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Meditation, Memory and Learning: Neurobiological Studies

Meditação, Memória e Aprendizagem: Estudos Neurobiológicos

Meditación, Memoria y Aprendizaje: Estudios Neurobiológicos

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Abstract

Introduction. The role of meditation on different aspects of human neurobiology has received greater attention from the scientific community in recent years. **Objective**. This article aims to investigate the impacts of meditative practice on memory and on the teaching-learning process. **Methods**. A literature review with a defined search strategy was carried out in the PubMed and Scielo databases, using the descriptors of the MeSH and Boolean operators, in the following terms: "Meditation" AND "Memory" and "Meditation" AND "learning", in English and Portuguese. Studies focusing on the role of meditation in the teaching-learning processes and in the neurobiologist aspects of memory were included. **Results and discussion**. The information obtained was organized into three sections: (1) basic concepts for the study of memory; (2) neural mechanisms of memory and learning, and (3) the practice of meditation, including the effects on memory and teaching-learning processes. **Conclusion**. The beneficial effects of meditative practice on the construction of teaching-learning processes were described, with emphasis on improving emotional balance, reducing stress and anxiety, in addition to increasing concentration, factors that promote the consolidation of long-term memory and, thus, help in the construction of learning.
Keywords. Meditation; Memory; Learning

Resumo

Introdução. O papel da meditação sobre distintos aspectos da neurobiologia humana tem recebido maior atenção da comunidade científica, nos últimos anos. **Objetivo**. O presente artigo tem por objetivo investigar os impactos da prática meditativa sobre a memória e sobre o processo ensino-aprendizagem. **Métodos**. Procedeu-se revisão da literatura com estratégia de busca definida no PubMed e no Scielo, utilizando os descritores da plataforma MeSH e operadores booleanos, com os seguintes termos: "Meditation" AND "Memory" e "Meditation" AND "learning", em inglês e português. Foram incluídos estudos dirigidos ao papel da meditação nos processos de ensino-aprendizagem e nos aspectos neurobiólogos da memória. **Resultados e discussão**. As informações obtidas foram organizadas em três seções: (1) conceitos básicos para o estudo da memória; (2) mecanismos neurais da memória e da aprendizagem e (3) a prática da meditação, incluindo os efeitos sobre a memória e o processo de ensino-aprendizagem. **Conclusão**. Os efeitos benéficos da prática meditativa sobre a construção dos processos ensino-aprendizagem, com destaque para o aprimoramento do equilíbrio emocional, da redução do estresse e da ansiedade, foram descritos, além do incremento da capacidade de concentração, fatores que favorecem a consolidação da memória de longo prazo e, assim, auxiliam na construção do aprendizado.
Unitermos. Meditação; Memória; Aprendizado

Resumen

Introducción. El papel de la meditación en diferentes aspectos de la neurobiología humana ha recibido una mayor atención de la comunidad científica en los últimos años. **Objetivo**. Este artículo tiene como objetivo investigar los impactos de la práctica meditativa en la memoria y en el proceso de enseñanza-aprendizaje. **Métodos**. Se realizó una revisión de la literatura con una estrategia de búsqueda definida en las bases de datos PubMed y Scielo, utilizando los descriptores de la plataforma MeSH y operadores booleanos, en los siguientes términos: "Meditación" AND "memoria" y "meditación" AND "aprendizaje". Se incluyeron estudios centrados en el papel de la meditación en los procesos de enseñanza-aprendizaje y en los aspectos neurobiólogos de la memoria. **Resultados y discusión**. La información obtenida se organizó en tres secciones: (1) conceptos básicos para el estudio de la memoria; (2) mecanismos neurales de memoria y aprendizaje y (3) la práctica de la meditación, incluidos los efectos sobre la memoria y enseñanza-aprendizaje procesos. **Conclusión**. Se describieron los efectos beneficiosos de la práctica meditativa en la construcción de procesos de enseñanza-aprendizaje, con énfasis en mejorar el equilibrio emocional, reducir el estrés y la ansiedad, además de aumentar la concentración, factores que favorecen la consolidación de la memoria de largo plazo y, por tanto, ayudan en la construcción del aprendizaje.

Palabras clave. Meditación; Memoria; Aprendizaje

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INTRODUCTION

Neurosciences have been characterized, by different authors, as a body of knowledge, with an interdisciplinary matrix, dedicated to the morphofunctional study of the constituents of the Central Nervous System (CNS), especially the brain, emphasizing its potential for establishing relationships, both with the internal environment (issues related to homeostasis) and with the "outside" world (life relationship)[1-3].

Among the different processes investigated in the sphere of neurosciences is memory, which, in general, is related to the ability of living beings to acquire, store, and evoke information[4,5]. This concept is not considered fully satisfactory – from a scientific perspective – since it aims to support, in its limits, a list of distinct, complex, and quite heterogeneous phenomena[5].

Memory has peculiar importance in several processes, such as emotion, cognitive control and planning[5,6]. Considering this relevance, brain regions – such as the amygdala, frontal cortex, medial temporal lobe, insular cortex, and hippocampus – have been the focus of recent investigations, which seek to better understand the circuits established between these different areas, involved in memory neurobiology, in an integrated way with other mental functions specific to Homo sapiens 6-8[6-8].

The consequences of these studies have been particularly significant for the understanding of teaching-learning processes, which are recognized as practices closely related to memory acquisition[3-5,8]. The teaching-learning binomial is certainly one of the most preeminent characters of the human experience of existing, which gives a prominent place to neuroscientific studies in educational área[9-11].

Despite the importance and need of these investigations, neurobiological events related to the teaching-learning process still present gaps, especially about aspects related to the positive or negative impacts of the different elements of memory consolidation dynamics[5,6]. In this particular, studies aimed at the role of meditation in generating benefits for both memory and teaching-learning processes have been deserved attention[12,13].

Meditative practice is articulated to the cultivation of human qualities of great relevance, such as the development of a more stable and clearer mind, emotional balance, sense of mindfulness and even the experience of feelings such as love and compassion. It is also considered a process of familiarization with a more serene and flexible way of being, which suggests better use of the experiences lived in society by the individual[14-20].

Positive effects of meditation have been pointed out in the prevention and recovery of mental disorders, such as depression and anxiety[20]. When meditative practice becomes a habit, the signals generated by repetitive stimuli trigger anatomical (structural) changes, such as volume changes in some areas of the brain[21], which keeps certain brain regions activated for more years of life. Moreover, it is noted the acquisition of greater emotional balance, a relevant point for the maximization of attention, a condition that may favor the development of learning[14-20].

In this context, the present study proposes to review the impacts of meditation on memory acquisition and teaching-learning processes, with emphasis on neurobiological investigations, to promote a reflection on the benefits of meditative practice as a tool for improving the different aspects of quality of life.

METHODS

Original articles were researched at the U. S. National Library of Medicine National Institutes of Health (Pubmed) and the Scientific Electronic Library Online (Scielo). The search strategy was based in the use of search filters, which were developed according to the thesaurus of the Medical Subject Headings (MeSH) terms platform. For the Pubmed and Scielo digital libraries, the descriptors and boolean operators "Meditation" AND "Memory" and "Meditation" AND "Learning" were used in English and Portuguese. Contiguously to the selection of articles, we sought consensus among the researchers in defining the texts that were in accordance with the inclusion criteria (commented below). No chronological restrictions were applied in the search of articles. The initial selection was made from the title and summary of all the texts found. In case of doubt, the publication was reviewed and archived. After initial screening, all potentially relevant studies were obtained in full text and evaluated for eligibility.

Inclusion and exclusion criteria

The inclusion criteria prioritized articles that addressed the role of meditation in the neurobiologist aspects of the teaching-learning and memory processes. This methodology allowed to selected specific studies on the impacts of meditation in the above-mentioned areas, emphasizing neurobiological investigations. Books that addressed the mentioned themes were also selected. The exclusion of the studies was based on well-defined criteria, such as: 1) investigations with a meditation approach in other aspects that are not related to memory and the teaching-learning process; 2) research related to teaching-learning unrelated to meditation; and 3) incomplete or secondary text studies, such as editorials, comments, and letters to the editor. Eligibility was independently analyzed by the researchers and the disagreements were resolved by consensus among them. The reference lists of the relevant articles chosen have been selected for potentially relevant documents. Possible bias was analyzed, according to Prisma guidelines, based on the objectives, design, instruments, participants, changes in habits, long-term meditation, interventions and their respective results.

RESULTS AND DISCUSSION

The results of the research as well as the respective discussion were organized into three sections: (1) Basic concepts for the study of memory, (2) Neural mechanisms of memory and learning, and (3) The practice of meditation and the effects on memory and in the teaching-learning process. Qualitative data to make up the discussion of the last section were extracted from 55 original articles.

1) Basic concepts for the study of memory

As brain areas receive external stimuli from the environment and lifelong experiences, memory is encoded, elaborated, and stored when the individual places attention and emotional value in each situation. Thus, it can be accessed according to the existence of motivation to evoke it[2,4,5]. Several types of memory have already been discriminated, such as short-term (STM) long-term and explicit working memories (LTM), which have been described for decades, reinforcing how the term memory does not cover a single and simple concept[4].

The first, STM – also known as secondary memory – is immediate and transient memory, which has ultra-fast duration (a few seconds) and retention capacity from five to nine items. It is elaborated by two verbal and visual-spatial information subsystems, coordinated by a third party, the executive control process, responsible for directing the attention resources to those, in addition to monitoring, manipulating, and updating the stored representations[3,5].

An example of short-term memory is the activation that happens in stimuli such as registering a phone number and its annotation on a sheet of paper. The information that passes rapidly through the prefrontal cortex, hypothalamus and amygdala is lost and is not stored – definitely – in any brain structure[3]. Because it is an activity that was carried out effortlessly, STM has a period from 30 minutes to six hours. This short-term memory can be selectively converted into LTM, which is characterized by remaining for hours, days and even years, being responsible for storing information that is perpetuated throughout life[3,5]. The transformation of STM into LTM occurs is more precisely in the parietal, inferior temporal and occipital extrastriatal cortices[3].

The LTM formation process is slow and involves two types of memory: explicit and implicit. The first, also known as declarative, is the conscious conjuncture of information about people, places and objects, and can be classified into *episodic memory and semantic memory*[2-4]. Episodic memory is individual and is constructed according to the point of view experienced by the individual, being then a subjective memory, which reflects some personal or autobiographical experience. In addition, it is very dependent on the hippocampus and easily lost in surgical procedures in this region[3,5]. Semantic memory, on the other hand, involves facts and attributes, linked to concepts and words such as music, goals, face recognition, among other things tangible. This type of memory is much more resistant to lesions than the episodic one and focuses more precisely on the prefrontal cortex[3-5].

Currently, two important questions about explicit memory are already well characterized. First, there is no single site of long-lasting storage in the brain for this memory. This process takes place widely distributed in various brain regions and can be accessed independently through sensory elements. Moreover, explicit memory is mediated by at least four types of processing, distinct from each other: coding (new information is observed and connected with other preexisting in memory), storage (mechanisms and neural areas that allow memory retention over time), consolidation (process that makes information still labile and stored temporarily become more stable) and evocation (process by which stored information is evoked)[21,22].

In turn, implicit memory, also known as non-declarative or procedure memory, manifests itself automatically, is considered a type of "unconscious" memory. It operates in several ways and one of them is through a type of memory called *priming*, in which the individual, when exposed to a word or object, increases his ability to detect what has been seen. When the subject can visualize the initial letters of a complete word and quickly relate to something that has been previously learned, he is able to evoke the whole word[3,5,22-25].

Implicit memories can also involve the individual in the emotional scenario, according to the experiences of fear, which confer protection and survival. Hearing noises while walking through a forest can lead the individual to associate the sounds with some specific type of animal and activate attention to the things positioned around them to plan an escape. Positive emotions can also be triggered, such as the recognition of the mother's face and the learning of social skills under maternal command[3,5].

Implicit memory in non-human animals can also be characterized as associative or non-associative. Studies indicate that, in associative learning, the animal observes the association between two stimuli or between a stimulus and a behavior. On the other hand, in non-associative memory, the animal is exposed once or again to a single stimulus. In this case, there are two phenomena: habituation (reduction of stimulus response) and sensitization (increased response to the stimulus, when it is harmful or intense)[3,19].

Another example would be learning with the repetition of motor acts, such as riding a bicycle or putting together a puzzle, conferring the ability to perform repetitive tasks with better skill, even without the awareness of having already done the same action previously[26]. In this case, it is a motor memory, which uses the cerebellum and the core of the base to command the movement abilities[3,5,27].

The acquisition of motor skills is the result of the coupling between perception and action, that is, the relationship between the actions performed by the performer and the sensory consequences arising from this action. In childhood, motor learning is associated with great variability of movement choice, which decays with the strengthening and refinement of the ability. Thus, in adults, the performance of motor skills is determined by the repetition of training, acquisition of habits and their stability after consolidation[26-28].

Thinking about the greatness of these processes and their consequences for the activities developed by the human being, the study of these mental functions has much to contribute to education and other areas of knowledge, leading the individual who experiences them[29]. As the human being proposes to deepen knowledge about certain brain areas and their functions, there is a maximization of forces and a minimization of weaknesses, preparing him to obtain the best as a result of the process in focus[30]. In this same line of thought, researchers such as Damásio[31], Isquierdo[5] and, Herculano-Houzel[32] scored the aspects of memory and learning in agreement with the relationship between body and mind for the subject's formation, reinforcing the importance of the theme.

2) Neural mechanisms of learning and memory

While memory involves a complex system, of short or long duration, dependent on the entire experience of the subject to be elaborated, learning arises from the human capacity to store information received or arising from the experience experienced and, according to the importance of this event for the individual, changes in the structure of specific nerve circuits can be triggered, promoting synapses and, thus, enabling further modulations in knowledge[33].

Thus, in an attempt to correlate the two terms, one can state that the acquisition of memory is deeply linked to learning or learning, since it is only possible to 'record' what has been learned[4]. Thus, stored memory can be accessed when stimuli from the environment trigger the evocation of this information[5]. Through this process, memory allows the individual to create his own identity, manipulate and understand the world, taking into account the current context and individual experiences, such as identifying and classifying sounds, signs, smells, tastes and sensations[4,6].

In the pedagogical context, the act of teaching is mediated by the teacher, in an articulated way when learning, in a process in which the understanding of content is constructed by the student[9] under stimuli of various natures, for example, emotional, psychological, and cognitive. Therefore, neuroscientists have invested efforts to elucidate the neural mechanisms involved in the processes of memory formation and learning, in order to promote a greater use of students in classroom activities, including the use of pedagogical tools used and sensory resources, in addition to creativity and didactics of the teacher when sharing knowledge.

The first investigations on memory and learning were developed by Hermann Ebbinghaus (1850-1909), which demonstrated the different memory duration times, in addition to the importance of the events association and ideas for the emergence of learning. Ebbinghaus suggested that repetition was effective in the more consistent fixation of mental associations in memory, based on three basic principles: contiguity (associating information that occurs together), similarity (associating subjects with similar traits) and contrast (associating subjects with polarity)[34].

With the advancement of neurosciences, recent research in the area of learning and memory[35] presented two central questions: (i) do specific regions of the brain contribute to specific forms of learning? and (ii) is the formation of MLP related to structural and functional changes in neurons? After several years of study, including confirmation of some data with animal experimentation, it was possible to evaluate the process that involves memory formation and learning according to the direction of these two propositions.

The first question, discussed for many decades, contributed to the review of previously adopted points of view, from which it was postulated that the nervous system, throughout its unit, would be responsible for learning and memory. According to this theory, cortical lesions would produce cognitive deficits with severity directly proportional to the size of the lesion. However, from the study of individuals with very delimited brain lesions, accompanied by very characteristic memory deficits, it has been suggested that specific types of tasks are learned within specific brain regions, with emphasis on the role of the hippocampus related to learning and memory. The hippocampus is a structure located in the temporal lobe and that composes the limbic system, which is responsible for the signaling of emotions[3,8].

Thus, patients with hippocampus lesions cannot form new memories of a specific type (anterograde), which is responsible for learning new facts or events. The individual is not able to remember, for example, what was ingested at breakfast or who was visited the day before. On the other hand, surprisingly, other types of memory remain intact, the oldest (retrograde), such as memories of childhood or the events experienced in the last holidays. The hippocampus and the medial temporal lobe, of data, are responsible for the formation of explicit memories, while several other regions of the brain, including the striatum, amygdala, and cerebellum, are involved in the elaboration of the traces of implicit memory, which reinforces the proposition raised in the first question[36].

In relation to the second central question, numerous studies indicate that, in order to have the formation of STM, structural and functional changes in neurons are necessary, including morphological changes in the synapses – neuronal communication points – from various intracellular signals. The explanation is based on the phenomenon of synaptic plasticity, observed in all regions of the brain. Thus, as these modifications promote learning, new synapses are formed and the old ones are strengthened, generating a large communication network that keeps the whole process in constant signaling[34-37].

To establish this communication between neurons, electrical signals (action potentials) trace from the dendrites toward the neuron axon. Upon reaching the end of the axon, in the pre-synaptic terminal, the vesicles contained inside this presynaptic neuron rupture and release into the synaptic cleft (the space between two neurons) neurotransmitters used in the CNS, which then bind to the specific receptors on the opposite side, the specific site in the post-synaptic neuron.

This is a simplified way of narrating the communication between neurons, as well as how this signal is processed below, which can cause long-term synaptic changes, conferring synaptic plasticity induced by experience[1-3,5,7]. This neural malleability, which involves all signaling states, is considered the pillar of plasticity, learning and memory[34-

[36]. According to Rota[37], learning is an act of brain plasticity, modulated by intrinsic (genetic) and extrinsic (experience) factors.

When receiving the neurotransmitter – or sometimes substances that play this role, such as hormones, growth factor, neuropeptides, substance P – the activation of intracellular signaling pathways of the post-synaptic neuron occurs, with consequent production of new proteins, necessary for the synaptic modifications[3,38-40]. A key element in these events is the pathway of protein kinases activated by myogenous (MAPK), important signaling proteins, activated by neurotransmitters and various growth factors.

A member of this family is kinase regulated by extracellular signals (ERK). The ERK cascade is used in all brain regions in which synaptic plasticity occurs and its activation is required for the formation of new memories[39,41,42]. If the activity of the ERKs is blocked by injecting an inhibitor into a brain region such as the amygdala, the formation of all learning modes associated with this structure, such as responses to fear, fight and scape reactions, as well as those of positive emotions, including the learning of social skills directed by the maternal command, will be blocked, as previously stated. Similarly, once blocked in the hippocampus, the activity of The ERK also prevents the formation of hippocampal types of explicit memories[40,42].

An example that illustrates this signaling is the memory traces developed in order to establish new pathways activated by a thinking mind, in order to reproduce the memories[43]. These "traces" prove that LPM is the result of real structural changes in synapses from mechanisms that amplify or suppress memory, obeying the specificity in which its acquisition occurred[44,45].

For a better understanding it is possible to evaluate, for example, an extracellular signal such as the gustation can activate specific cascades of second messengers and enzymes such as 1,2-kinase-signal-regulated (ERK1-2) in the insula, culminating in the modulation of gene expression for the codification of an MLP of a new certain flavor, in the same way that the hearing system is the protagonist in establishing cortical memory traces in musicians for the design of melodies[46-48].

In the hippocampus there is a mechanism similar to long-term potentiation, which at the cellular level represents a coding movement proportional to the intensity of the synaptic connection. Such a process requires simultaneous firing in pre- and post-synaptic neurons. The construction of MLD depends on the binding of neurotransmitters to specific receptors in the post-synaptic membrane to initiate a cascade of biochemical reactions, which are the key to producing favorable effects in the formation of MLP[3,5,8,43].

In this scenario, glutamate, once bound to metabotropic receptors, NMDA and AMPA (alpha-amino-3-hydroxy-5-methylisoxazole-4-propionic acid), activate the guanilil-cyclase enzyme. With this, there is an increase of the second messenger guanidine-monophosphate-CYCLIC (GMPc), with activation of protein kinase G, promoter of nitric oxide (NO) and carbon monoxide (CO)[48]. These, in turn, amplify the response potentiating the action of glutamate, both at the pre- and post-sinaptic level[47,48].

Other activations that glutamate performs are capable of favoring glutamatergic transmission, extending it to varying times, such as the activation of protein kinase C (an increase of half an hour of glutamatergic activation); as well as the Glutamate-Receptor NMDA and GLUTAMATE-RECEPTOR AMPA binding (with an increase of three more hours)[49]. In addition to these, protein kinase A promotes the activation of CREB-type nuclear proteins, starting transcription of cell binding proteins capable of strengthening newly stimulated synapses to maintain the long-term potential of the post-synaptic membrane and thus favor MLD[50]. At the end of the acquisition of each memory, the events subsequent to the CREB activation process extend for up to six hours[49], and the consolidation is an event that is repeated along with the activation of memories[51].

Different mechanisms have been proposed for the persistence of memories with the involvement of cyclic reiteration of calmodulin kinase (CaMK) enzyme activation and simultaneous elevation of adenosine-cyclic monophosphate (PCM) levels in the hippocampus after consolidation. Research suggests that the activation of this enzyme is extremely important, especially for the maintenance of memories in the hippocampus[52,53].

Another signaling involves brain-derived neurotrophic factor (BDNF), which falls between the main proteins that regulate neuronal plasticity and memory formation, mediating the main processes dependent on external stimuli. It is mainly produced by glial cells and neuronal nuclei and has great expression in the hippocampus, neocortex, tonsil and cerebellum[3,5,8]. BDNF is considered a potential neurobiological mediator of the effects of life experiences because it performs important roles such as modulation of various synaptic functions, inducing stimulation of maturation, nutrition, growth and neuronal integrity[54]. A simple exogenous stimulus, through the application of BDNF, enhances the presynaptic efficacy by increasing the release of glutamate in excitatory synapses[55], highlighting the dimension of the importance of this neuropeptide.

Some studies with animal experimentation have pointed to a variation in the level of BDNF in the hippocampal region related to stressful factors, in which elements of acute stress decrease the long-term potential in its dorsal region, selectively increasing, however, monoamine levels and long-term potential in the ventral region. These data suggest that the hippocampus plays a double role in stress response, with the dorsal part submitted to adaptive plasticity, perhaps to facilitate escape or avoid the stressor, and the ventral part involved in the affective facets of the experiment[53,56].

Studies are still divergent in relation to the ideal level of BNDF for memory consolidation. A research with animal experimentation, whose study group was composed of animals under immobilization stress, found an increase in BDNF in the hippocampus[57], which promoted a decrease in explicit memory in the short term. Another study suggested that stress may act differently in the hippocampus[56]; in fact, the level of BDNF would also be affected differently. Researchers also showed that the decrease in BDNF can affect the consolidation of some types of memory[58]. Therefore, although BDNF is considered an excellent neurobiological marker for this function, further research is needed in order to evaluate the level of BNDF determining the successful implementation of the MLP, given the emotional variations of the individual.

Research also points out that dopaminergic signaling activates the hippocampus and then there is information storage[49]. From this process, there is the determination of consolidation period of these memories, which may persist for a few days or weeks, promoting the reinforcement of memory-learning[59]. Dopamine is a natural precursor to adrenaline and norepinephrine, both catecholamines with CNS stimulating function. It is produced by dihydroxyphenylanine (DOPA) decarbonization in the black substance and ventral tegmental area (VTA)[3,5,8]. In addition to memory and learning, dopamine is involved with control of movements, mood, emotions, cognition and sleep[3,5].

3) The practice of meditation and the effects on memory and the teaching-learning process

Meditation can be defined as a wide variety of activities that have as common objective the development of consciousness, with expansion of the mind and its functioning, almost always achieved by the forms of sentinic-motor discipline, such as remaining in silence, relaxing, closing the eyes, breathing consciously, and adopting an object of consciousness[60]. Among the numerous meditative techniques already described, eleven of the best-known ones were: Hindu bhakti, Jewish cabal, Christian hesicasm, Sufism, transcendental meditation, yoga ashtanga, Indian tantra, Tibetan Buddhism, Zen Buddhism, Gurdjieff's fourth way and krishnamurti's unchoice conscience – pointing out the cultural, philosophical, and structural diversity that surrounds the concept of meditation[61].

In addition to these, numerous benefits of the Mindfulness or *Full atention* technique have been studied as a meditative practice for controlling consciousness focused on the present moment, without judgments, such as a self-regulatory process of care, conferring decreased repetitive thinking and cognitive reorganization[62,63].

Regardless of the chosen meditation technique, as practice becomes a habit among adherents, significant changes are observed in various scenarios of the individual's life[64,65], among which are the acquisition of skills to deal with automatic thoughts[66], cultivation of physical, mental, and emotional well-being[66,67], with decreased negative thoughts and symptoms of stress, anxiety, and depression[68-72]. In addition, meditation is pointed out in many studies as a tool to improve the level of consciousness and benefits for life in general, such as sleep improvement, social interaction, as well as reflections on life and practices of forgiveness, compassion and gratitude[61,64], among others.

In pedagogical practice, focused care meditation has produced gains in cognitive functions, especially attention and memory[18,73]. Training through attention-focusing activities, such as mindfulness, in addition to improving attention, increases information processing capacity, alertness and consolidation of LTM[65]. Added to these data, meditation is a beneficial factor for cognition, considering the positive effects on emotional reactivity, empathic response to people, attention, and memory reinvigoration[74].

Emotional control is achieved to the detriment of the properties that meditative activities must activate integral structures of the limbic system, whose areas participate in the fixation of memories related to emotional content[5]. The brain performance achieved during meditation establishes a connection between the amygdala, hippocampus, hypothalamus and neural fibers that are responsible for motivation and emotion, reinforcing the importance of controlling the limbic system in the relationship between memory and learning[66,68,69]. This time, individuals who have control of their emotions, focusing on the present moment, have more abilities to deal with extreme situations, not impairing concentration and ability to retain memories.

In addition, factors such as increased autonomic stability[75] and humoral modulation significantly decrease plasma cortisol and norepinephrine levels[76], with simultaneous increase in serotonin and dopamine[72], contributing to well-being[77], which places the individual in a state of pleasure, inner peace, and motivation. In addition to physical well-being, familiarization and control of mental activity have a significant and lasting impact on attention and memory[74,75].

Chan et al. use the term "mind-body exercises" to refer to the practice of meditation activities such as physical posture training, breathing control, concentration, and attention exercises[78]. In this sense, one of the main tools used is breathing itself. The intentional maintenance of attention and awareness causes practitioners to develop refined memory states. In this sense, meditation usually encompasses two main forms: concentrative and mindfulness.

Concentrative meditation can be performed based on attention on a single focus, such as respiratory movements with synchronized breathing count, a mantra, or any sound, for example[61,64]. Whenever there is some distraction, the practitioner should simply return his attention to the chosen focus and resume the practice. Mindfulness, in another way, is characterized by the awareness of the experience of the present moment, with an attitude of acceptance, without introduction of thoughts or judgments. As internal or external stimuli reach consciousness, the practitioner simply observes them and, as they emerged, lets them disappear, without any analysis, keeping the focus on attention[62,63,67].

With the repetition of practices, the techniques promote changes in the physical and functional structures of short and long term in regions of the brain such as the dorsolateral and medial prefrontal cortex, the anterior and posterior cingulate cortex, the insula, and the amygdala, assisting these structures in the control of homeostasis and functional performance. This simple exercise that initially serves to control respiratory activities, and continues with attention to the present moment, without judgments or distractions, contributes to the decrease anxiety, which allows a broader view at the moment of decision-making[67]. Such state of absolute mental presence is, therefore, a method that reduces stress and assists awareness in controlling emotions, helping in the recovery of attention and in the recall of memory[65,66,69,70].

These cognitive-behavioral alterations contribute to the better affective interaction between individuals, expand the interpersonal contact network and provide better responses to sensory and environmental stimuli among the various experiences that occur throughout life, enabling the individual to select the aferental signals necessary for the present moment, in order to prioritize the proposed activities for this. Thus, the distracting elements can be blocked, which contributes to the process of acquisition, consolidation and recall of memories[17,69] and favors the individual in different situations. In the student context, it can be important to help maintain focus and motivation in studies, with important emotional control that will result in gain in learning.

Studying the benefits of meditation in the brain, identified that the habit of meditation induces cortical thickening with increased concentration of gray matter in areas of the brain associated with attention, sensory processing, learning, and memory[21]. The research also presented significant results related to greater emotional control and less discomfort in relation to pain by already experienced meditators, adding factors that, once related, predispose the individual to greater cellular signaling[62,67].

An evaluation of the brain structures of long-term meditators detected an increase in the anterior insula, involved in the observation of internal physical sensations and, in the sensory cortex, associated with the observation of external physical sensations, concomitant with the decrease in the density of the gray matter of the amygdala[20,79]. This structure, consisting of different nuclei, is pointed with the "trigger button" of emotional interactions, demonstrating another benefit of meditation practice[5,8].

Referring to the previously changes, it is essential to elucidate how these structural changes are established in the individual's organism. Long-term changes in behavior promote a new brain reorganization, linked to neuroplasticity[63,67,68]. This process is characterized as the ability of the CNS to modify its structure and function as a result of experience. The process of neurophysiological reorganization is based on the theory that the human brain is a dynamic and adaptive structure and, in turn, is able to restructure due to new environmental requirements or functional limitations imposed by brain lesions, considering the structural perspective (sinatic configuration) and functional (behavior modification)[1,3,4].

The analysis of the biological aspects of the CNS allows relating factors of influence of the environment, emotional state, and cognitive level of individuals, responsible for modifying – directly or indirectly – the plasticity of brain cortexes and, consequently, the neurophysiological remodeling of a given patient who performs meditation techniques[79]. There is evidence to suggest that meditation has a strong influence on the preservation of cognitive functions of elderly practitioners of the activity and on the deceleration of neurodegenerative diseases, protecting, for example, some memory-related disorder[80,81].

Similarly, a study suggests that changes in brain morphology may occur in response to the practice of long-term meditation, especially the cortical thickness of some areas responsible for attention, with noticeable increased attentional capacity of these individuals, which reinforces the idea that meditation is an effective technique for improving such function, contributing to the learning processes[79].

Furthermore, research indicates that with the constant practice of meditation, all the sense of objectivity and the processes of attention, memory and learning are improved[68,82]. Moreover, through interconnections involving areas that process emotions and memory, it is possible to control more intense emotional changes, contributing to balance and marked improvement in mental health[64,67]. To this end, the mental training developed in meditation reveals that, through practice, the regions of the amygdala and limbic system, as well as the frontal lobe, the insula and the cingugulum gyration are stimulated, with the modification of such structures[80]. Training with meditators suggested a greater aptitude of these structures in keeping themselves in a waking state compared to individuals who did not perform the practice[6,69]. Analyses were also performed during the meditation activity, which showed an activation of the prefrontal cortex and the cingulate gyration, concomitantly, suggesting that the state of concentration happens at the beginning, right after the activation of these two regions[9,83].

This dynamic interaction – signaled during meditation – happens to the detriment of the impulses that reach the right hippocampus of the meditator and that, in equivalence, boost the action of the right amygdala[69]. From this concept, the result for those who are in the state of meditation is the stimulation of the lateral parts of the hypothalamus, causing the feeling of pleasure and tranquility. In addition, this process stimulates the prefrontal cortex, responsible for decision making and the individual's operational abilities, empowering the entire system to obtain a progressive concentration that intensifies in relation to the object, during practice[9,83].

Some of these benefits pointed out by meditation and current discoveries in the field of neurosciences converge to the fact that the adult brain can be modified through experiments. Thus, the practitioner of meditation is constantly tied to the regulation of mental states, modifying the structure and brain function incessantly, leading him to an improvement of his cognitive capacity and quality of life[84].

As a consequence, the reduction of stress and adverse factors limiting cognitive impairment, such as anxiety, depression, insomnia and social exclusion, combined with mental training through developed and improved exercises, was possible a significant reduction in the risk of the onset of deficient cognitive conditions. This fact allowed the observation of memory enrichment and learning by regulating the care and emotional level of this population, through non-pharmacological interventions[80], which is important for reducing drug dependence as the first and only choice of treatment.

In the scenario of processes that unite memory and teaching-learning signs, studies show that regular meditation, performed as an individual's habit of life, promotes the expansion of the mind. The deepening of these investigations has been following the progress of knowledge about the CNS, its mechanisms, thought circuits and its outcomes[10,85]. The simple exercise of maintaining focus, a situation that can be acquired with the various types of meditation that exist, contributes to the reduction of anxiety, and allows ease in decision making, in addition to increased creativity and concentration[6,10], thus contributing to learning[85,86].

Meditation promotes a greater stimulation of prefrontal and temporal areas, cortical regions related to concentration, responsibility and decision-making[13]. Practicing meditators report greater motivation and interest to study and learn, besides feeling a greater emotional involvement in these processes[87], pointing to the existence of interaction between brain circuits and the processing of external stimuli received that activate attention and memory to build teaching-learning processes[6].

Although studies that relate the effects of meditative techniques with cognitive and behavioral aspects are less numerous, researchers point out that the practice, by positively influencing the improvement of attention[88-90], can promote the improvement of verbal performance and fluency[91], reinforcing the benefits for memory acquisition. In fact, the integration of the brain areas cited for memory formation occurs through the release of neurotransmitters and neuronal interaction established by synapses. With the intensity of the mechanisms that promote the circuit between the pre-synaptic terminals and post-synaptic membranes, the LTM is formed, which enables the neurocognitive consolidation responsible for the retention of information in the CNS[23]. Thus, the use of meditative practices has great potential to intensify biochemical events related to memory and other spheres of brain homeotase[92,93].

Regardless of the age of the individual performing the technique, meditation shows positive results in relation to the evolution of neurocognitive capacity in different studies[94,95]. Among adults, in the professional sphere, the incorporation of meditation techniques in large companies led to the improvement of employee activities[96], with significant improvement of executive functions, creativity and emotional control, in addition to motivation for work and maintenance in focus, without deviations or judgments. Regarding the school performance of children and adolescents exposed to meditative practices as a discipline of the curriculum matrix, advances that include improvement of selective care in the school environment, progress in engagement in tasks, elevation of self-control and behavioral stability in the classroom and even increased cognitive performance of patients with Attention Deficit Hyperactivity Disorder (ADHD) in activities to quantify attention and cognition[85,87], when compared to children who do not meditate, which can also be a hope of support for these children, contributing to improvement in quality of life and teaching-learning processes.

CONCLUSIONS

The acquisition and storage of memory are intrinsic and essential processes for the development of learning, a step in which the individual can evoke the previously stored memory. Such events depend on different stimuli and experiences of each individual, and involve neural signals at different intensities, depending on the importance given to the stimulus received. In addition to synapses and neurotransmitters, there is production and release of other chemicals, according to messengers and hormones, with consequent activation of several brain areas in a dynamic process of memory signaling and learning, which is increasingly intensified along with neural plasticity stimuli.

Therefore, the mental training developed in meditation reveals morphological and physiological changes in brain regions such as the amygdala, frontal lobe, insula and cingules gyrus, as well as modification and amplification of the cerebral cortex in meditators, with possible increase in cortical mass and, consequently, in the number of synapses, which can optimize the attention processes, executive practices, labor activities and the stages of memory elaboration.

Thus, meditative practice can be used as a tool for improving the different aspects of memory and teaching-learning processes, besides acting as an element of promoting quality of life and well-being. It is necessary, therefore, more studies in the area to promote these discussions with education professionals, so that they can extend the knowledge and application of the technique in the institutional scope, focusing on learning, especially for students who have difficulty concentrating and memorizing.

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