ijlpr 2023; doi 10.22376/ijlpr.2023.13.5.L30-L41

International Journal of Life science and Pharma Research

ISSN 2250-0480

Review Article

Nootropic drugs in Ayurvedic Medical Sciences

Memory, Nootropics and Ayurveda- A Critical Appraisal

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Abstract: Memory is an essential function of our cognition that helps us to remember events, learn lessons and preserve emotions; to live each day with new learning and optimum behavior. There have been talks on using safe nootropic drugs to enhance Memory in healthy patients with memory disorders. The ancient sages of Ayurveda and Vedic civilizations advocate learning and memorizing many hymns and verses by their pupils. It leads to the discovery of the cognition and memory enhancing drugs known as *Medhya Rasayana.* Ayurveda possesses a treasure of *Medhya Rasayana*, known as nootropics. This review aims to elaborate on and explain the Ayurvedic concept of memory and nootropics about the contemporary concept. Online research databases like DHARA, Ayush Research Portal, Pubmed, Google Scholar, etc., were searched for relevant research articles by applying adequate keywords. Ayurvedic concepts of *Buddhi*, acquisition of knowledge, *Medha,* and *Medhya Rasayana* were reviewed from Ayurvedic classics. This paper discusses the contemporary concept of memory along with its classification, mechanisms of production, and probable mode of its enhancement. The well-described Ayurvedic concept of the cognitive process and *Medha* and *Pragya* (intellect) have been analyzed, elaborated, and explained as per contemporary knowledge. A few *Medhya* drugs like *Brahmi* (*Bacopa monnieri*), *Mandookaparni* (*Centella asiatica*), *Shankhpushpi* (*Convolvulus pluricaulis*), and *Vacha* (*Acorus calamus*) are analyzed for their properties explained in Ayurveda and their neuropharmacological activities in the light of recent experimental and clinical studies. The probable two groups based upon the mode of action of *Medhya* drugs- one which promotes *Dhriti* and the other which promotes *Medha* (mainly *Dhi* & *Smriti*) are also discussed. In conclusion, memory enhancement in healthy and pathological states is requisite in today's competitive world. With its vast treasure of *Medhya* drugs, Ayurveda can greatly help in this field.

Keywords- Memory, nootropics, memory enhancer, Medhya herbs, Brahmi, Ayurveda

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Received On 21 December, 2022

Revised On 21 March, 2023

Accepted On 10 April, 2023

Published On 1 September, 2023

Funding This research did not receive any specific grant from any funding agencies in the public, commercial or not for profit sectors.

Citation Jitesh Verma, Renu Rathi, Ibamedabha, Anamika, Bharat Rathi and VB Pandey , Memory, Nootropics and Ayurveda- A Critical Appraisal.(2023).Int. J. Life Sci. Pharma Res.13(5), L30-L41 http://dx.doi.org/10.22376/ijlpr.2023.13.5.L30-L41

1. INTRODUCTION

The quest for knowledge and excellency has been human beings' first and foremost goal for ages. Since the immortal ages, human beings have wanted to acquire as much knowledge as possible during their small life span about themselves and their periphery. In this quest, they must use their brains and evolute various structures throughout the generations.[1] Memory is one such tool that gets incorporated into various organisms in different forms, and the process of evolution continues. Not only in the pursuit of knowledge, but memory also plays a crucial role even to behave appropriately in the social setting and adapt to various situations.[2] Memories of past experiences are utilized to better the present and future.[3] Humans have always searched for methods and medicine to enhance their intellect and Memory. The last 5-6 decades have seen swift evolution of the idea of memory, but still, many hypotheses are to be proven.[4] Many classifications system for understanding memory and its associates has been hypothesized and proven with many experimentations.[5] The research has given insight into the various mechanism forming memories. [6,7] Along similar lines, many searches are going on for memory enhancers, brain promoters, or so-called nootropic drugs. Many scholars and institutes have taken-up researches to probe their efficacy, mode of action, neuropharmacological actions, etc.[8,9] Natural and synthetic nootropics are being explored for their potency, mechanism of action, and possible side effects. Natural nootropics are supposed to be better due to their diverse, active compounds and less risk of toxicity, even at higher doses.[10] Ayurveda, the traditional system of medicine in the Indian subcontinent, possesses a treasure of herbal medicines, including nootropics. It described the concept of intellect, the process of knowledge acquisition, Memory, and *Medhya Rasayana* (intellect enhancers/ nootropics) thousands of years ago.[11] It has also explained the factors responsible for the acquisition and retrieval of memory.[12] *Rasayana* therapy is one of the eight main branches of Ayurveda.[13] In *Rasayana* therapy, various procedures and medicines are used to prevent the effects of aging on the human body. *Rasayana* therapy possesses properties like the promotion of intellect, memory, luster, complexion, voice quality, physical and mental strength, youthfulness, and longevity. Different types of *Rasayana* modalities are described like *Kutipraveshika* (rejuvenation therapy in an indoor setting), *Vatatapika* (rejuvenation therapy in an outdoor setting), *Aachara Rasayana* (rejuvenation by following a social code of conduct), Netra *Rasayana* (rejuvenation therapy for vision), Medhya *Rasayana* (therapy for the promotion of intellect), etc. Ayurveda also has a systemic description of the formation of *Budhhi* (the process of knowledge acquisition) and its constituents like *Dhee, Dhriti, and Smriti*. It also describes their role in maintaining one's health as well as in the production of diseases. Ayurveda considers *Pragyapradha* (improper functioning of *dhee, dhriti* & *smriti*) as one of three main causative factors for disease.[36] However, this Ayurvedic concept of memory and *Medhya Rasayana* has yet to be evaluated thoroughly and is still to be assimilated into the modern system of medicine.[14] Many research works are being done to evaluate the efficacy of ayurvedic nootropic herbs in enhancing memory and, more precisely, in improving overall mental health[15,16] Some of the *Medhya Rasayana,* like *Brahmi*, *Shankhpushpi,* etc., have been established for their nootropic effects. However, their mechanism of action is still being researched.[17,18] This article elaborated on various modern theories of memory, interferences in memory acquisition, and the mechanism of memory formation. It also analyzed the Ayurvedic concept of knowledge acquisition, the role of memory and nootropic drugs, and their mechanism of action.

2. MATERIALS & METHODS

Online research databases like DHARA, Ayush Research Portal, PubMed, Google Scholar, etc., were searched for the relevant research articles by applying different keywords like Memory, types of Memory, mechanism of Memory, the process of memory formation, nootropics, *Medhya* herbs, nootropic herbs, mechanism of nootropic herbs, etc. with their mesh term in combination to AND, OR. The search for these keywords was limited to English literature within a time frame. Relevant references for the concept of Memory, like *Dhi*, *Dhriti*, *Smriti*, *Medha*, *Medhya Rasayana*, etc., were also assessed from classical Ayurvedic texts. The articles were analyzed for their content and various aspects regarding physiological, anatomical, and neuropsychological aspects of memory, the mechanism of memory formation and enhancement, the mechanism of nootropic drugs, and possible mechanisms of *Medhya* drugs used in Ayurveda. The results are discussed as follows.

3. RESULTS

3.1.A Memory

Memory is the process of encoding the information (understanding/ perceiving), consolidating it (storing), and retrieving (recovering) it whenever required.[19]

3.2.A Types of Memory

Memory is usually categorized into three basic types (Figure 1)- Sensory, short-term, long term.

3.3.A A Sensory memory

"Sensory memory is the capacity for briefly retaining the large amounts of information that people encounter daily."[20] Sensory memories can be classified into three subtypes- Iconic, Echoic, and Haptic. The Memory of information received through sight is called Iconic memory. In contrast, echoic memory is information received through auditory stimuli, and haptic memory is the memory of information received through tactile stimuli. Of these three sensory memories, iconic Memory is the most studied one. According to Di Lollo, Iconic Memory has two components- the persistence of vision & information.[21] The characteristics of iconic Memory (or that of sensory memory) are that it is of a huge volume, for a brief period, and has a pre-categorical nature.[22]

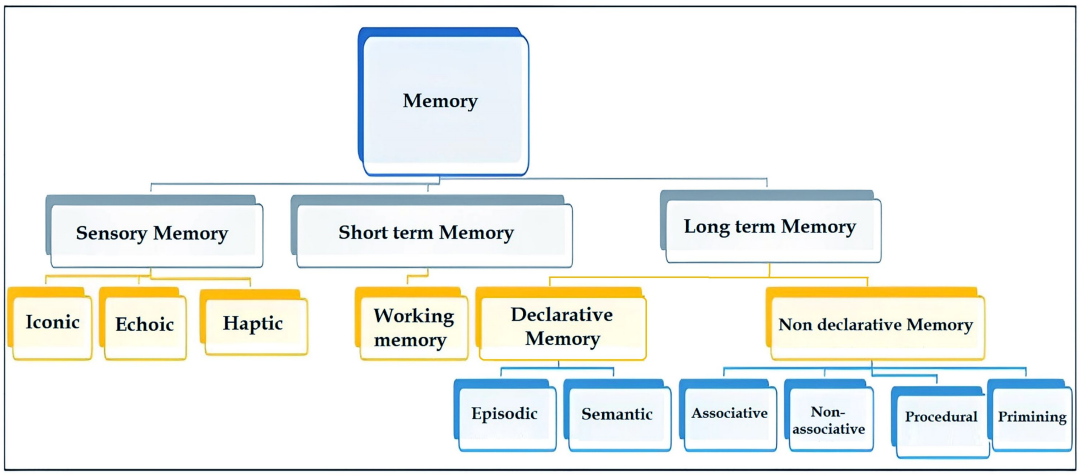

Fig 1: Showing types of Memory

3.4.A Short Term Memory (STM)

Short-term memory is a restricted-sized memory system. It retains a small quantity of information for a brief time interval.[23] It receives information from both sensory Memory and long-term memory storehouses. Also, it can send memory into a long-term memory storehouse. It is said to produce reasoning and new inferences from prevailing ones. The most accepted model of STM is Baddeley & Hitch's model, which incorporates working memory. This model proposes three subsystems within STM-: the central executive, a phonological or articulatory loop, and a visuospatial sketchpad. Later, in a chronological illustration, the episodic buffer was added as another subsystem and postulated to be related to information association between other subsystems.

3.4.B1 Working Memory (WM)

It is that type of memory that briefly keeps a small amount of data/information in mind for performing various activities like learning, reasoning, etc. This type of memory is thus the main reason to exercise central executive functions.[24] Initially, the central executive was considered a system capable of processing and storing. Later, Baddeley and Logie[25] anticipated it to have attention capacity only. Subsequent studies have proposed another storage system, the organizational system complemented by the episodic buffer.[26]

3.4.B2 Visuospatial Sketchpad

Its main function is to prepare and uphold the visuospatial image of the visual world, and it continues through the irregular eye movement pattern.[27]

3.4.B3 Phonological Buffer

The phonological buffer helps in the attainment of language by providing the facility to stock new words until their consolidation into long-term memory. This buffer has two elementary methods: a brief acoustic stockroom and a subvocal articulatory rehearsal process.

3.4.B4 Episodic Buffer

It is a brief or temporary storage system that is governed by a central executive and is used for the integration of data from different subsystems of Memory. "The buffer is episodic in that it holds episodes whereby information is integrated across space and potentially extended across time."[28] This buffer can be found intact in impairment of long-term episodic memories and amnesic patients. With these characteristics, it is now proposed that the episodic buffer may be considered conceptual short-term Memory.[29]

3.4.C Long Term Memory

This type of memory can keep a huge /unlimited quantity of information for long intervals, even throughout the lifespan. It is categorized into two main types: declarative or explicit memories and non-declarative or implicit memories.[30]

Declarative/ explicit Memory – This type denotes memories that can be consciously evoked. This type consists of memory of an episode (individual experiences) and semantic memory (general facts).

Nondeclarative/ implicit Memory denotes all unconscious memories like skills, abilities, etc. This system includes four types of memories- procedural, associative, non-associative, and priming.[30]

Procedural Memory – Also known as the process of acquiring habits and skills. This memory stores and retrieves information for the execution of executive and motor skills necessary for performing the task.

Associative Memory- It is so-called because, in this memory system, information is stored and retrieved through association with some other information. This type of memory is attained by classical conditioning and operant conditioning.

Non-associative Memory refers to acquiring new behavior or skill through routine and repetitive exposure to a stimulus. The new behavior may be differentiated into two developments- habituation and sensitization.

Priming- In priming, a later stimulus is affected by an earlier definitive stimulus. The parts of the brain related to explicit memories are the prefrontal cortex and hippocampus. At the same time, basal ganglia, their connections with the thalamus and the prefrontal cortex are the main areas related to implicit motor memories.

3.5.A Process of memory formation[31]

There are three basic steps in the whole process of memory formation. They are encoding, consolidation, and retrieval.

Encoding, the first process in the formation of Memory, is the transformation of information which may be internal, like thoughts or external, into STM and LTM. Data is managed and characterized for storing and retrieving in the encoding process. The information or memories thus encoded are not stable and are fragile. The interference of other similar information can disrupt them. The next process in the formation of LTM is consolidation. Different molecular mechanisms store the encoded information for the long term in this process. These mechanisms are through gene expression, synaptic remodeling, and neuromodulations. Sleep plays a definitive role in the consolidation of Memory. Finally, retrieval is how information or previous events encoded and stored in Memory are retrieved.

3.6.A The Cognitive Process -Ayurvedic perspective

Ayurveda explains the process of knowledge acquisition through a set process. This process includes the coherence of four basic contents- *Indriyartha* (sensory stimuli or object of that sense), *Indriya* (senses), *Mana* (mind/ attention or concentration), and *Atma* (the soul or consciousness). In the first, sense organs receive their object/ stimuli, which undergo *Manovyapar* (activities of mind) like *chintya* (that which is thought upon), *vicharya* (that which is analyzed), *uhya* (that which is contemplated upon), *dheya* (that which is meditated upon), *Sankalpa* (to intend/volition) in conjugation with *Atma* (the consciousness). This results in the production of *Indriya*-specific *Buddhi* (Sensory memory).[32] This sensory knowledge or Memory is called *kshanika* (momentary, i.e., of short duration) and *nischyatmaka* (definite of form/ categorical). *Mana* (mind or here can be considered prefrontal cortex & other areas related to consciousness) can also process knowledge without combining with *Indriya* (sense organ), and that is known as *Manortha* (subject/ activities of mind). These are *chintya, vicharya, uhya, dhyeya, and Sankalpa*. These are necessarily involved in the production or acquisition of *Buddhi* (knowledge), whether it is *Indriyasapekhsa* (with the help of senses) or *Indrinirpeksha* (without the use of special senses).[33] For the mind to perform its works, it requires knowledge acquired previously which is stored in the form of *Smriti* (Memory). Thus, s*mriti* is needed to acquire new knowledge/ learning and to act or behave according to previous experiences. Thus, in the production or acquisition of knowledge or intellect, Ayurveda has explained a well-established process where in stimuli are received by sensory organs in conjunction with attention and concentration, resulting in sensory Memory (*Inriyatmaka Buddhi*), which is then retained and recollected by a controlled *Mana* (mind or memory pathways) with the various faculties of *Pragya*.

3.6.B Medha in Health & Disease

Shabdkalpadrum defines *Medha* as the intellect that restores knowledge. *Medha* is sometimes a synonym for *Buddhi* (the intellect); however, various commentators explained it as retention power.[34] The broad term used for *Buddhi* is *Pragya*. Acharya Charaka described three basic types or subcategories of *Pragya* (knowledge/intellect), which is *trikalatmaka Buddhi* (the wisdom/intelligence) in the context of causative agent for *dukhah* (pain/ diseases). These three types are *Dhi* (understanding), *Dhriti* (retaining power), and *Smriti* (memory/recollection). *Dhi* or *Buddhi* is referred to the intellect or understanding of any subject. It can be considered the true perception of any object as it is. The word *Dhriti* is described in multiple contexts and thus has different contextual meanings. Acharya Charaka described *Dhriti* as the faculty of *Pragya*, which is *Niyamatmika,* i.e., which controls *Mana* (mind) from excessive or wrong indulgence in its subjects.[35] The third faculty of *Pragya* is *Smriti* which means retention and recollection of knowledge acquired by previous experiences. In addition to these three faculties of intellect, Ayurveda uses another word *Medha* to define another facility of intellect. *Pragya* plays an important role in health and disease, as knowledge acquired through experience helps one to act in a way to avoid any harmful effect on health. A person is said to do *Pragyapradha* when they do not listen to their intellect (acquired knowledge) and knowingly perform acts that will harm their health. Ayurveda has opined *Pragyapradha* is one of the three major reasons for any illness.[36]

3.7.B Medhya Rasayana-the nootropics

Ayurveda also explained various measures to promote intellect. They are collectively known as *Medhya Rasayana*. *Medhya* is derived from *Medha* (the intellect or retaining power) and means measures (therapeutic procedure or drugs) promoting *Medha*. *Rasayana* (rejuvenating therapy) is used to the measures (therapeutic procedure or drugs) that provide the best body tissue and their optimum physiological functions. *Rasayana* possesses properties like promotion of intellect, memory, luster, complexion, voice quality, physical and mental strength, youthfulness, and longevity.[37] Thus, *Medhya Rasayana* is the measure or drug which provides good intellect with the longevity of mental faculties. These are the drugs that enhance all the faculties of *Buddhi*/*Medha,* like *Dhi* (perception/ understanding), *Dhriti* (attention & concentration), *Medha* (retention), and *Smriti* (memory or retrieval process). Acharya Charaka has mentioned various drug formulations and single drugs to possess *Medhya* properties. Single mentioned drugs are *Mandukaparni*, *Madhuyashti*, *Guduchi*, and *Shankhpushpi*. Other drugs mentioned as *Medhya Rasayana* by various Acharya are *Brahmi*, *Vacha*, *Suvarna, Triphala, Chitraka, Shatpushpa, Shatavari, Danti, Nagabala, Trivrita,* Ghee, *Bilva, Kushmanda, Jyotishamati, Jatamansi*, etc. In addition to drugs, some other measures are also described to promote intellect, and these are *Adhyayana* (studying), *Adhyapana* (teaching), *Tada vidha sambhasha* (participation in debates or conferences), *Partantra avlokana* (cross-referencing from other texts) and *Tadavida achrya seva* (service of or supervised by experts of that branch). [42,43]

3.7 Nootropics-Memory Enhancers

The substances useful in improving cognition, Memory, and other cognitive functions of the brain are called memory and cognition enhancers.[44] They may include functional foods, supplements, and drugs. The other popular term being used for these substances is 'Nootropics.' The word 'nootropic' originates in Greek, where *nos* stand for the mind, and *trope* means to monitor. These drugs are often called 'smart drugs' as they affect our brain cells.[45] There are different mechanisms of action through which nootropics may enhance cognition and other mental functions.

3.8 Mechanisms of Memory Enhancement

Different mechanisms to increase Memory have been hypothesized and are being evaluated for potential pharmacological intervention. Some of the known mechanisms Include-Gene expression, synaptic remodeling, neuromodulation, the release of endogenous substances, and

the use of behavioral methods. Gene expression is an essential mechanism for consolidation which was recognized first. LTM consolidation involves *de novo* protein and RNA synthesis, controlled by gene expression.[46] Synaptic remodeling is one of the basic mechanisms for forming LTM. Synaptic remodeling includes two main processes: the development/trimming of synapses, the changed efficacy of synapses, or even both.[47] Neuromodulation is another mechanism by which memory gets encoded and consolidated. This mechanism involves the release of various neuromodulators in different circumstances resulting in better memory retention and retrieval. These neuromodulators may include dopamine,[48] stress hormones like corticosteroids,[49], and adrenaline.[50] A few endogenous substances have shown positive memory enhancing effects. They are mainly either substrates in metabolism like glucose or vital factors of metabolism, viz. insulin.[51] In behavioral manipulation, repetition of learned or memorized subjects is well known to increase memory performance. It may be due to retrieval-induced reconsolidation.[52]

3.9 Memory Enhancing Drugs and Their Mechanism

Ayurveda possesses a wide variety of *Medhya Rasayana* (nootropics), which are used to promote cognition, memory, and other mental function and treat various mental disorders in its day-to-day practice. Many of these drugs have been researched thoroughly in experimental and clinical settings and found effective. Some of them are discussed in this paper.

Table 1- Properties of reviewed *Medhya* Drugs as per Ayurveda

S. No.	Medhya Drug	Properties	Actions	Dosha-Prabhava
1.	Brahmi[53] (*Bacopa monnieri*)	*Rasa- Tikta* (bitter), *Kashaya* (Astringent), *Madhura* (Sweet) *Vipaka- Madhura* (Sweet after digestion) *Veerya- Sheeta* (Cool potency) *Guna- Laghu* (light), *Sara* (mobile)	*Medhya* (Nootropic), *Smritprada* (improves recollection), *Ayushya* (increases longevity), *Rasayana* (anabolic), *Swarya* (improves voice), *Vishaghna* (anti-toxin), *Jwarghna* (antipyretic), *Kasaghna* (Anti-tussive), *Shothahara* (anti-inflammatory), *kushthaghna* (useful in skin disorders)	*Kapha- Pitta Shamana*
2.	Mandukaparni[53] (*Centella asiatica*)	Same as above	Same as above	Same as above
3.	Shankhpushpi[54,55] (*Convolvulus pluricaulis*)	*Rasa- Katu* (pungent), *Tikta* (bitter), *Kashaya* (Astringent), *Vipaka- Madhura* (Sweet after digestion) *Veerya- Ushna* (hot potency) *Guna- Sara* (mobile)	*Medhya* (Nootropic), *Smritida* (improves recollection), *Kantida* (improves complexion), *Balada* (improves strength), *Agnida* (improves digestive fire), *Vrishya* (aphrodisiac), *Manasarogahrita* (anti-psychotic), *Rasayana* (improves longevity), *Apshmara-hara* (anti-epileptic), *Vishaghna* (anti-toxic)	*Kapha- Pitta Shamana*
4.	Vacha[56,57] (*Acorus calamus*)	*Rasa- Katu* (pungent), *Tikta* (bitter), *Vipaka- Katu* (pungent after digestion) *Veerya- Ushna* (hot potency) *Guna- laghu* (light), *Ruksha* (dry), *Tikshna* (sharp/potent)	*Medhya* (Nootropic), *Deepana* (improves digestive fire), *Pachana* (digest food), *Ayushya* (increases longevity), *Apshmara-hara* (anti-epileptic), *Unmadahara* (anti-psychotic), *Kanthya* (improves voice), *Vivandhahara* (laxative), *Shoolahara* (antispasmodic), *Vantikrit* (emetic), *Mutrala* (diuretic), *Jantughna* (antimicrobial)	*Vata-Kapha-shaman*

3.9.A Brahmi (Bacopa monnieri)

Brahmi is used for its *Rasayana* properties from time immortal. It derived its name from Lord Brahma, the creator of this universe, as per the ancient texts of the Hindu religion. It has been described to be used almost every decade of life as a health promoter and *Rasayana*. Brahmi has been meticulously researched at CDRI, Lucknow[58], and shown to have properties ascribed to it in Ayurvedic classics. Numerous experimental and clinical studies have been conducted on the *Medhya* effect of Bacopa. However, few randomized control trials are available, indicating its efficacy in improving attention, learning, and memory. In their systematic review of Bacopa, Pase et al. has written that "*Bacopa* could potentially be clinically prescribed as a memory enhancer" in healthy persons.[59] The possible mechanism of memory-enhancing by Bacopa has been discussed by Aguiar & Borowski.[60] They have given plenty of evidence for the various mechanisms of action in enhancing Memory. These putative mechanisms include – Oxidant scavenging and neuroprotective activity, inhibition of acetylcholinesterase activity, reduction in the production & accumulation of β-amyloid, activation of choline

acetyltransferase, increasing cerebral blood flow, and potentiation and modulation of monoamine.

3.9.B Mandukaparni (Centella asiatica)

Ayurvedic classical texts describe *Brahmi* and *Mandukaparni* side by side; both drugs have almost similar properties.[61,62] Acharya Charaka has mentioned *Mandukaparni* as one of the selected four *Medhya* herbs.[63] Thus, *Mandukaparni* must have a nootropic effect, just like *Brahmi*. However, *Mandukaparni* needs more research in clinical studies for its nootropic effects. Experimental studies have shown that *Mandukaparni* has a good nootropic effect. Many experimental and animal studies have demonstrated *C. asiatica* as a potent cognition enhancer & anti-oxidant,[64] antinociceptive & anti-inflammatory,[65] anti-anxieties, antidepressant[66], and anti-epileptic.[67] A few clinical studies also had been done to evaluate the efficacy of *C. asiatica* in various activities proven in various experimental trials. In these studies, *C. asiatica* is proven to possess wound healing properties,[68] cognition & mood enhancing activity,[69] anxiolytic activities,[70] and antidepressant activity.[71] Gohil *et al*., in their review of *C. asiatica,* have concluded that a review of various studies on this plant is indicative of its multiple uses in clinical practice, mainly to stabilize or improve relative age decline of cognition functions.[72]

3.9.C Shankhpushpi (Convolvulus pluricaulis)

Shankhpushpi is mentioned as the best *Medhya* herb by Acharya Charaka in the description of four *Medhya* drugs. However, four different herbs are being used in the name of *Shankhpushpi* in various geographical locations in India. The four herbs used are *Convolvulus pluricaulis* Choisy., *Evolvulus alsinoides* Linn., *Clitorea ternatea* Linn. and *Canscora decussata* Schult.[73] These drugs have been evaluated for their nootropic effects and found to have various neuropharmacological actions. In experimental and animal studies, all these four herbs used as *Shankhpushpi* were shown to have nootropic, anxiolytic, memory enhancing, antioxidant, acetylcholinesterase enhancer, and anti-depressant activities.[74] Parsania S, in his clinical study, reported the anti-anxiety effect of *Shankhapushpi* in *Chittodvega* (anxiety disorders).[75]

3.9.D Vacha (Acorus calamus)

Vacha is very useful for infants and possesses properties like the promotion of *Medha* (retention power), *Smriti* (memory), longevity, and health. Acharya Vagbhatta has advised carrying a small packet of *Vacha* over the body for the effects. As mentioned above,[76] *A. calamus* is shown to have different and wide variety of pharmacological actions, including anti-diabetic,[77] anti-hypertensive, anti-obesity,[78] anti-inflammatory, and immunomodulatory effects.[79] However, its neuropharmacological profile shows antioxidant, anti-convulsant,[80] anti-depressants,[81] neuroprotective, and learning and memory enhancing effects.[82] These pharmacological actions of *A. calamus* were also tested in various clinical studies and found effective. In their clinical study, Bhattacharya *et al.* [83] on 33 patients with anxiety disorder found a noteworthy reduction in this disorder. They used 70% hydroalcoholic extract of *A. calamus* in a dose of 500mg twice daily for 2 months. *In various clinical studies, Vacha* has been evaluated as a polyherbal compound for its neuropharmacological action and found effective as a sedative, anti-anxiety, and cognition enhancer. In one such study,[84], a polyherbal medicated ghee preparation named *Vachadi Ghrit* was assessed for its effect on cognition. It was found to have significant improvement in mental state scores as well as various memory tests. The probable mechanism of neuropharmacological effects of *A. calamus* may include antioxidant effect, modulatory effect on brain stress hormones, inhibition of acetylcholinesterase (AChE) activity, and dopamine antagonistic activity.[85]

Table 2- Neuropharmacological Activities of *Medhya* Drugs

S.No.	Medhya Drug	Neuropharmacological activities
1.	Brahmi (*Bacopa monnieri*)	Cognition enhancer,[86] anti-oxidant,[87] neuroprotective,[88] anti-convulsant,[89] antipsychotics,[90] antidepressant,[91] anxiolytics,[92] adaptogenic,[93] analgesic,[94] anti-amyloidogenic,[95] anti-cholinestrase[96]
2.	Mandukaparni (*Centella asiatica*)	cognition enhancer & anti-oxidant,[97] antinociceptive & anti-inflammatory,[98] antidepressant,[99,100] anti-convulsant & anti-oxidant,[101] cognition & mood enhancing activity,[102] anxiolytic activity[103]
3.	Shankhpushpi (*Convolvulus pluricaulis*)	nootropic,[104] neuroprotective,[105] anti-depressants,[106] analgesic & anti-inflammatory,[107] anti-oxidant,[108] anti-convulsant,[109] anxiolytics,[110] sedatives,[111] acetylcholinesterase enhancer[112]
4.	Vacha (*Acorus calamus*)	antioxidant,[113] anti-inflammatories,[114] anticonvulsants,[115] anti-depressants,[116] and neuroprotective[117]

4. DISCUSSION

The concept of Memory and its enhancement has evolved rapidly in the last 60-70 years.[118] The same applies to the level of competition, wish to excel in studies, to have the best intelligence, and incidence of mental illness as well as their treatment.[119] As memory and the mechanism of its formation and enhancement are now better understood, there have been searches for drugs that can be utilized in various disorders of memory and cognition. It opens the opportunity for traditional systems like Ayurveda to contribute vastly in providing not only the treasure of herbal nootropic drugs but also various other methods for mental health like meditation,[119] *Panchkarma* procedures like *Shirodhara* (procedure of pouring/dripping liquid drugs upon head),[120] *Nasya* (instillation of drugs through nostrils), etc., chanting of hymens, etc. The concept of cognition and memory is well established in Ayurveda, and *Medhya* herbs used in Ayurveda are a boon for the researcher to establish their efficacy and mode of action. The knowledge acquisition and memory formation concept in Ayurveda described 3000 years back, is similar to modern concepts. *Medhya* drugs, thus described in Ayurveda, have been used for thousands of years, and their mechanistic evaluation with individualized use is a need of the hour. Many of these drugs are being evaluated for their active components, neuropharmacological activities, nootropic efficacy, and mechanism of action. In this review, we have discussed four selected herbs, and their mechanism of action as per Ayurveda

and modern pharmacology has been explained. In Ayurveda, these nootropic herbs can be broadly classified into two groups-

- Drugs with *Madhura* (sweet), *Tikta Rasa* (bitter), *Madhura Vipaka* (sweet after digestion), and *Sheeta veerya* (cold potency), e.g., *Brahmi*, *Shankhpushpi*, *Mandookaparni*, *Madhuyashti*, *Kushmand,* etc.
- Drugs with *Katu* (pungent), *Tikta Rasa* (bitter taste), *Katu Vipaka* (pungent after digestion), and *Ushna veerya* (hot potency), e.g., *Vacha*, *Jyotishmati*, *Guduchi*, etc.

The first group acts by improving the quality of *Kapha*, which is responsible for *dhriti* (retention power). *Dhriti* is described as the physiological function of *Kapha*.[122] In the commentary on the physiological functions of *Dosha* (functional regulatory factors of the body), Acharya Chakrapani defines *Dhriti* as *Mansoachanchlayam*, i.e., stability of mind.[123] In other words, it can be understood as the attention and concentration of *Mana* (mind) during the process of acquisition of knowledge towards the conjugated *Artha* (it's subject) or *Indriya* (sense organ). Thus, the drugs of the first group can be used to improve attention, concentration, and retaining power. Various research on Brahmi (*Bacopa monnieri*), the most researched herbal nootropic drug, has shown its efficacy in improving attention and concentration in healthy[124,125] and persons with attention deficits.[126] Also, *Shankhpushpi,* in a clinical trial, has shown significant results in improving attention, concentration, and long-term memory retention.[127] Second group of *Medhya* drugs improves Pitta's quality*,* which is responsible for *Medha* (intellect/retention) and *Prashad* (clarity of mind).[128] The *avarana* (obstruction) of *Manovaha strotas* by *Raja* and *Tama* can lead to *Dhee* and *smritibhrnsha* (poor perception and recollection).[129] This second group of *Medhya* drugs removes this by their *Katu* and *tikta rasa* leading to *deepana* and *pachana* effect and *laghu* (light), *tikshna* (sharp), removing *Kapha* and *Tama* and providing *Prashadatva* of *Mana* (clarity of mind). Thus, this group is more useful in improving perception, recollection, and subjects of mind like *chintya* (subjects to be taught), *uhya* (analysis), etc. *Vacha* has shown anti- Alzheimer[130] and anti- Parkinson[131] effects, anxiolytic effect[132], and is useful in various metabolic problems, including obesity, hyperlipidaemia[133], etc. Thus, these nootropic herbs described in Ayurveda can be used and researched by understanding their mode of action as per Ayurvedic principles and conventional pharmacological methods. In addition to the use of nootropic herbs according to their properties and effects on *Dosha* (body humor), *Dhatus* (tissues), *Agni* (digestive fire as well as metabolism), and *Srotas* (body channels), they must be used according to *Prakriti* (body type) of the person. Ayurveda always advocates using medicine with an individualized approach, i.e., depending upon the *Prakriti* (body type).[134,135] Many studies[15, 136,16] are being taken to fulfil these objectives, and leads are being found to establish their use in health and disease. In this paper, we have shown that concept of *Smriti* and *Medhya* drugs is at par with the modern concept of Memory and nootropics. Well-directed and precisely planned research will provide evidence for the productive and individualistic use of various herbal nootropic drugs for the betterment of human beings.

5. CONCLUSION

Memory is one of the most valuable cognitive functions that help us enjoy life fully. Its enhancement in health and pathological states is requisite in today's competitive world. With its vast treasure of *Medhya* drugs, Ayurveda can help a lot in this field. The ongoing research on ayurvedic nootropic herbs may be accelerated along with more concentration on clinical trials, mainly randomized control trials.

6. AUTHORS CONTRIBUTION STATEMENT

Dr. Jitesh Verma conceptualized and drafted the manuscript. Dr. Ibamedabha and Dr. Vidya Bhushan Pandey collected and shorted various research articles. Dr. Renu Rathi and Dr. Bharat Rathi give valuable and necessary inputs in the drafting and designing the manuscript. Dr. Anamika discussed and drafted the classical concepts of Ayurveda in the manuscript. All authors discussed the methodology and design of the manuscript and contributed to the final manuscript.

7. CONFLICT OF INTEREST

Conflict of interest declared none.

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