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Neuroanatomical Changes in Memory-Related Brain Regions Associated with Yoga Practice: A Narrative Review

Rahul R. K.[1]; Aswathy H. V.[2]

[1,2] Sree Ramakrishna Medical College of Naturopathy and Yogic Sciences, Kulasekharam, Tamil Nadu, India.

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Abstract:

- ***Background:***

Yoga has gained increasing attention as a potential non-pharmacological approach for supporting cognitive health and memory through its combined effects on physical activity, mindfulness, and stress regulation.

- ***Objective:***

To review current evidence on yoga-associated neuroanatomical and functional changes in brain regions involved in memory and cognition.

- ***Methods:***

Literature published between 2000 and 2026 was identified through PubMed, Scopus, Web of Science, PsycINFO, and Google Scholar. Seminal studies published before 2000 were included where necessary to provide conceptual background. Studies employing neuroimaging techniques and examining memory-related brain regions were reviewed.

- ***Results*:**

Neuroimaging studies suggest that yoga practitioners may exhibit structural and functional differences in the hippocampus, prefrontal cortex, anterior cingulate cortex, and insula. These regions play key roles in memory, attention, and executive functioning. Proposed mechanisms include stress reduction, enhanced neuroplasticity, improved cerebral blood flow, increased neurotrophic support, and reduced inflammation. However, most studies are cross-sectional and involve relatively small sample sizes.

- ***Conclusion:***

Current evidence indicates that yoga may support memory-related brain health through neuroplastic adaptations in key cognitive regions. While findings are promising, well-designed longitudinal and randomized controlled studies are needed to determine whether yoga directly improves memory and induces measurable changes in brain structure.

Keywords: *Yoga; Memory; Neuroplasticity; Neuroimaging; Hippocampus; Cognitive Function; Brain Health; Healthy Aging.*

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I. INTRODUCTION

The maintenance of memory and cognitive function has become an increasingly important public health concern as populations age and the prevalence of neurodegenerative disorders continues to rise worldwide. Memory underpins learning, decision-making, social interaction, and independent living, making its preservation essential for quality of life across the lifespan (1). Consequently, considerable scientific attention has focused on identifying modifiable lifestyle factors capable of supporting cognitive health and promoting resilience against age-related neurological decline.

Research over the past three decades has demonstrated that the adult brain retains a remarkable capacity for structural

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and functional adaptation. This phenomenon, commonly referred to as neuroplasticity, encompasses changes in synaptic organization, dendritic architecture, neural connectivity, and regional brain volume in response to behavioural and environmental influences (2).

Among memory-related structures, the hippocampus is particularly notable because it retains substantial plasticity and is highly sensitive to physical activity, psychological stress, and cognitive stimulation. Among memory-related structures, the hippocampus is particularly notable because it retains substantial plasticity and is highly sensitive to physical activity, psychological stress, and cognitive stimulation. Adult hippocampal neurogenesis has been reported in humans, although its extent and cognitive significance remain under investigation (3,4). Physical activity, cognitive stimulation, and stress reduction have all been associated with favourable hippocampal adaptations, whereas chronic stress and prolonged glucocorticoid exposure have been linked to hippocampal atrophy and memory impairment (5,6).

Within this context, yoga has emerged as a promising candidate for supporting brain health. Traditionally originating in India, yoga integrates physical postures (asanas), breathing practices (pranayama), and meditative techniques intended to cultivate physical and mental well-being. Unlike many lifestyle interventions that target a single physiological pathway, yoga combines physical activity, attentional training, emotional regulation, and stress management within a unified practice. Consequently, yoga has been proposed to influence cognitive function through multiple interconnected physiological and psychological mechanisms (7,8).

Emerging theoretical perspectives have further proposed that breath-centered contemplative practices may influence consciousness through respiratory modulation of interoceptive and autonomic neural networks, particularly involving the insular cortex and anterior cingulate cortex. These mechanisms may complement existing neuroplastic models of yoga by providing an additional physiological pathway through which sustained contemplative practice could influence brain function (9).

Interest in yoga's neurological effects has increased substantially with the development of modern neuroimaging techniques. Structural magnetic resonance imaging (MRI), functional MRI (fMRI), positron emission tomography (PET), and other imaging modalities have enabled investigators to examine whether long-term yoga practice is associated with measurable changes in brain morphology and neural function. Several studies have reported greater grey matter volume, increased cortical thickness, and altered functional connectivity in experienced yoga practitioners compared with non-practitioners (10–12). Notably, many of the regions identified in these investigations—including the hippocampus, prefrontal cortex, anterior cingulate cortex, and insula—are directly involved in memory, attention, and executive functioning (8).

A recent systematic review of 23 neuroimaging and neurophysiological studies similarly suggested that yoga may be associated with changes in brain structure and function. However, substantial heterogeneity in study populations, research designs, yoga definitions, and imaging methods limited the strength and comparability of the available evidence (13).

Despite growing interest, important questions remain unanswered. Most available studies have employed cross-sectional designs and relatively small sample sizes, limiting the ability to establish causal relationships between yoga practice and observed neuroanatomical differences (8). Furthermore, relatively few investigations have simultaneously examined objective memory outcomes and structural brain measures. As a result, the extent to which yoga can directly improve memory and induce measurable neuroanatomical adaptations remains uncertain.

The aim of this review is to examine current evidence regarding yoga-associated structural and functional changes in memory-related brain regions. Particular attention is given to findings involving the hippocampus, prefrontal cortex, anterior cingulate cortex, and insula, as well as to biological mechanisms that may explain observed neuroplastic adaptations. By synthesizing the available evidence and identifying current research gaps, this review seeks to provide a foundation for future intervention studies investigating the effects of yoga on memory and brain structure.

II. LITERATURE SEARCH STRATEGY

A literature search was conducted using PubMed, Scopus, Web of Science, PsycINFO, and Google Scholar to identify relevant publications between 2000 and 2026.Seminal studies published before 2000 were included where necessary to provide conceptual background. Search terms included combinations of "yoga," "memory," "hippocampus," "brain structure," "neuroimaging," "grey matter," "cortical thickness," "MRI," "neuroplasticity," and "cognition." Priority was given to peer-reviewed human studies employing structural or functional neuroimaging techniques and examining brain regions associated with memory and cognitive function.

III. NEUROIMAGING EVIDENCE OF YOGA-ASSOCIATED BRAIN CHANGES

The application of neuroimaging techniques has substantially advanced understanding of the potential relationship between yoga practice and brain structure. Although the number of studies remains relatively small compared with research on aerobic exercise or meditation, available findings suggest that yoga may be associated with structural and functional differences in several brain regions involved in memory, attention, and executive functioning. Among these regions, the hippocampus, prefrontal cortex, anterior cingulate cortex, and insula have emerged most consistently across studies (8).

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- *Hippocampal Structure and Memory*

The hippocampus has received the greatest attention within yoga-related neuroimaging research because of its central role in memory formation and consolidation (1,14). The biological plausibility of hippocampal adaptation is supported by evidence demonstrating that this region remains capable of neuroplastic change throughout adulthood and is highly sensitive to environmental influences such as physical activity, stress, and cognitive stimulation (4,6).

A small cross-sectional study compared 13 experienced yoga practitioners with 13 age- and sex-matched controls using structural and functional magnetic resonance imaging. Yoga practitioners demonstrated greater left hippocampal grey-matter volume and lower activation of the left dorsolateral prefrontal cortex during the encoding phase of a working-memory task. However, task accuracy and reaction time did not differ significantly between the groups (12). These findings indicate an association between long-term yoga practice and specific structural and functional brain characteristics but do not establish causality.

Similar findings have been reported in older Hatha yoga practitioners. Afonso et al. compared 21 healthy older women who had practised Hatha yoga for at least eight years with 21 age-, education-, and physical-activity-matched controls. The yoga practitioners demonstrated greater cortical thickness in a left prefrontal cluster involving portions of the middle and superior frontal gyri (11). Because the investigation was cross-sectional, it cannot determine whether yoga practice caused the observed cortical differences.

Evidence from mindfulness research provides additional context. A study reported increases in grey matter density within the hippocampus following an eight-week mindfulness-based stress reduction intervention (15). Likewise, a meta-analysis identified consistent structural differences in brain regions involved in learning, memory, and emotional regulation among meditation practitioners (16). Because many forms of yoga incorporate mindfulness and attentional training, these findings strengthen the hypothesis that yoga-related practices may influence memory-related neural structures.

However, interpretation of these findings requires caution. Most studies have employed cross-sectional designs, making it difficult to determine whether observed differences are caused by yoga practice or reflect pre-existing characteristics of individuals who choose to engage in yoga. Furthermore, many studies involve relatively small samples, limiting statistical power and generalizability (8). Consequently, while the available evidence supports an association between yoga and hippocampal structure, definitive conclusions regarding causality remain premature.

- *Prefrontal Cortex and Executive Networks*

Beyond the hippocampus, several investigations have reported differences within the prefrontal cortex, a region critical for executive functioning, working memory, attentional control, and decision-making (17). Effective memory performance depends not only on the storage of information but also on the ability to allocate attention during encoding and retrieval. Consequently, structural or functional adaptations within prefrontal networks may indirectly influence memory outcomes.

Frontal brain regions are among the most frequently reported sites of yoga-associated neuroplasticity in studies examining yoga practitioners. Structural differences within frontal areas have been observed among experienced practitioners, and functional imaging studies have reported altered activation patterns during cognitive tasks (12). Similar findings have been highlighted in a comprehensive review of yoga neuroimaging research (8). These observations are consistent with broader findings from contemplative neuroscience suggesting that long-term attentional training may enhance neural efficiency within executive control networks (18).

Although the precise significance of these findings remains uncertain, they suggest that yoga may influence memory through mechanisms extending beyond the hippocampus alone. Enhanced executive functioning and attentional regulation may improve the efficiency with which information is encoded and retrieved, thereby contributing to better cognitive performance.

- *Anterior Cingulate Cortex and Insular Cortex*

Two additional regions frequently identified in yoga-related neuroimaging studies are the anterior cingulate cortex (ACC) and the insular cortex. The ACC plays a key role in attentional monitoring, cognitive control, and emotional regulation, whereas the insula is involved in interoception, self-awareness, and integration of sensory and emotional information (19,20).

Neuroimaging findings suggest that the anterior cingulate cortex and related attentional networks may be particularly responsive to contemplative practices. Structural and functional changes within cingulate regions have been reported following mindfulness-based interventions, and similar patterns have been identified in studies examining yoga practitioners (8,15,18). Because many forms of yoga require sustained attention to breathing, posture, and bodily sensations, repeated engagement of these neural systems may contribute to adaptive neuroplastic changes over time.

The insula has also emerged as one of the most consistently reported brain regions in yoga-related neuroimaging research. Associations between years of yoga experience and insular morphology have been observed, suggesting that long-term practice may influence neural systems involved in interoceptive awareness, self-regulation, and body perception (21). This finding is particularly relevant because interoceptive awareness has been linked to emotional regulation and attentional stability, both of which may indirectly support memory performance (20).

- *Functional Connectivity and Neural Networks*

While structural MRI studies focus on brain morphology, functional neuroimaging studies provide insight into how neural networks operate during cognitive processes.

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Several investigations have suggested that yoga practitioners exhibit altered functional connectivity within networks involved in attention, executive control, and self-referential processing (8).

Particular attention has been directed toward the default mode network (DMN), a large-scale brain network associated with internally focused thought and mind wandering. Excessive DMN activity has been linked to reduced attentional engagement and poorer task performance. Meditation-based practices have been shown to modify DMN activity and connectivity, potentially improving cognitive efficiency (16,18). Given the overlap between meditation and yoga, similar mechanisms may contribute to observed cognitive benefits among yoga practitioners.

Functional adaptations within executive control networks have also been reported. These findings suggest that yoga may influence not only the structure of individual brain regions but also communication among distributed neural systems responsible for attention and memory. Such network-level changes may ultimately be more relevant to cognitive performance than isolated anatomical differences.

➢ *Overall Synthesis of Neuroimaging Findings*

Taken together, current neuroimaging evidence suggests that yoga practice is associated with structural and functional differences in regions involved in cognitive and emotional processing. The hippocampus, prefrontal cortex, anterior cingulate cortex, and insula repeatedly emerge as regions demonstrating differences between practitioners and non-practitioners (8,12). Importantly, these regions form part of an interconnected network supporting memory, attentional regulation, executive functioning, and emotional processing.

Nevertheless, the strength of the evidence should not be overstated. Most studies are cross-sectional, sample sizes are often modest, and considerable heterogeneity exists regarding yoga style, duration of practice, and neuroimaging methodology. As a result, current findings are best interpreted as evidence of association rather than proof of causation. Despite these limitations, the recurrence of findings across several studies provides a rationale for continued investigation into yoga as a potential intervention for cognitive health and memory preservation.

IV. BIOLOGICAL MECHANISMS LINKING YOGA, NEUROPLASTICITY, AND MEMORY

Although neuroimaging studies suggest an association between yoga practice and structural or functional differences in memory-related brain regions, understanding the biological mechanisms underlying these observations remains essential. Current evidence indicates that yoga may influence brain health through several interconnected pathways, including modulation of stress physiology, enhancement of neuroplasticity, improvement of cerebral perfusion, and reduction of systemic inflammation. While direct mechanistic evidence remains limited, these pathways provide biologically plausible explanations for the neuroanatomical findings reported in the literature.

➢ *Stress Reduction and HPA-Axis Modulation*

One of the most widely proposed mechanisms involves the regulation of the hypothalamic–pituitary–adrenal (HPA) axis. Chronic psychological stress activates the HPA axis and results in prolonged secretion of glucocorticoids, particularly cortisol. Sustained elevations in cortisol have been associated with hippocampal atrophy, impaired neurogenesis, reduced synaptic plasticity, and deficits in memory performance (5,6).

The hippocampus is especially vulnerable to chronic stress because it contains a high density of glucocorticoid receptors. Excessive cortisol exposure has been linked to reductions in hippocampal volume and poorer memory outcomes in both healthy individuals and clinical populations (5). Consequently, interventions capable of reducing chronic stress may help preserve hippocampal integrity and cognitive function.

Yoga interventions have frequently been associated with improvements in perceived stress, anxiety, and psychological well-being, although the magnitude and consistency of these effects vary across populations and intervention protocols. A separate systematic review and meta-analysis also reported potential benefits among individuals with post-traumatic stress disorder, but the findings should be interpreted in view of the limited and heterogeneous evidence base (22,23). These observations are relevant because chronic psychological stress has been associated with hippocampal dysfunction, impaired neuroplasticity, and memory difficulties (5,6). By reducing sustained stress-system activation, yoga may contribute to a physiological environment more supportive of cognitive and neural health.

➢ *Brain-Derived Neurotrophic Factor and Neuroplasticity*

Another potential mechanism involves brain-derived neurotrophic factor (BDNF), a protein that plays a crucial role in neuronal survival, synaptic plasticity, learning, and memory. BDNF is particularly important within the hippocampus, where it supports neurogenesis and facilitates long-term potentiation, a cellular process underlying memory formation (24).

Research examining physical activity has consistently demonstrated associations between increased BDNF expression, improved cognitive performance, and enhanced hippocampal plasticity, suggesting that neurotrophic signalling may represent an important pathway linking behavioural interventions to brain health (25,26). Evidence directly linking yoga practice to changes in BDNF remains limited. Because yoga combines physical activity, breath regulation, and contemplative practice, an influence on neurotrophic signalling is biologically plausible; however, it has not yet been established as the mechanism responsible for the neuroimaging findings observed in yoga practitioners. The relationship between BDNF and neuroimaging findings remains largely theoretical in the context of yoga research. Nevertheless, the repeated observation of structural differences in memory-related brain regions is consistent with biological pathways known to involve neurotrophic support and neural remodelling. Future studies measuring both

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neuroimaging outcomes and circulating neurotrophic factors may help clarify these relationships.

➢ *Adult Neurogenesis and Neural Adaptation*

The possibility that yoga may influence adult neurogenesis has also attracted scientific interest. Adult neurogenesis refers to the generation of new neurons within the mature brain and has been reported within the hippocampal dentate gyrus, although its extent and functional relevance in adult humans continue to be investigated (3,4). Experimental research suggests that neurogenesis contributes to learning, memory formation, and cognitive flexibility.

Several factors associated with yoga practice may theoretically promote conditions favourable for neurogenesis. Physical activity has been shown to stimulate neuronal growth and hippocampal plasticity, while stress reduction may remove inhibitory influences on neural development (6,25). Although direct evidence linking yoga to increased neurogenesis in humans is currently unavailable, the convergence of these mechanisms provides a plausible explanation for observed structural differences in memory-related brain regions.

It is important to acknowledge that neurogenesis remains difficult to measure directly in living humans. Consequently, claims that yoga increases neurogenesis should be regarded as hypotheses rather than established conclusions. At present, available evidence supports the possibility of neuroplastic adaptation but does not allow definitive statements regarding underlying cellular processes.

➢ *Cerebral Blood Flow and Vascular Health*

Adequate cerebral blood flow is essential for maintaining neuronal function and supporting long-term brain health. Reduced cerebral perfusion has been associated with cognitive decline, impaired memory, and increased vulnerability to neurodegenerative disorders. Physical activity is known to improve vascular function, cerebral circulation, and overall neurocognitive health, and these vascular adaptations are considered important mediators of exercise-related cognitive benefits (25,26).

Yoga may influence cerebral blood flow through both physical and autonomic mechanisms. Physical postures promote movement and muscular activity, while controlled breathing practices may affect cardiovascular regulation and autonomic balance.

➢ *Inflammation and Brain Health*

A growing body of research suggests that chronic low-grade inflammation contributes to cognitive decline and neurodegenerative disease. Elevated inflammatory markers have been associated with impaired memory, reduced cognitive performance, and structural changes within the hippocampus and other brain regions (6).

Several investigations have reported reductions in inflammatory biomarkers following yoga-based interventions. Although findings vary across studies, systematic reviews suggest that yoga may exert modest anti-inflammatory effects, particularly among individuals experiencing chronic stress and chronic health conditions (27).

The anti-inflammatory hypothesis is particularly relevant because inflammation, stress, and neuroplasticity are closely interconnected. Chronic stress can promote inflammation, while inflammation may impair neurogenesis and synaptic plasticity. Therefore, yoga's potential influence on multiple physiological systems simultaneously may explain why structural brain differences have been observed despite relatively modest physical demands compared with conventional exercise programs.

Although direct evidence linking yoga-induced changes in cerebral blood flow to structural brain adaptations remains limited, improved vascular support represents another biologically plausible pathway through which yoga could influence memory-related neural structures.

➢ *Mechanistic Synthesis*

Current evidence suggests that no single mechanism is likely to explain the relationship between yoga and brain structure. Instead, yoga appears to influence brain health through multiple interacting biological pathways. Reduced exposure to chronic stress may protect the hippocampus from glucocorticoid-related damage, neurotrophic signalling may support neural plasticity, improved vascular function may enhance cerebral perfusion, and reduced inflammation may contribute to a more favourable environment for neuronal function and adaptation (5,6,25,26). Collectively, these mechanisms provide a biologically plausible explanation for the structural and functional brain differences reported in yoga practitioners.

This multifactorial model is consistent with the unique nature of yoga as a mind–body intervention that integrates physical activity, attentional training, breath regulation, and emotional self-regulation. Although direct mechanistic evidence remains limited, findings from neuroscience, exercise physiology, and contemplative research collectively support the possibility that yoga may influence neural systems involved in memory and cognition (8,16,18).

Importantly, many proposed mechanisms remain inferential rather than experimentally confirmed in yoga-specific populations. Future longitudinal studies incorporating neuroimaging, standardized memory assessments, and biological markers such as cortisol, brain-derived neurotrophic factor (BDNF), and inflammatory mediators are needed to determine whether these pathways directly contribute to neuroanatomical changes and improvements in memory performance.

V. LIMITATIONS OF CURRENT EVIDENCE AND RESEARCH GAPS

Despite growing interest in the neurological effects of yoga, several limitations restrict the interpretation of current findings. Most neuroimaging studies have used cross-sectional designs, making it difficult to determine whether

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observed brain differences are caused by yoga practice or reflect pre-existing characteristics of practitioners (8,12). In addition, many studies have included relatively small sample sizes, which may limit statistical power and the generalizability of findings (10,11).

Another challenge is the considerable variation in yoga interventions across studies. Differences in yoga style, duration, frequency, and the inclusion of breathing or meditation practices make direct comparisons difficult and may contribute to inconsistent findings. Furthermore, only a limited number of studies have examined both neuroimaging outcomes and objective measures of memory, restricting our understanding of whether structural brain differences translate into meaningful cognitive benefits.

Taken together, the existing evidence suggests that yoga may be associated with structural and functional differences in memory-related brain regions; however, the clinical significance of these differences and their causal relationship with yoga practice remain uncertain. Future longitudinal and randomized controlled studies incorporating standardized yoga protocols, validated memory assessments, and neuroimaging measures are needed to determine whether yoga can directly improve memory and induce measurable structural brain changes.

VI. CONCLUSION

The emerging neuroimaging literature suggests that yoga practice is associated with structural and functional differences in brain regions involved in memory and cognition, particularly the hippocampus, prefrontal cortex, anterior cingulate cortex, and insula. These observations are consistent with broader evidence that sustained behavioural and contemplative training may influence neural plasticity, stress regulation, and functional organisation. However, because much of the yoga-specific evidence is cross-sectional, the observed differences cannot yet be interpreted as changes caused directly by yoga practice.

A range of biological pathways may help explain these observations. These include modulation of the HPA axis, increased neurotrophic support, improved cerebral blood flow, and reduced inflammatory activity. Together, these mechanisms offer a plausible explanation for how yoga might support the neural systems underlying memory. However, the current evidence base is still largely correlational, and methodological limitations across studies make it difficult to draw firm conclusions about causality.

Overall, the literature positions yoga as a promising and underexplored area within cognitive and contemplative neuroscience. However, well-designed longitudinal and intervention studies are still needed to determine whether yoga can directly enhance memory and produce measurable changes in brain structure. Clarifying this relationship would be important for understanding whether yoga may serve as a practical and relatively low-cost approach to supporting cognitive health and healthy brain aging.

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