Review Paper

The Neuroscience of Spiritual Meditation: Interactions Between Embodied Posture, Rhythmic Sound, and Neural Network Organization

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ABSTRACT

Introduction: Neuroscientific research increasingly shows that contemplative practices affect brain function primarily through large-scale network dynamics rather than isolated regional changes. Despite the unique integration of embodied movement, rhythmic contemplative spiritual embodiment (RCSE)/rhythmic embodied spiritual meditation, sustained attention, and emotional–spiritual engagement, meditation practice has received less attention than RCSE. This review reframes spiritual meditation as a multimodal neurocognitive system in the context of network neuroscience, predictive processing, and neuroplasticity

Methods: This study was conducted using Web of Science, PubMed, Scopus, and Google Scholar (2010–2026). Inclusion focused on human studies reporting neural, physiological, molecular, or behavioral effects of spiritual meditation or sound recitation via electroencephalography (EEG)/quantitative electroencephalography (QEEG), magnetoencephalography (MEG), or functional magnetic resonance imaging (fMRI). The findings were synthesized qualitatively due to methodological heterogeneity.

Results: According to studies, RCSE was linked to enhanced alpha-theta power, reduced default-mode network activity, strengthened prefrontal-cingulo-insular recruitment, and parasympathetic dominance, supporting attentional regulation and stress reduction. Structural MRI showed corpus callosum neuroplasticity; endocrine data indicated normalized cortisol/alpha-amylase and modulated BDNF/IL-6 expression. Behavioral outcomes included improved emotional stability and mindfulness in psychiatric groups. Comparisons with virtual reality meditation, motor imagery, and rhythmic stimulation revealed shared embodied cognition and plasticity mechanisms. Neurophenomenological analyses highlighted between-network integration as a contemplative expertise marker.

Conclusion: Spiritual meditation emerges as a cohesive mind-body practice influencing networks, autonomic balance, and neuroplasticity at multiple levels. Future research using quantitative EEG (QEEG), magnetoencephalography (MEG), high-field functional MRI (fMRI), tractography, and molecular profiling is needed to elucidate causal pathways and extend findings to cellular/epigenetic domains.

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Introduction

Contemplative practices are increasingly examined in systems neuroscience as structured behavioral interventions capable of modulating large-scale brain networks, autonomic balance, and experience-dependent neuroplasticity [1].

Rhythmic contemplative spiritual embodiment (RCSE)/ rhythmic embodied spiritual meditation represents a highly organized, multimodal practice that integrates rhythmic recitation, sustained attentional focus, regulated breathing, and precisely coordinated postural transitions [2, 3]. Despite its global prevalence and daily performance by nearly two billion people, its neurobiological mechanisms remain comparatively underexplored relative to secular mindfulness paradigms.

From an embodied cognition perspective, ritual prayer consists of repeated sensorimotor sequences-standing, bowing, and prostration- that engage vestibulo-cerebellar pathways and proprioceptive feedback systems central to spatial orientation and motor–cognitive integration [4-6]. The controlled head-down positioning in prostration transiently influences cerebral perfusion and activates baroreflex-mediated autonomic regulation [7, 8], while such repetitive structured movements align with established models of experience-dependent plasticity in distributed motor and parietal networks [5]. The ritual ablution (aesthetic self-cultivation) preceding prayer introduces patterned somatosensory and thermoregulatory stimulation; cutaneous activation projects to insular cortices implicated in interoception and emotional regulation [9], and controlled water exposure may promote a parasympathetic shift that prepares the practitioner for contemplative engagement [10] (Figure 1).

Understanding these anatomical mechanisms is crucial for medical education, as surveys show students often undervalue clinical anatomy unless taught effectively [11]. Respiratory regulation during recitation is typically slow and diaphragmatic, a pattern associated with increased vagal tone and heart-rate variability [12]. Nasal respiration entrains limbic oscillations and modulates attentional processes [13], while respiration–cortical coupling has been linked to enhanced alpha–theta synchronization-oscillatory signatures commonly observed in meditation [14]. Rhythmic spiritual recitation further provides structured acoustic–prosodic input capable of inducing auditory–motor entrainment and thalamocortical synchronization [15-17]. Similar contemplative paradigms demonstrate attenuation of default-mode network (DMN) activity alongside strengthened executive-network recruitment [16]. Cognitively, intentional visualization and semantic reflection during prayer engage dorsolateral prefrontal circuits involved in executive control and predictive simulation [6, 18, 19].

Collectively, the coordinated interplay between breathing, cardiac rhythms, and cortical oscillations during RCSE may foster system-wide physiological coherence [20, 21]. These multimodal components position Islamic prayer as an integrative neurocognitive practice spanning sensorimotor, autonomic, oscillatory, and large-scale network domains.

Meta-analyses of structural and functional neuroimaging have consistently documented meditation-related changes, including increased gray-matter volume and white-matter integrity in prefrontal, cingulate, insular, and hippocampal regions [4], as well as convergent engagement of large-scale networks, such as the DMN, salience network (SN), and fronto-parietal network, with reduced DMN and amygdala activity and strengthened between-network coupling [7, 9, 10]. However, these findings are largely derived from cross-sectional designs and heterogeneous practices, limiting causal inference [5]. Within contemporary taxonomies, loving-kindness meditation shares core features with RCSE-including sustained attention, rhythmic repetition, alpha-theta modulation, and coordinated fronto-parietal and DMN recruitment-suggesting overlapping mechanisms of attentional control and affective regulation despite distinct cultural contexts [12-15].

Religious and spiritual practices are increasingly recognized as embodied, repeatable behaviors capable of shaping brain function and health outcomes. RCSE, performed five times daily with standardized structure, provides a unique framework for emotional regulation and stress reduction through attentional restoration and a profound sense of divine connection [6, 16-21]. Neurophysiological studies report increased alpha power, gamma activity, and interhemispheric coherence during RCSE- signatures of calm, focused attention [22-24]—while both Islamic and Christian contemplative prayer engage prefrontal regions and reduce parietal sensory activity, reflecting sustained attention and altered self-representation [20, 22-25].

This review synthesizes electrophysiological, neuroimaging, endocrine, and molecular evidence to evaluate whether spiritual meditation recruits mechanisms comparable to those in contemporary contemplative neuroscience, while highlighting its distinctive embodied and

theistic features. It further proposes an interdisciplinary AI–neuroscience framework to examine the linguistic, acoustic, and motor structure of RCSE, offering a novel empirical foundation for studying neurospiritual practices.

Materials and Methods

Study design

This study was conducted as a systematic narrative review examining neurophysiological and neuroimaging evidence related to RCSE and closely associated meditative and mind–body practices.

Data sources and search strategy

A comprehensive literature search was conducted across ISI Web of Science, PubMed, Scopus, and Google Scholar, covering studies published between January 2010 and January 2026. The search strategy was designed to capture empirical investigations linking Islamic prayer and meditation-related practices to brain function, connectivity, learning, and motivational processes using objective neuroimaging methods. The following Boolean search string was applied consistently across databases, explicitly incorporating the target keywords:

([Prayer] OR [prayer [MeSH]] OR [meditation] OR [rhythmic recitation] OR [rhythmic embodied spiritual meditation] OR [spiritual practice] OR [rhythmic contemplative spiritual embodiment [RCSE]] OR [therapeutic exercise] AND [Neuroimaging] OR [EEG] OR [QEEG] OR [quantitative electroencephalography] OR [functional magnetic resonance imaging [fMRI]] AND [brain connectivity] OR [functional connectivity] OR [neural networks] OR [default mode network] AND [brain oscillations] OR [alpha waves] OR [theta waves] OR [gamma waves] AND [learning] OR [motivation] OR [mental health] OR [spiritual health] OR [emotion regulation] OR [hormonal regulation] OR [stress] NOT [Animals [MeSH]]).

Inclusion and exclusion criteria

Studies were eligible for inclusion if they involved human participants, employed objective neurophysiological or neuroimaging methods- specifically EEG, QEEG, fMRI, or diffusion tensor imaging - and reported neural, physiological, cognitive, emotional, or psychological outcomes directly related to RCSE, rhythmic recitation, or closely associated Islamic meditative practices. Only articles published in peer-reviewed scientific journals and written in English were considered to ensure methodological rigor, interpretability, and reproducibility. Studies were excluded if they lacked objective neural or physiological measures, were conducted on animal models, consisted solely of theological, philosophical, or doctrinal discussions without empirical data, or were editorials, commentaries, opinion papers, conference abstracts, letters to the editor, book chapters, or other forms of grey literature without original experimental findings. Articles with insufficient methodological details to allow reliable evaluation of electrophysiological or neuroimaging outcomes were also excluded. To ensure comprehensive coverage and reduce selection bias, a broad and sensitive search strategy was implemented across multiple databases using extensive Boolean operators, and reference lists of all eligible studies were manually screened to identify additional relevant publications not captured in the initial search.

Data synthesis

Due to substantial heterogeneity in study design, participant characteristics, neuroimaging modalities, analytical approaches, and outcome measures, a quantitative meta-analysis was neither appropriate nor methodologically justified. Accordingly, findings were synthesized using a qualitative integrative approach, emphasizing convergence and divergence across studies rather than pooled effect sizes. Results were systematically compared across neurophysiological (EEG/QEEG) and neuroimaging (fMRI) domains, with particular attention to recurring patterns in brain oscillatory dynamics, large-scale functional connectivity, autonomic regulation, and cognitive–emotional outcomes. Interpretation of the evidence was guided by the proposed ligand–receptor neurospiritual framework, in which RCSE and related practices are conceptualized as meaning-laden, embodied behavioral inputs (ligands) interacting with neural systems (receptors) to modulate network-level brain dynamics, mental states, and experience-dependent plasticity. This framework enabled mechanistic integration of findings across disparate methodologies while avoiding overgeneralization and preserving sensitivity to contextual, phenomenological, and neurobiological variability.

Results

Neural oscillatory dynamics during rhythmic contemplative spiritual embodiment

Across electrophysiological, neuroimaging, autonomic, molecular, behavioral, and interventional studies, converging evidence indicates that RCSE and related spiritual meditative practices are associated with systematic modulation of brain dynamics, autonomic regulation, and experience-dependent neuroplasticity.

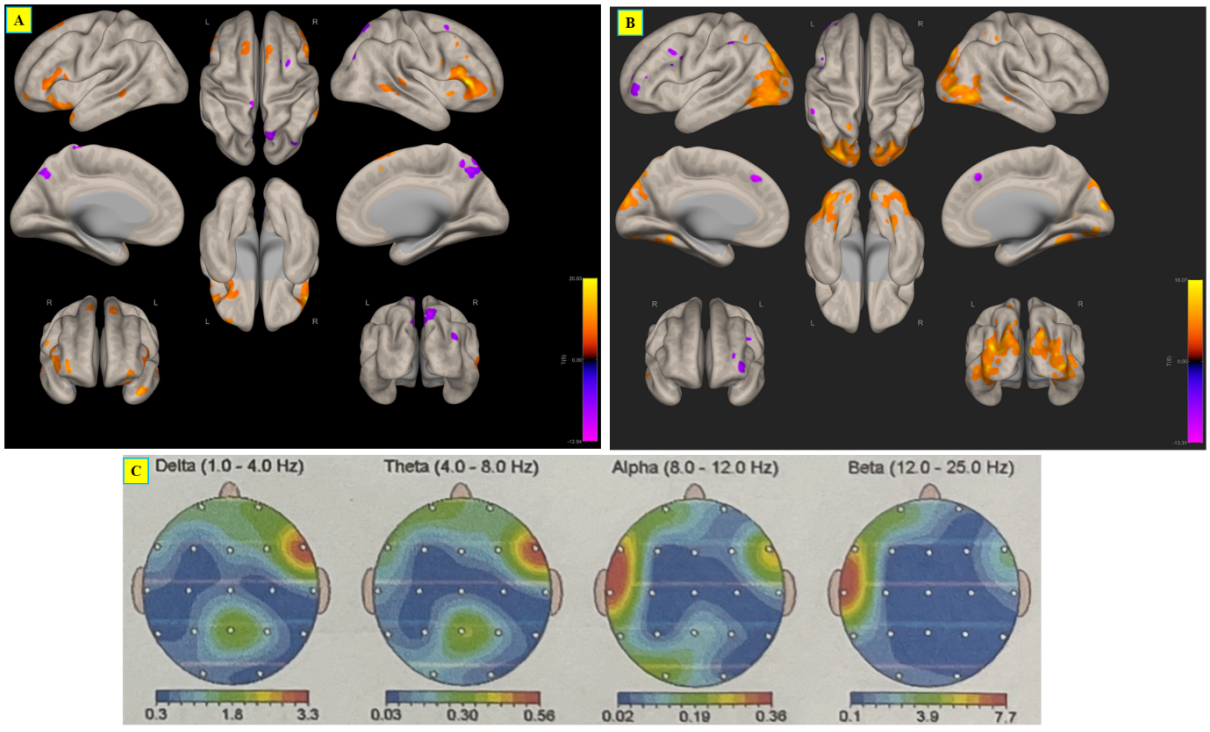


Figure 1. Spiritual meditation engages an integrated network of attentional, emotional, cognitive, and autonomic processes A) Attentional control: Engagement of frontoparietal regions, including the frontal eye field and dorsal attention network, supports sustained attention, visuospatial selection, and cognitive control. B) Socio-emotional processing: Modulation of posterior superior temporal and temporoparietal regions may reflect changes in social–emotional integration and higher-order perceptual processing. C) Neural oscillations: Meditative states are commonly associated with changes in theta and alpha activity, reflecting sustained attention, internal monitoring, and reduced cognitive interference.

MahdiNejad et al. reported that spirituality-related neural states vary as a function of age and gender, with older individuals exhibiting stronger alpha and theta activity and faster transition into spiritually defined EEG states [26]. Focusing specifically on rhythmic recitation, Khanam et al. demonstrated that two rak'ahs of rhythmic recitation elicited significantly greater frontal and parietal alpha relative power compared with both eyes-open and eyes-closed resting conditions ($P<0.05$) [27]. Similarly, Doufesh et al. observed increased occipital and parietal alpha power during rhythmic recitation, accompanied by elevated parasympathetic indices (normalized unit of high frequency [nuHF]) and reduced sympathetic markers (normalized unit of low frequency [nuLF], LF/HF), with significant correlations between alpha power and heart-rate variability measures [3].

Complementary findings from dhikr-based practices show increases in delta and theta oscillations during recitation-based meditation states [28, 29]. Broader meditation research has confirmed that alpha–theta enhancement represents a robust electrophysiological correlate of attentional stabilization and reduced mind wandering [30, 31]. Together, these findings indicate that RCSE engages oscillatory mechanisms comparable to focused-attention meditation while maintaining distinct ritual and motor characteristics.

Molecular and endocrine correlates of prayer-induced regulation

Beyond electrophysiological modulation, emerging evidence suggests that Islamic prayer influences endocrine and molecular stress pathways. Sobhani et al. demonstrated that a brief four-cycle Ritualized prayer induced rapid normalization of salivary cortisol and alpha-amylase levels, with bidirectional adjustment depending on baseline stress levels [32]. Additionally, state-dependent modulation of stress-related gene expression-including brain-derived neurotrophic factor (BDNF) and interleukin-6 (IL-6)-was observed post-prayer [32].

Beyond endocrine effects, the prostration posture in RCSE may influence cerebrospinal fluid (CSF) dynamics and intracranial pressure regulation. During sujud, the head-down position creates transient hydrostatic gradients that enhance CSF pulsatility, facilitating its return from the spinal subarachnoid space to the fourth ven-

tricle via the foramina of Magendie and Luschka. This mechanism supports glymphatic clearance, potentially reducing neurotoxic buildup and preventing headaches or tension by modulating intracranial and intraocular pressure. Preliminary studies suggest that repeated postural inversions promote ependymal cell reorganization in cerebral ventricles, fostering neuroplasticity through improved ciliary motility and CSF circulation, which aligns with RCSE's role in autonomic balance and stress reduction [8, 33, 34].

At a broader level, multimodal meditation-based interventions have been shown to produce coordinated neural and molecular changes. Jinich-Diamant et al. reported reductions in default mode and SN intra-connectivity alongside plasma-based alterations in glycolytic enzymes (neuron-specific enolase [ENO2], lactate dehydrogenase A [LDHA]), immune pathways, and neuroplasticity-related markers [35]. Although not specific to Salah, these findings provide mechanistic context suggesting that prayer-related states may engage systemic neuroendocrine and transcriptional pathways associated with adaptive stress regulation.

Structural neuroplasticity and interhemispheric integration

Structural neuroimaging evidence indicates potential experience-dependent adaptations associated with sustained prayer practice. Baykara et al. identified significant subregional shape differences in the corpus callosum (body, rostrum, splenium) in regular RCSE practitioners compared with controls ($P<0.001$) [36], implicating interhemispheric pathways connecting motor, sensory, parietal, and prefrontal cortices.

Meditation research more broadly reports cortical thickness alterations and white-matter changes in frontoparietal and insular regions [37-40]. Effective connectivity (EC) analyses further demonstrate that meditation expertise is better characterized by whole-brain network reconfiguration than isolated structural metrics [41].

In contrast, stereological and MRI-based studies in different neurological and psychiatric disorders consistently report volumetric reductions and network disintegration in cortical and subcortical regions [42-45]. These comparisons highlight the relevance of examining structured embodied practices as potential modulators of large-scale structural integration.

Functional network reconfiguration and large-scale connectivity

Converging fMRI, magnetoencephalography (MEG), and EEG evidence suggests that prayer-related states involve dynamic modulation of large-scale brain networks. Reduced activity within the DMN-a network implicated in self-referential processing and rumination-has been consistently reported across contemplative practices [9, 21, 46-48]. Simultaneously, increased recruitment of prefrontal, anterior cingulate, and insular cortices supports enhanced executive control and interoceptive awareness [25, 49].

Meditation-induced expertise has been associated with increased between-network integration, particularly coupling between default and cognitive control networks [50, 51]. High-field 7T fMRI investigations of advanced meditative states have demonstrated reliable engagement of thalamic and large-scale cortical systems aligned with first-person phenomenology [52].

Behavioral and computational studies further support the importance of dynamic network diversity and plastic reconfiguration in shaping cognitive flexibility and learning efficiency [52, 53]. Together, these findings suggest that RCSE-related neural states may involve coordinated attenuation of internally focused DMN activity alongside strengthened integration with control and salience systems.

Embodied and sensorimotor mechanisms of prayer: Clinical and behavioral outcomes

Islamic prayer incorporates repeated postural transitions (standing, bowing, and prostration), controlled breathing, and rhythmic vocalization, engaging sensorimotor and proprioceptive systems (Figure 2). Neuroplasticity-based rehabilitation studies demonstrate that virtual reality–based action observation and motor imagery (VR-AOMI) can enhance long-term potentiation–like plasticity in motor cortex circuits [53-55]. Similarly, neuromuscular and proprioceptive training programs improve sensorimotor function and psychological well-being in older adults [56].

Consistent with these findings, Nagai et al. showed that a 10-week neuromuscular and proprioceptive training program focusing on posture, balance, movement control, and slow breathing significantly improved sensorimotor performance, mental health, stress, and sleep quality in active seniors [57]. Technology-mediated contemplative practices further support these mechanisms:

Lee et al. reported reductions in depressive and anxiety symptoms following immersive VR meditation, while Faria demonstrated that a single 10-minute VR relaxation session significantly reduced perceived stress and improved well-being, particularly in individuals with higher baseline depression [37, 58, 59]. Cinalioglu et al. reported comparable benefits in younger adults while highlighting the need for further investigation in older populations, an issue currently being addressed in an ongoing randomized controlled trial evaluating eight 15-minute VR meditation sessions over four weeks in adults aged 60 and older, with outcomes spanning mental health, sleep, quality of life, and mindfulness [50]. De Filippi et al. demonstrated that meditation induces both short- and long-term alterations in brain function and structure. Using MRI-based network modeling, the authors showed that whole-brain EC more accurately distinguished meditation states and practitioner expertise than conventional functional or structural connectivity. Discriminative EC patterns primarily involved large-scale networks, particularly within the left hemisphere, while structural analyses revealed modest but significant strengthening of connections among somatomotor, dorsal attention, subcortical, and visual systems [41]. Ganesan et al. demonstrated that meditation encompasses a spectrum of attentional training practices capable of substantially modulating consciousness, perception, and emotional well-being, with effects that intensify with sustained practice and expertise. Using ultra-high-field 7 Tesla fMRI, the authors examined neural activity during jhana meditation in an expert practitioner across multiple sessions and observed consistent engagement of the thalamus and large-scale brain networks, including somatomotor, limbic, default-mode, control, and temporo-parietal systems. Notably, attention and SN exhibited enhanced reliability when neural activity was aligned with first-person phenomenological reports. These findings underscore the utility of high-field fMRI for characterizing the neural dynamics of advanced meditative states and highlight the value of neurophenomenological approaches in meditation research [52]. Complementing exercise-based interventions, Martínez-Molina et al. highlighted the neurorehabilitative potential of rhythmic auditory stimulation (RAS) and music-based therapies. RAS, delivered via metronomic or musical rhythms, enhances motor synchronization and neuroplasticity and can be integrated with robotics and VR. Music-based interventions, such as melodic intonation and singing, engage distributed language and motor networks, supporting recovery in stroke, aphasia, and other neurological conditions [60]. Jinich-Diamant et al. demonstrated that a 7-day mind–body retreat combining meditation, cognitive reconceptualization, and open-label placebo rituals induces coordinated neural and molecular changes consistent with systemic mind–body modulation. fMRI revealed meditation-related reductions in intra-network connectivity within the default mode and SN, decreased prefrontal–cerebellar coupling, and global desynchronization, indicating suppression of self-referential and predictive processing. These neural effects converged with plasma-based molecular alterations, including enhanced glycolysis (elevated neuron-specific enolase [ENO2] and lactate dehydrogenase A [LDHA]), upregulation of neuroplasticity-related factors, immune pathway modulation, endogenous opioid activation, and transcriptomic changes in extracellular RNAs linked to neurotransmission and metabolic regulation (e.g. RIBC1, MIR455). Together, these findings identify between-network integration as a core neural signature of meditation expertise and highlight tightly coupled neuroimaging and molecular adaptations underlying mind–body interventions [35]. Beaty et al. demonstrated that individual differences in Openness to Experience as a trait closely linked to imagination and creativity are associated with distinct patterns of large-scale brain network dynamics at rest. Using resting-state fMRI and dynamic functional connectivity analyses across two large cross-cultural samples, the study showed that individuals high in openness spend more time in a brain state characterized by integrated activity between the default network and cognitive control systems (including executive, salience, and dorsal attention networks [DAN] [Figure 2]). This connectivity profile was robust across cultures and independent of intelligence and other personality traits, suggesting that imaginative cognition relies on flexible cooperation between internally generated thought and top-down control systems rather than isolated default-network engagement [51]. Zhang et al. showed that dynamic changes in perception, cognition, and performance are driven by two core brain properties: Mental state diversity, reflected in spatially distinct functional network configurations, and neuroplasticity, reflected in experience-dependent reorganization of network topology over time. EEG analyses demonstrated that different mental states are associated with marked differences in information-processing efficiency, while cognitive training reshapes small-world network organization to improve global efficiency and skill acquisition [61]. Farahbakhsh et al. provide behavioral evidence that visual imagination- understood as top-down activation of perceptual representations in the absence of sensory input- can bias perception in ways comparable to real sensory experience. Using priming and adaptation effects in ambiguous figures, the study introduces an ob-

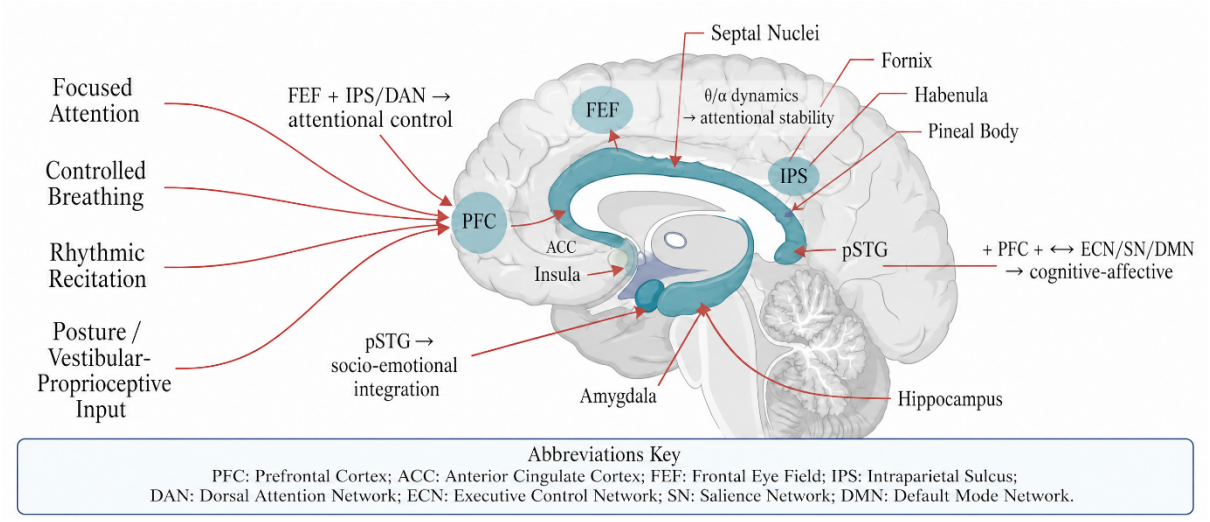


Figure 2. Network-level brain–body regulation during spiritual meditation

The schematic depicts a proposed multimodal framework linking focused attention, controlled breathing, rhythmic recitation, posture, and sensory–vestibular input with distributed cortical–limbic and large-scale network dynamics. Prefrontal cortex, anterior cingulate cortex, insula, frontal eye field, intraparietal sulcus, posterior superior temporal gyrus, hippocampus, and amygdala represent complementary substrates for attentional control, interoceptive processing, socio-emotional integration, memory, and affective regulation. Reciprocal interactions among the executive-control, salience, and default-mode networks may facilitate adaptive switching between externally focused attention and self-referential processing. Coordinated autonomic activity and cortical oscillatory dynamics may further contribute to stress regulation, emotional stability, cognitive control, and embodied contemplative experience.

jective measure of imagination beyond self-report and demonstrates strong individual-level correspondence between real and imagined perceptual conditioning. These findings support predictive-processing models in which internally generated representations shape perceptual inferences via top-down priors [62]. Reddan et al. showed that imagined exposure to threat reduces neural and physiological threat responses as effectively as real exposure by engaging a shared extinction network centered on the ventromedial prefrontal cortex and its interactions with the amygdala, hippocampus, sensory cortex, and nucleus accumbens. Notably, imagined extinction uniquely recruited the nucleus accumbens, underscoring the role of internally generated simulations in updating threat values [63] (Table 1).

These converging findings support the interpretation of RCSE as an embodied neurocognitive practice integrating auditory–motor coupling, proprioceptive input, and autonomic regulation within a repeated behavioral framework.

Discussion

Meditation practices span diverse cultural and religious traditions, sharing core cognitive and neural mechanisms despite philosophical differences [64]. From a neuroscience viewpoint, rhythmic recitation mirrors focused-attention and mantra-based meditation through sustained focus, Quranic recitation, and timed movements, yielding similar neural outcomes, such as enhanced fronto-parietal connectivity, reduced default-mode activity, and boosted alpha-theta oscillations [65]. Its emotional elements-gratitude, hope, and trust-resemble loving-kindness meditation, promoting emotional control and lessened limbic reactivity. However, rhythmic recitation stands out with its theistic and embodied ritual structure, engaging key networks for attention, emotion, and self-reference in ways that support mental, emotional, and physical well-being [66, 67].

Mindfulness meditation cultivates non-judgmental present-moment awareness, boosting attention regulation, body awareness, emotion control, and adaptive self-view. Neuroimaging reveals short-term "state" changes during practice and long-term "trait" adaptations, with structural MRI showing greater gray-matter volume and cortical thickness in the DMN, dorsal attention network (DAN), fronto-limbic, and insular regions, plus stronger resting-state connectivity across these networks [38-40]. These shifts enhance self-regulation, resilience, and flexibility, offering therapeutic value for stress and psychiatric issues [40]. As a body-mind relaxation method, RCSE shows promise in easing stress and depression

Table 1. Neurophysiological and sensorimotor mechanisms underlying balance and proprioceptive integration during the ritual postures of RCSE

Domain	Visual/Experimental Representation	Mechanistic Interpretation (Evidence-based Scientific Framing)
Vestibular regulation and postural control	Stabilometric platform showing center-of-pressure (CoP) excursion during standing, bowing, and prostration; 3D motion capture of head and trunk orientation; semicircular canal and otolith organ schematics.	Sequential postural transitions in prayer activate semicircular canals and otolith organs. Cerebellar integration refines vestibulospinal reflexes, supporting dynamic balance. Repetitive cycles enhance anticipatory postural adjustments and sensorimotor recalibration.
Proprioceptive integration	Joint-angle tracking (motion capture) and muscle spindle afferent schematic projecting to dorsal columns, spinocerebellar tracts, and somatosensory cortex; plantar mechanoreceptor activity mapped.	Multimodal proprioceptive input converges in cerebellum and posterior parietal cortex, refining internal body schema. This improves limb position sense, postural symmetry, and coordinated movement, which are essential for accurate ritual postures.
Cerebrospinal fluid (CSF) dynamics	Phase-contrast MRI of CSF flow during head-down vs. upright posture; pressure gradient vectors illustrated.	Head-down tilts transiently alter CSF hydrodynamics, potentially modulating glymphatic clearance. Stable cerebral perfusion supports cortical and cerebellar function, indirectly enhancing sensorimotor processing for postural control.
Neurovascular & network-level effects	fMRI and functional connectivity maps showing cerebellar, vestibular, and somatosensory network integration; DMN suppression and salience network activation during prayer postures.	Structured prayer movements combined with attention and recitation reduce DMN hyperactivity and enhance sensorimotor–cognitive network coherence. Increased alpha–theta oscillations facilitate internally directed attention and fine-tuning of balance and proprioceptive feedback.
Autonomic nervous system modulation	HRV spectral analysis (↑ HF power, ↓ LF/HF ratio) synchronized with posture transitions and breathing cycles.	Parasympathetic dominance during slow rhythmic breathing stabilizes cardiovascular function, supporting vestibular and proprioceptive integration. Reduced sympathetic arousal optimizes cerebellar and cortical processing of postural and spatial information.
Electromagnetic field (bioelectromagnetic activity)	MEG/EEG and MCG conceptual maps illustrating cortical and cardiac oscillatory coupling during meditation/prayer postures.	Coherent cardiac–cortical oscillations may enhance network-level synchronization, facilitating sensorimotor integration, body schema stability, and attention modulation relevant for precise balance and posture maintenance.

ANATOMICAL SCIENCES

Abbreviations: RCSE: Rhythmic contemplative spiritual embodiment; fMRI: Functional magnetic resonance imaging; DMN: Default-mode network; HRV: Heart rate variability; HF: High frequency; LF: Low frequency; MEG: Magnetoencephalography; EEG: Electroencephalography; MCG: Magnetocardiography.

among young adults. Neuro-spiritual practices, such as zikr, increase delta waves for calm states [28, 68, 69].

Similarly, resting-state fMRI studies have demonstrated that Benson's Mind-Body Relaxation Movement normalizes aberrant thalamocortical functional connectivity in medication-naive adolescents with major depressive disorder, particularly strengthening connections between thalamic subregions and the default mode network, which support attention, self-referential processing, and higher-order cognitive functions [70, 71]. The above findings suggest that auditory-guided spiritual practices and meditative prayer can change neurophysiology and connectivity to decrease stress and provide effective non-pharmacological interventions for depression [28, 29, 70].

Spiritual meditation has positive effects on mental health. However, Zahir and Qoronfleh emphasize the scarcity of research regarding Islamic practices, such as dhikr and reciting the Quran. Traditionally, these practices have been effective in dealing with issues like anxiety, addiction, and emotional problems. The positive effects of these practices are religion-neutral and can act as complementary and integrative medicine [72].

Sobhani et al. showed that a short four-cycle Ritualized prayer significantly normalizes salivary cortisol and alpha-amylase levels and modulates stress-related genes (interleukin-6 [IL6], brain-derived neurotrophic factor [BDNF]), suggesting that Islamic prayer affects stress-regulatory mechanisms at both the endocrine and genetic levels [32]. Qualitative studies from psychiatric samples emphasize the importance of religious practice by demonstrating that participating in rhythmic recitation in patients with schizophrenia promotes emotional stability, mindfulness, focused attention, and comfort, while barriers to religious practice are related to negative emotional and physical outcomes [73]. Neuroimaging studies indicate that practicing forms of RCSE, such as rhythmic recitation, relate to structural and functional changes in the corpus callosum, implying a neuroplastic relationship with interhemispheric systems involved in prayer [36]. The complementary evidence from fMRI, MEG, and EEG studies indicates that these prayer-induced states decrease activity in the default mode network, which is related to mind-wandering and rumination, and increase activation in the prefrontal, anterior cingulate, and insular cortices, related to executive control, emotional regulation, and interoception [21, 46-48, 74, 75].

In particular, technology-assisted contemplative practices, such as immersive VR meditation, have been shown to have positive effects in alleviating stress, anxiety, and depression at various ages [37, 50, 58, 59, 76]. Moreover, research has demonstrated the importance of whole-brain effective connectivity in the development of meditation expertise [41]. Neuroplasticity relates contemplative practices to body plasticity. Virtual reality–based action observation and motor imagery (VR-AOMI) stimulates long-term potentiation-like plasticity in the motor cortex, especially in those less responsive to stimulation [56, 77]. Structured neuromuscular and proprioceptive training for posture, breathing, balance, and movement control helps improve sensorimotor function and psychological well-being in older adults [57]. The process of RCSE consists of repeated body movements, including posture, breathing, and attention, which may be linked to overlapping mechanisms of embodied plasticity. The study established the interrelationship between movement, attention, and consciousness, and the increase in blood flow to the brain during the process of prostration, or sujud, indicating improvements in attention and memory via distinct physical-neural mechanisms [28]. At the end of contemplative expertise, Ganesan et al. used ultra-high-field 7T fMRI to show reliable engagement of thalamic and large-scale cortical networks during jhana meditation, underscoring the value of neurophenomenological approaches for characterizing deep altered states of consciousness [52]. Finally, RAS provides an additional mechanistic bridge. Decades of research have demonstrated that physical exercise broadly enhances brain plasticity across the lifespan [78], while Martínez-Molina et al. highlighted how RAS and music-based therapies promote motor synchronization and recovery via distributed language and motor networks. In this context, structured spiritual Islamic recitation, with its rhythmic, melodic, and repetitive properties, represents a culturally meaningful auditory stimulus capable of engaging similar neuroplastic mechanisms supporting cognitive, emotional, and sensorimotor integration [24, 60, 79].

Meditation states are embedded in systemic changes, with fMRI showing reduced network connectivity and plasma adaptations in glycolysis, neuroplasticity, and immune pathways [35]. Predictive-processing evidence shows imagined threats attenuate via vmPFC-limbic networks [63, 80], with visual imagination biasing perception through top-down priors [62]. Imaginative cognition integrates default and control systems [51], while dynamic networks reshape topology for efficiency [61]. Thus, RCSE integrates meaning, control, and sensory inputs for adaptive priors via multilevel plasticity. An AI-neuroscience framework modeling Quranic rhythm with neuroimaging could probe auditory processing, predictive coding, and network integration, comparing objectively with other texts [81].

Conclusion

The evidence reviewed demonstrates that RCSE is not merely a devotional or symbolic act, but a multimodal neurocognitive and embodied practice capable of systematically modulating brain dynamics, autonomic regulation, and experience-dependent neuroplasticity. Across electrophysiological, neuroimaging, endocrine, behavioral, and clinical studies, spiritual recitation and related practices have consistently engaged large-scale brain networks involved in attention, emotion regulation, self-referential processing, sensorimotor integration, and stress adaptation. Key convergent findings include modulation of alpha–theta oscillatory dynamics, attenuation of default mode network activity, enhanced recruitment of prefrontal–cingulo–insular control systems, coordinated parasympathetic dominance, and evidence of structural and functional network reorganization. These effects align closely with contemporary frameworks of mental state diversity, predictive processing, and neuroplasticity, positioning RCSE alongside music-based therapies and embodied movement interventions. Importantly, emerging molecular and endocrine data suggest that prayer-related states influence stress hormones, gene expression, metabolic pathways, and immune signaling, extending RCSE effects beyond neural circuits to epigenetic and cellular levels. However, despite this converging evidence, definitive conclusions on causality, dose–response relationships, and underlying mechanisms remain limited by methodological heterogeneity and small sample sizes. To rigorously establish the psychological, epigenetic, and cellular dimensions of Islamic prayer, future research must employ precise experimental designs and multimodal measurement strategies, leveraging advanced technologies such as QEEG, MEG, high-field fMRI, diffusion tensor tractography, magnetic resonance spectroscopy, and molecular profiling. Such integrative approaches are essential to shift the field from correlational observations toward a mechanistic, systems-level understanding of how RCSE shapes mind–body health.

Ethical Considerations

Compliance with ethical guidelines

There was no need for ethics approval.

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Authors' contributions

Conceptualization and supervision: Auob Rustamzadeh; Methodology and validation: Auob Rustamzadeh and Enam Alhagh Gorgich; Investigation and data curation: Enam Alhagh Gorgich and Amir Raoofi; Formal Analysis and Visualization: Amir Raoofi; Writing the original draft: Enam Alhagh Gorgich; Review & editing: Auob Rustamzadeh and Amir Raoofi; Final approval: All authors.

Conflict of interest

The authors declared no conflict of interests.

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