

Clinical Efficacy of Medhya Rasayana in Combating Smart-Screen Induced Cognitive Fatigue: A Neuro-Ayurvedic Framework for Contemporary Digital Illness

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ABSTRACT

Prolonged exposure to high-luminance smart-screens across vocational, academic, and domestic environments has introduced a modern epidemiological crisis known as screen-induced cognitive fatigue. This clinical syndrome is characterized by a multi-systemic failure of top-down cognitive governance, presenting as executive dysfunction, depleted working memory capacity, severe attentional lapses, neuro-visual exhaustion, and continuous low-grade digital burnout. In contemporary biomedical systems, treatment options remain predominantly limited to non-pharmacological behavioral revisions, failing to offer direct neuro-restorative or targeted chemical protection. In contrast, classical Ayurveda provides a robust conceptual, diagnostic, and therapeutic matrix that maps this state through the interlocking pathologies of Majja Dhatu Kshaya (depletion of nervous system tissue essence), Prana-Sadhaka Disruption, and Prajnaparadha (volitional transgressions against somatic boundaries). This paper presents an exhaustive clinical investigation into the efficacy, molecular mechanisms, pharmacokinetics, and neuro-Ayurvedic synthesis of Medhya Rasayana—a highly specific category of nootropic botanicals including Bacopa monnieri (Brahmi), Centella asiatica (Mandukaparni), Convolvulus prostratus (Shankhapushpi), and Glycyrrhiza glabra (Yashtimadhu). Combining findings from a 180-day randomized triple-arm trial with extensive institutional data across diverse clinical cohorts, we demonstrate that structured administration of Medhya Rasayana significantly reverses digital cognitive depletion. Statistically reliable improvements are observed in objective metrics of attention retention, executive processing speed, and working memory

performance. These outcomes correlate with a significant down-regulation of acetylcholinesterase (AChE) activity, attenuation of cortisol-driven HPA-axis hyper-reactivity, and robust up-regulation of brain-derived neurotrophic factor (BDNF). This clinical synthesis provides an evidence-based, safe, and highly effective therapeutic path for deploying traditional nootropics as a structural countermeasure against digital cognitive attrition.

KEYWORDS: *Medhya Rasayana, Cognitive Fatigue, Smart-Screen Overuse, Neuro-Ayurvedic Paradigm, Bacopa monnieri, Acetylcholinesterase, Neuroplasticity, Digital Burnout.*

INTRODUCTION

The modern human environment has shifted profoundly toward digital spaces, tethering daily professional, educational, and personal life to high-intensity smart-screens. Desktop computers, smartphones, tablets, and virtual-reality systems deliver a constant stream of high-luminance light and complex sensory data. While this shift has vastly optimized global information accessibility, it has simultaneously introduced a widespread neurological challenge: screen-induced cognitive fatigue. This condition manifests as an objective decline in attention allocation, impaired executive control, slowed cognitive processing speed, and persistent mental exhaustion. Unlike classic physical or transient mental tiredness, digital cognitive fatigue is a systemic issue driven by prolonged over-engagement of top-down attention networks and continuous visual-sensory stimulation.

At the cellular and systems level, the neurobiology of this condition is centered on the prefrontal cortex (PFC) and the hippocampal formation. Sustained demands on executive attention require high metabolic activity in these regions, depleting astrocyte glycogen reserves and causing extracellular adenosine to accumulate. This rise in adenosine downregulates striatal dopamine release, which patients experience as diminishing motivation, reduced mental resilience, and a steep increase in perceived cognitive effort. Furthermore, exposure to high-energy short-wavelength blue light (450–480 nm) directly suppresses the natural nocturnal synthesis of melatonin in the pineal gland. This disruption of circadian rhythms compromises the glymphatic system's ability to clear metabolic waste during deep sleep, creating a cycle of low-grade neuroinflammation and oxidative stress that

hinders long-term potentiation (LTP) and neuroplasticity.

Despite the scale of this issue, contemporary biomedicine has few target pharmacological treatments. Clinical guidance typically relies on behavioral adjustments, such as enforced screen breaks, blue-light filters, and generic sleep hygiene protocols. While helpful, these steps do not address the underlying neuro-chemical depletion, nor do they active pathways to repair damaged synaptic structures. This gap highlights the need for safe, evidence-based neuroprotective strategies capable of increasing cognitive capacity and strengthening the central nervous system against modern environmental stress.

Ancient Ayurvedic clinical frameworks, particularly those preserved in the Caraka Samhita, Sushruta Samhita, and Ashtanga Hridaya, offer valuable perspectives on these challenges. Ayurveda conceptualizes this condition through a systematic breakdown of internal balance, specifically identifying the degradation of Medha (the multi-faceted intellectual matrix governing retention, processing, and recall), the vitiation of Prana Vata and Sadhaka Pitta, and the structural depletion of Majja Dhatu (nervous tissue essence). These changes are understood to stem from Prajnaparadha—the intellectual error of exceeding natural somatic limits through the chronic over-utilization (Atiyoga) of the visual and auditory senses (Indriyas).

Crucially, the classical Ayurvedic pharmacopoeia contains a highly specialized class of therapeutic formulations known as Medhya Rasayana. These are not simple stimulants; they are comprehensive, tissue-specific formulas designed to nourish the nervous system, reduce oxidative stress, enhance cognitive resilience, and stimulate neurogenesis. This paper provides a thorough examination of the clinical efficacy, underlying mechanisms, and integrative deployment of Medhya Rasayana—specifically focusing on *Bacopa monnieri*, *Centella asiatica*, *Convolvulus prostratus*, and *Glycyrrhiza glabra*—as a primary, scientifically validated intervention against smart-screen induced cognitive fatigue.

PATHOPHYSIOLOGY OF SMART-SCREEN INDUCED COGNITIVE FATIGUE

Neurobiological and Biochemical Mechanisms

Understanding screen-induced cognitive fatigue requires looking closely at how sustained, top-down focus affects the brain's metabolic and chemical networks. The frontoparietal

control network and the prefrontal cortex are crucial for filtering out digital distractions and maintaining goal-directed behavior. This intense processing demands significant energy, fueled by the rapid breakdown of adenosine triphosphate (ATP) within both neurons and supporting astrocytes. As metabolic waste accumulates over hours of screen use, extracellular adenosine concentrations rise. Adenosine acts on inhibitory A1 receptors, suppressing the release of key neurotransmitters like dopamine and acetylcholine in the prefrontal cortex. This neuro-chemical shift explains why patients experience a distinct drop in motivation and executive processing speed as the day progresses.

Concurrently, the constant visual input from modern back-lit displays strains the eyes and brain. High-energy blue light penetrates deep into the eye, stimulating intrinsically photosensitive retinal ganglion cells (ipRGCs). These cells project directly to the suprachiasmatic nucleus (SCN), suppressing the natural evening rise of melatonin. This delay disrupts the restorative stages of slow-wave sleep. During deep sleep, the brain's glymphatic system expands, flushing out metabolic waste and proteins accumulated during waking hours. When sleep is shortened or disrupted by late-night screen use, these waste products remain, triggering microglial activation and a low-grade inflammatory response. This chronic inflammatory state leads to an overproduction of reactive oxygen species (ROS), which damages lipid membranes in the hippocampus and reduces the expression of brain-derived neurotrophic factor (BDNF), ultimately impairing synaptic plasticity and memory consolidation.

The Ayurvedic Clinical Matrix and Pathodynamics

Ayurveda provides a clear, parallel framework for analyzing these digital illnesses. It views the chronic overuse of digital devices as a classic example of Asatmyendriyartha Samyoga—specifically the excessive and improper engagement (Atiyoga) of the eyes (Chakshurendriya) and ears (Shravanendriya) with intense, artificial inputs. This sensory overload disrupts the primary functional forces (Doshas) and structural foundations (Dhatus) of the body, initiating a predictable sequence of systemic imbalance.

First, the highly kinetic, rapidly changing nature of digital media directly provokes Prana Vata, the subtype of Vata governing the mind, sensory inputs, and neural impulses. When Prana Vata becomes hyper-reactive, it destabilizes Manas (the mind), manifesting as split

attention, restlessness, and disrupted sleep. Simultaneously, the intense, high-luminance light from smart-screens provokes Sadhaka Pitta, the subtype of Pitta located in the heart and brain, responsible for processing emotions, logic, and decisive focus. This excess heat exhausts the subtle neurochemical substrates that support clear thinking and focused determination.

Over time, this continuous functional stress strains the body's deeper structural tissues. In Ayurvedic anatomy, the brain, spinal cord, and entire central nervous system are recognized as components of Majja Dhatu. This tissue depends on an unctuous, grounding quality (Snigdha Guna) to cushion neurons and facilitate smooth mental processing. Chronic mental overexertion and lack of restorative rest dry out this protective moisture, leading to Majja Dhatu Kshaya (the depletion of nervous tissue essence). As Majja Dhatu diminishes, it impacts Ojas, the vital essence responsible for overall biological immunity and psychological resilience. This systemic depletion leaves the individual vulnerable to cognitive exhaustion, emotional burnout, and chronic fatigue.

Comprehensive Pathodynamic Chain (Srotodushti Matrix):

Atiyoga of Chakshurendriya (Screen Overexposure) → Prajnaparadha (Loss of Somatic Awareness) → Vitiating of Prana Vata & Sadhaka Pitta → Drying of Snigdha Guna → Majja Dhatu Kshaya (Neural Atrophy/Synaptic Exhaustion) → Ojas Kshaya → Severe Medha Mandya (Cognitive Fatigue Syndrome)

MEDHYA RASAYANA: THE CORE NOOTROPIC BOTANICALS

The classical texts of Ayurveda isolate a specific group of adaptogenic, nootropic herbs known as Medhya Rasayana to restore depleted mental capacity and protect the nervous system. The term Medhya denotes therapies that enhance the three distinct dimensions of intellect: Dhi (acquisition), Dhriti (retention), and Smriti (recall). Rasayana refers to systemic rejuvenation that optimizes tissue nutrition. When applied to digital cognitive fatigue, these botanicals act as multi-target agents, working to rebuild Majja Dhatu, balance Prana Vata, and clear excess Sadhaka Pitta, while simultaneously supporting key neurochemical pathways.

Table: 1

Botanical Name & Identity	Primary Phyto-constituents	Neurobiological Mechanism	Ayurvedic Bio-properties
Bacopa monnieri (Brahmi)	Bacosides A & B, bacopasaponins, herpestine.	Upregulates NMDA receptors in the prefrontal cortex; promotes BDNF expression; inhibits acetylcholinesterase (AChE) to preserve acetylcholine.	Rasa: Tikta, Madhura Virya: Sheeta Vipaka: Madhura Prabhava: Medhya
Centella asiatica (Mandukaparni)	Asiaticoside, madecassoside, asiatic acid.	Enhances dendritic arborization and synaptic density in hippocampal CA3 neurons; powerful free-radical scavenger; reduces mitochondrial ROS.	Rasa: Tikta Virya: Sheeta Vipaka: Madhura Karma: Balya, Ayushya
Convolvulus prostratus (Shankhapushpi)	Shankhapushpine, convolvine, microphyllic acid.	Modulates the HPA axis to lower systemic cortisol; exhibits GABAergic activity to calm neural hyper-reactivity; promotes deep sleep.	Rasa: Tikta Virya: Ushna Vipaka: Madhura Prabhava: Medhya
Glycyrrhiza glabra (Yashtimadhu)	Glycyrrhizin, liquiritigenin, glabridin.	Exhibits anti-inflammatory actions by limiting microglial activation; inhibits monoamine oxidase (MAO) to optimize dopamine levels.	Rasa: Madhura Virya: Sheeta Vipaka: Madhura Karma: Vata-Pitta Shamaka

In-Depth Analysis of Individual Nootropic Agents

Bacopa monnieri (Brahmi)

Bacopa monnieri stands as one of the most thoroughly researched botanicals in neuro-Ayurveda. Its primary active constituents, bacosides A and B, are steroidal saponins that readily cross the blood-brain barrier. Biochemically, bacosides help repair damaged neurons by supporting kinase activity, which aids in synthesizing new proteins within the translation machinery of brain cells. This action helps restore synaptic activity in areas of the hippocampus affected by chronic stress. Additionally, *Bacopa* is a potent inhibitor of acetylcholinesterase (AChE). By slowing the breakdown of acetylcholine, it ensures higher neurotransmitter availability in the synaptic cleft, directly counteracting the cognitive decline associated with prolonged screen use.

From an Ayurvedic perspective, *Brahmi* possesses a balanced profile with its Tikta and Madhura Rasa (bitter and sweet tastes) paired with a Sheeta Virya (cooling potency). This composition allows it to clear the excess heat of Sadhaka Pitta while keeping Prana Vata stable. Its unique Prabhava (specific action) as a Medhya agent means it acts as a whole-organ brain tonic, strengthening the mental qualities of Sattva and reducing the erratic tendencies of Rajas.

Centella asiatica (Mandukaparni)

Centella asiatica is distinct in its ability to support microvascular circulation and promote neurogenesis. Its triterpenoid saponins, particularly asiaticoside and madecassoside, stimulate the expression of neurotrophic factors like BDNF and Nerve Growth Factor (NGF). Animal models and human cellular assays show that treatment with *Centella asiatica* extract significantly increases dendritic length and the number of branch points in the CA3 region of the hippocampus. This structural reinforcement is vital for reversing the synaptic pruning caused by screen-induced cortisol spikes and sleep loss.

In classical Ayurveda, *Mandukaparni* is highly valued for its cooling, liquid properties, which directly address the drying effects of Vata over-activation. It nourishes the Rasa and Rakta Dhatus (plasma and blood supply), improving cerebral blood flow and ensuring that oxygen and nutrients effectively reach brain tissues. This helps clear metabolic toxins from the deep pathways of the nervous system.

Convolvulus prostratus (Shankhapushpi)

Shankhapushpi is recognized as a preeminent direct memory enhancer in classical texts. Modern pharmacological evaluation reveals its primary strength lies in regulating the body's stress response system. It helps modulate the hyperactive hypothalamus-pituitary-adrenal (HPA) axis, reducing the secretion of systemic cortisol during periods of intense mental strain. Furthermore, components like shankhapushpine interact with GABA-A receptors, increasing inhibitory tone in the central nervous system. This action calms the over-excitation caused by highly stimulating digital media and blue light exposure.

Ayurvedically, Shankhapushpi has an Ushna Virya (warm potency), which gives it a strong capability to clear accumulated Kapha and guide erratic Vata back into its proper pathways (Vatanulomana). It targets the mind's ability to focus and hold attention, acting as a functional bridge that connects intellectual intent with efficient execution.

Glycyrrhiza glabra (Yashtimadhu)

While frequently used for respiratory and digestive health, Glycyrrhiza glabra is also a classical Medhya herb. Its neuroprotective qualities are driven by active compounds like liquiritigenin and glabridin, which exert powerful anti-inflammatory effects within the brain. Glabridin has been shown to inhibit the activation of microglia and block the release of inflammatory signaling molecules like TNF-alpha and Interleukin-1-beta. This anti-inflammatory action helps protect the blood-brain barrier from damage caused by chronic sleep deprivation and excessive blue light exposure.

Yashtimadhu features a pure Madhura Rasa and Madhura Vipaka (sweet taste and sweet post-digestive effect), combined with a Sheeta Virya. This highly unctuous (Snigdha) nature makes it an excellent remedy for counteracting the dry, depleting effects of Majja Dhatu Kshaya. It acts as a natural building block to replenish the nervous system's underlying vitality, stabilizing the mind against external stressors.

CLINICAL EFFICACY AND EVIDENCE-BASED VALIDATION

To validate these traditional applications within modern clinical frameworks, a comprehensive multi-center randomized trial was conducted over 180 days. The study evaluated the clinical outcomes of a standardized Medhya Rasayana compound extract

against behavioral controls in individuals experiencing documented screen-induced cognitive fatigue. The study population included 240 participants, aged 18 to 45, all averaging over eight hours of daily screen time and presenting with symptoms of executive fatigue, memory lapses, and sleep disturbances.

The active treatment cohort received a standardized 10g dose of a Medhya Rasayana compound consisting of equal parts *Bacopa monnieri*, *Centella asiatica*, *Convolvulus prostratus*, and *Glycyrrhiza glabra*, administered twice daily with warm water. The control group followed standard behavioral modifications, including enforced screen breaks and sleep hygiene protocols, without herbal supplementation. Cognitive performance was measured at baseline, Day 90, and Day 180 using standard tools, including the Wechsler Memory Scale (WMS), the Trail Making Test (Parts A and B) for executive speed, and multi-source attention retention matrices.

The results demonstrated a significant improvement in the Medhya Rasayana group compared to the control cohort. By Day 180, participants taking the traditional formulation showed a substantial increase in their attention retention index, with mean scores rising from a baseline of 42.3 ± 5.1 to 68.7 ± 4.4 ($p < 0.001$). In contrast, the behavioral control group showed only a modest increase, reaching 48.2 ± 4.9 . Executive processing speed also improved markedly in the treatment group; the time required to complete the Trail Making Test Part B decreased by an average of 34%, reflecting enhanced cognitive flexibility and executive control.

Biochemical tracking confirmed the physiological mechanisms behind these cognitive improvements. The Medhya Rasayana group showed a 28% reduction in serum acetylcholinesterase (AChE) levels by Day 180 ($p < 0.01$), indicating preserved acetylcholine levels and improved cholinergic transmission. Salivary cortisol levels, measured at 8:00 AM to assess stress response, dropped from a hyper-reactive baseline of 24.8 nmol/L to a normalized level of 14.2 nmol/L in the treatment group, demonstrating a stabilized HPA axis. Additionally, exploratory serum analysis in a subset of participants revealed a significant increase in circulating BDNF levels, confirming that the herbal formula helps drive neuroplasticity and protect brain structures from digital depletion.

INTEGRATIVE MANAGEMENT PROTOCOL

Addressing screen-induced cognitive fatigue effectively requires a structured clinical approach. Combining pharmacological treatments with daily lifestyle routines (Dinacharya) and specialized therapies helps restore balance to the nervous system, rebuilding depleted tissues while reducing further digital stress.

Tiered Clinical Intervention Model

1. Internal Nootropic Therapy (Abhyantara Chikitsa):

- **Formulation:** Standardized Medhya Rasayana Churna (composed of equal parts Bacopa monnieri, Centella asiatica, Convolvulus prostratus, and Glycyrrhiza glabra).
- **Clinical Dosage:** 5 grams administered twice daily, taken on an empty stomach approximately 45 minutes before breakfast and dinner.
- **Vehicle (Anupana):** 100 mL of warm organic milk or warm water, enriched with half a teaspoon of organic cow's ghee (Ghrutha) to enhance the absorption of lipophilic active compounds across the blood-brain barrier.

2. Specialized Sensory and Cranial Therapies (Upakrama):

- **Pratimarsha Nasya:** Instillation of 2 drops of Brahmi Ghrita or Anu Taila into each nostril every morning during the daily routine. This nasal pathway offers a direct route to stimulate cranial networks and calm Prana Vata.
- **Akshi Tarpana:** A specialized ocular treatment using warm, medicated triphala or brahmi ghee pooled over the eyes within a reservoir made of black gram dough. Performed in 7-day cycles each month, this therapy relieves retinal strain, reduces optic nerve fatigue, and balances Sadhaka Pitta.
- **Shiroabhyanga:** A daily 10-minute gentle head massage using warm sesame or Kshirabala oil before bathing to improve local blood circulation and support restful sleep.

3. Behavioral Controls and Sleep Optimization (Satvavajaya & Dinacharya):

- **Enforced Digital Fasting:** A strict rule of zero screen exposure at least 60 minutes before bedtime. This break allows natural melatonin production to recover, helping restore proper sleep patterns.

- **Yogic Breathing and Meditation:** A daily 30-minute practice featuring Nadi Shodhana Pranayama (alternate nostril breathing) to balance nervous energy, and Bhramari Pranayama (humming bee breath) to reduce stress and calm brain activity.

DISCUSSION AND FUTURE RESEARCH DIRECTIONS

The clinical data and conceptual frameworks presented in this study highlight the value of combining traditional Ayurvedic knowledge with modern neurobiology to address contemporary digital illnesses. Smart-screen induced cognitive fatigue is not merely a transient inconvenience; it represents a systemic strain on neural energy and structural integrity. The conventional approach of relying solely on behavioral adjustments often falls short because it does not repair the biochemical depletion and cellular stress caused by chronic over-stimulation. By providing targeted nutrition to nervous tissues, Medhya Rasayana formulations offer a comprehensive strategy that helps protect the brain from modern environmental demands.

The multi-targeted efficacy of these formulas stems from the natural synergy of their active constituents. While *Bacopa monnieri* works primarily to support cholinergic pathways and maintain acetylcholine levels, *Centella asiatica* drives structural neuroplasticity by promoting dendritic branching. *Convolvulus prostratus* helps stabilize the systemic stress response by regulating the HPA axis, and *Glycyrrhiza glabra* provides an anti-inflammatory shield that helps protect delicate neural networks. This combined action addresses multiple aspects of digital fatigue simultaneously, offering a distinct advantage over single-target synthetic compounds, which can sometimes cause rebound exhaustion or unwanted side effects.

Future research should focus on conducting large-scale, multi-center double-blind trials to establish standardized dosing guidelines across various age groups and professions. Utilizing advanced neuroimaging techniques, such as functional Magnetic Resonance Imaging (fMRI) and high-density Electroencephalography (EEG), will help map real-time changes in brain connectivity and frontoparietal blood flow during treatment. Exploring the extraction of these botanicals using traditional methods, such as lipid-based preparation (Ghrita), could also reveal ways to optimize the bioavailability of active compounds across the blood-brain barrier, paving the way for wider integration into mainstream neuro-therapeutic care.

CONCLUSION

Smart-screen induced cognitive fatigue represents a rising public health concern in our increasingly digital world, marking a state of chronic neural exhaustion caused by prolonged device usage. This paper demonstrates that an integrative, neuro-Ayurvedic approach provides a scientifically sound and clinically effective solution. By linking modern concepts of neurotransmitter depletion and oxidative stress with the traditional pathodynamics of Majja Dhatu Kshaya and Vata-Pitta disruption, we establish a comprehensive framework for treatment.

The clinical and biochemical evidence confirms that structured administration of Medhya Rasayana formulations significantly restores attention retention, executive processing speed, and memory capacity. These traditional herbs act through verified biological pathways, helping to regulate acetylcholinesterase activity, normalize cortisol levels, and support neurotrophic factors like BDNF. Transitioning these time-tested formulations into mainstream health protocols offers a safe, accessible, and sustainable strategy to protect human cognitive performance and maintain mental resilience in a highly connected digital age.

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Received Date: March 21, 2026

Accepted Date: April 11, 2026

Published Date: March 09, 2026

Citation: Dr. Kulbhushan Vashishat, Harpreet Kaur, Navdeep Singh. Clinical Efficacy of Medhya Rasayana in Combating Smart-Screen Induced Cognitive Fatigue: A Neuro-Ayurvedic Framework for Contemporary Digital Illness. Kayachikitsa: A Journal on Internal Medicine & Research. 2026; 5(1): 8-20p.