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Dhyana (Meditation) and Cognitive Neuroscience: A Critical Integrative Review

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Abstract

Dhyana is described in classical Yoga as a continuous flow of attention that develops from concentration and precedes meditative absorption. Contemporary research examines related practices through cognitive testing, neuroimaging, electrophysiology, and physiological measures. This narrative review considers classical accounts alongside evidence on attention, memory, executive control, emotion, stress, and brain plasticity. Meditation training is associated with small-to-moderate improvements in several psychological outcomes, particularly stress, anxiety, rumination, and aspects of attentional control. Imaging studies report differences in prefrontal, cingulate, insular, hippocampal, amygdala, and default-mode systems, but many findings come from small or cross-sectional samples and cannot establish causation. Claims about neurotransmitters, neurogenesis, or prevention of cognitive decline remain less certain than claims about short-term psychological benefit. *Dhyana* should therefore be understood neither as a simple relaxation technique nor as a validated treatment for every neurological or psychiatric disorder. It is a trainable attentional practice that may complement appropriate care. Stronger conclusions require well-defined techniques, active comparison groups, preregistered outcomes, adequate samples, long follow-up, adverse-event reporting, and culturally sensitive interpretation.

Keywords

Dhyana; meditation; cognitive neuroscience; attention; neuroplasticity; mindfulness; Yoga

1. Introduction

Meditation originated within diverse contemplative traditions rather than as a single standardized clinical intervention. In Yoga, *Dhyana* is linked to ethical discipline, posture, breath regulation, sensory withdrawal, and concentration. Modern studies often isolate one technique and measure changes in cognition, emotion, symptoms, or physiology [1–3].

fMRI, EEG, PET, and diffusion imaging have made neural correlates accessible, but a brain difference is not automatically a clinical benefit. Experienced practitioners may differ from control

participants before training, while brief trials vary in instructor skill, home practice, expectancy, and comparator quality [2]. A useful integrative account must preserve these distinctions.

Aim and Scope

The review describes *Dhyana* in classical Yoga, evaluates evidence on cognition and neural function, distinguishes stronger findings from speculative claims, and proposes priorities for clinically responsible research.

2. Review Method

Classical sources included the *Patanjali Yoga Sutra*, *Bhagavad Gita*, selected Upanishads, *Hatha Yoga Pradipika*, and *Gheranda Samhita*. Biomedical material was drawn from PubMed, Scopus, Web of Science, Google Scholar, and the Cochrane Library using concepts related to meditation, mindfulness, cognition, neuroimaging, electrophysiology, and neuroplasticity. Randomized trials, systematic reviews, meta-analyses, and mechanistic studies were emphasized. This narrative approach was not preregistered and does not provide a formal risk-of-bias calculation.

3. Classical Context of *Dhyana*

Meditative practices appear across Vedic, Upanishadic, Buddhist, and Yogic traditions. The *Katha Upanishad* discusses steadiness of the senses and mind, while the *Bhagavad Gita* emphasizes discipline, equanimity, and self-regulation [4]. Patanjali positions *Dhyana* as the seventh limb of *Ashtanga Yoga*, between *Dharana* and *Samadhi* [3]. Later Yoga texts elaborate posture, breath, sensory discipline, and absorption.

The aphorism *Tatra Pratyayaikatanata Dhyanam* is commonly interpreted as continuity of cognition or awareness toward an object [5]. *Dharana* establishes a chosen focus; *Dhyana* describes a more sustained flow; *Samadhi* denotes absorption. These categories concern lived practice and liberation as well as attention, so they cannot be reduced to laboratory constructs.

4. Meditation Practices Studied Today

Focused-attention practice repeatedly returns attention to the breath, a *mantra*, an image, or bodily sensation. Open-monitoring practice observes changing experience with less selection. Mindfulness programs combine present-centred awareness with attitudes such as non-judgment and acceptance. Loving-kindness practices cultivate benevolence, while *mantra*-based programs and *Yoga Nidra* use different instructions and goals.

Pooling these practices as if they were identical can obscure technique-specific effects. Duration, teacher contact, retreat experience, cultural setting, and adherence should be reported in enough detail to permit replication [19,20,28].

5. Cognitive Outcomes

Attention is the most direct target of many meditation practices. Training may improve sustained attention, conflict monitoring, and resistance to distraction, especially when tasks resemble the practiced skill [27,28]. Evidence for broad gains in intelligence or everyday executive performance is less consistent.

Working memory and cognitive flexibility sometimes improve after training, but effects are influenced by baseline ability, practice dose, and choice of control group [16]. Self-reported clarity does not necessarily correspond to objective test performance. Future studies should specify primary cognitive outcomes and limit multiple exploratory comparisons.

6. Emotion and Stress Regulation

Mindfulness-based interventions can reduce anxiety, depressive symptoms, perceived stress, and rumination in some populations [17–20]. Effects are usually compared with no treatment, education, relaxation, or established psychotherapy, and their size depends on the comparator. Mindfulness-based cognitive therapy has a defined role in relapse prevention for selected people with recurrent depression, but meditation is not a universal substitute for psychotherapy or medication.

Possible mechanisms include improved recognition of emotional cues, reduced automatic elaboration, reappraisal, acceptance, and changes in physiological arousal. These psychological processes are better supported than simple claims that one neurotransmitter explains the benefit.

7. Structural Neuroimaging

Cross-sectional studies of long-term practitioners report differences in cortical thickness or grey-matter measures in prefrontal, anterior cingulate, insular, and hippocampal regions [7,8,14]. Longitudinal work has also reported regional change after training [9]. However, analytic flexibility, modest samples, and selective reporting can inflate apparent consistency.

Structural MRI does not directly demonstrate neurogenesis, improved synaptic function, or protection from dementia. Associations may reflect prior lifestyle, education, health, or self-selection. Replication with harmonized pipelines and active controls is essential.

8. Functional Networks

Meditation engages systems involved in attention, salience detection, interoception, cognitive control, and self-referential processing. Studies often describe altered activity or connectivity within the default mode network and between default, executive, and salience systems [10]. Reduced mind-wandering may accompany lower or differently coupled default-mode activity, but the network is not inherently harmful; it also supports memory, simulation, and social cognition.

Reduced amygdala reactivity and altered prefrontal–limbic coupling have been reported after training [9]. These findings may relate to emotional regulation, although task design and analytic choices vary.

9. Electrophysiology

EEG studies report changes in alpha, theta, and, among some highly experienced practitioners, gamma activity [12,15]. Oscillations differ by technique, expertise, recording conditions, and artifact control. Alpha cannot simply be translated as calmness, theta as creativity, or gamma as higher consciousness. These signals index neural dynamics and require interpretation within the specific task and analysis.

10. Neurochemical, Endocrine, and Immune Claims

Meditation and Yoga research has examined GABA, dopamine, serotonin, BDNF, cortisol, inflammatory markers, and autonomic measures [11,13]. Cortisol and stress-related physiological outcomes have some supportive evidence, though effects are variable. Direct evidence for durable neurotransmitter changes is limited, and peripheral BDNF does not by itself prove brain neurogenesis.

Sleep, physical activity, breathing patterns, social contact, and expectancy may contribute to measured biological change. Mechanistic studies should isolate these components and control collection time, diet, medication, and prior practice.

11. Neuroplasticity: What Can Be Concluded

Practice-dependent change is plausible because attention and emotion-regulation skills are learned experiences. Longitudinal studies indicate functional and sometimes structural differences after training [9,13]. Neuroplasticity, however, is a general property of the nervous system, not proof that every observed change is beneficial or lasting. Claims should link a neural measure to a replicated behavioural or clinical outcome.

12. Clinical Applications

For anxiety, depression, stress, chronic pain, and insomnia, structured mindfulness programs may offer modest adjunctive benefit [17,18,20]. In chronic pain, improvement may reflect reduced distress or disability even when pain intensity changes little. People with significant symptoms should receive assessment and evidence-based care rather than relying on meditation alone.

Evidence for ADHD, mild cognitive impairment, dementia prevention, and cognitive rehabilitation remains preliminary [21]. Trials are often small and heterogeneous. Meditation cannot be said to prevent Alzheimer's disease on current evidence. In healthy ageing, it may support well-being and attentional engagement, but long-term disease outcomes are unresolved.

13. Safety and Accessibility

Meditation is generally low risk, but adverse experiences can include anxiety, agitation, traumatic memories, depersonalization, insomnia, or worsening mood in susceptible individuals. Intensive practice is not equivalent to brief supervised training. Programs should provide informed choice, qualified

instruction, trauma-sensitive adaptations, and routes to clinical support.

Accessibility depends on language, disability, culture, time, and cost. Secular clinical programs should acknowledge the traditions from which practices were adapted without imposing spiritual commitments.

14. Classical Concepts and Neuroscience

Dharana can be compared cautiously with focused-attention training, *Pratyahara* with regulation of sensory engagement, and *Dhyana* with sustained meditative awareness. Such comparisons can generate research questions. *Chitta* is not simply a cognitive-processing system, *Vritti* is not synonymous with neural activity, *Sattva* is not a biomarker, and *Samadhi* is not established by an imaging pattern [22,29].

Classical terms belong to philosophical, ethical, and experiential systems. Neuroscience describes measurable relationships among brain, behaviour, and experience. Dialogue is valuable when neither framework is made to validate the other by superficial equivalence.

15. Methodological Limitations

Meditation research faces small samples, heterogeneous interventions, weak active controls, incomplete blinding of outcome assessors, self-selection, multiple outcomes, and limited long-term follow-up. Instructor allegiance and participant expectation can influence results. Neuroimaging studies add risks from motion, analytic flexibility, and publication bias [14,19,20].

Stronger trials should preregister hypotheses, use credible active comparators, measure adherence, report prior experience, blind assessors and analysts where feasible, share analysis plans, and record adverse events. Multisite and culturally diverse cohorts would improve generalizability.

16. Future Directions

Comparative trials can test which practices help which people and through what mechanisms. Repeated cognitive assessment, ecological momentary sampling, wearable physiology, and harmonized imaging may clarify dose and durability. Digital or AI-guided systems require validation against qualified instruction and careful privacy, bias, and safety oversight.

Research on children, older adults, trauma-exposed populations, and people with neurological disease should proceed with population-specific safeguards. Cost-effectiveness and implementation studies are needed before broad health-system adoption [25,26,31,32].

17. Conclusion

Dhyana offers a disciplined account of sustained meditative awareness within the wider path of Yoga. Contemporary evidence supports meditation as a potentially useful adjunct for stress, emotional regulation, and some aspects of attention, with emerging but less definitive neural findings. Brain images and molecular measures do not justify claims of universal cognitive enhancement, neurotransmitter correction, or prevention of neurodegeneration. A mature integrative science will define the practice precisely, respect its classical context, test clinically meaningful outcomes, report harms, and distinguish plausible mechanisms from metaphor.

18. Conceptual Comparison

Classical term	Cautious research comparison
Dharana	Focused-attention training
Dhyana	Sustained meditative awareness
Pratyahara	Regulation of sensory engagement
Chitta and *Vritti*	Experiential-philosophical concepts; not direct neural variables
Samadhi	Advanced contemplative state; no established biomarker

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