meditation might be promising for the treatment of clinical disorders and facilitate the cultivation of a healthy mind and increased well-being.

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Conflict of Interest

The author(s) declared no conflict of interest.

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