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Sleep neurophysiology and its effects on the organism

Summary

Sleep is a mechanism that has intrigued humanity since ancient times, but the advent of science has enabled its understanding. However, contemporary society has been experiencing a time in which the quality and quantity of individual sleep hours have virtuously declined, while the establishment of a competitive incentive system increasingly emphasizes the development of cognitive functions. Therefore, this article aims to shed light on the relationship between the physiological aspects that govern sleep and the formation of memory in the learning process. Additionally, we will also discuss the organic resource of neural regeneration and how the nervous system develops means to repair its faults, maintaining the proper functioning and communication of its structures. In this sense, neuroplasticity has been identified as a key component in understanding the mechanisms that contribute to cognitive expansion. A literature review study was conducted based on articles found on platforms such as Scielo Brasil, Biblioteca Virtual em Saúde, PubMed, and Google Scholar. The main theme of these articles revolved around the study of sleep and its relationship with other explored neural resources. Our findings demonstrate the impact of sleep on the neurophysiological functions of the organism, particularly memory and learning, such that these aspects are compromised in deprivation scenarios. We also discussed how the neural plasticity mechanism is influenced by an individual's sleep routine and habits. Consequently, there is a need for reflection on the lifestyle that has become imperative in contemporary times, as it is the main factor responsible for alterations in sleep physiology.

Keywords: sleep, neurophysiology, neuronal plasticity, memory

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Introduction

The simple act of sleeping may seem, under a little in-depth look, to be a banal need inherent in the daily life of human beings, after all, this practice is so common that even lower beings on the evolutionary scale, such as insects, have a need for rest that it would represent a kind of rudimentary sleep. However, depending on the perspective that sleep is subjected to, it can have multiple meanings that demonstrate the real complexity related to the habit of sleeping. Thus, in the same way that the most diverse beliefs seek their own understanding of sleep, science also strives to study and understand the mechanism behind this physiological phenomenon.[1]

The relationship between sleep and body homeostasis is clear. The concept of homeostasis, which was formulated throughout the 1920s by the physician and physiologist Walter Brandford Cannon, concerns the organism's quest to maintain the conditions of its internal environment stabilized in a pattern of dynamic balance, aiming to maintain possible oscillations of vital factors within an acceptable parameter. In this context of homeostatic attempts to maintain the body in a condition considered ideal, sleep plays a crucial role, as it influences the most diverse bodily factors, such as hormonal regulation, heartbeat, respiratory rate and the autonomic nervous system.[2–4]

Despite the notion of the relationship between sleep and homeostasis, little was understood about the neurophysiology of sleep itself, as the scarcity of mechanisms responsible for studying brain functioning made it difficult to delve deeper into this area. But, in 1929, German neurologist and psychiatrist Hans Berger announced to the scientific community that the presence of oscillating waves, responsible for representing brain electrical activity, could be identified in humans and recorded on paper without the need to carry out invasive procedures that result in at the opening of the skull. It is worth mentioning that the study of brain wave activity was already developed by scientists before Berger, however, they were restricted to the neurophysiology of animals used experimentally, such as dogs and monkeys. This method of recording human brain waves was named encephalogram by Berger, which was quickly incorporated into clinical practice and allowed the development of Sleep Medicine.[1]

Currently, through the use of encephalography and the advent of other more modern complementary resources, such as the recording of eye movements using the electro-oculogram, it has become possible to understand that bodily homeostasis is influenced according to the quality of sleep, as this, in addition to presenting different phases that modify its expressiveness, it is also related to multiple cycles inherent to the development of the human body, such as hormonal physiology and the alternation between the state of alert and the state of rest.[5]

However, ironically, as the study related to the need for sleep became more and more expanded, human beings in the 21st century began to increasingly neglect the habit of sleeping. This is proven, as sleep deprivation has proven to be a growing problem in modern society, affecting millions of people around the world. With the demand for productivity and a busy lifestyle, many individuals sacrifice precious hours of sleep in favor of other activities. Previous studies have consistently demonstrated that sleep deprivation is associated with impairments in cognitive function, including deficits in attention, working memory, logical reasoning capacity and brain neuroplasticity.[6] Therefore, through a brief notion of the impact of sleep on our lives, it becomes essential to understand the neurophysiology of sleep and the consequences of sleep deprivation. Sleep disorders are associated with a number of medical conditions, such as cardiovascular disease, obesity, diabetes, psychiatric disorders and cognitive impairment. Understanding the neurophysiology of sleep can lead to advances in the prevention, diagnosis and treatment of these conditions. Furthermore, understanding this process can help elucidate the neural and physiological processes involved in sleep, including the regulation of the circadian rhythm, the neural networks involved in inducing and maintaining sleep, and the different stages of sleep.[6,7]

This study aims to analyze the neurophysiology of sleep and its effects on memory and learning. Specifically, we aim to unveil the neuronal circuits that involve the pathways responsible for neuroplasticity, correlating how this factor reflects the individual's intellectual potential. Furthermore, discuss the hypersensitivity of dopaminergic receptors to sleep deprivation, as well as analyze the effects of sleep deprivation on the hypothalamic-pituitary-adrenal axis.

Methodology

A literature review was carried out, between 2002 and 2023, in the most diverse scientific databases already recognized by the academic community, such as Scielo Brasil, Biblioteca Virtual em Saúde, PubMed and Google Scholar. During the search, descriptors that covered the neurophysiology of sleep and its effects on the body were used. As an example of these keywords we have: sleep deprivation, neurophysiology, memory consolidation, hippocampus, neuronal plasticity and circadian rhythm sleep disorders. The Boolean operators used were: "AND" and "OR", and the topics researched included: effects of sleep on memory, relationship between sleep and memory, association between sleep and learning.

A total of 112 articles were found, with the main exclusion criteria being: those that did not have sleep as the main theme and those that were related to the themes: learning, memory, sleep habits, sleep deprivation and neuroplasticity and predilection for literature more recent, but at times covering older writings that included relevant discoveries. In view of this bibliographical selection effort, 40 main articles were used to support the current work, seeking to identify gaps in the knowledge produced so far, in terms of a descriptive nature, insofar as it also summarizes the main findings relating to the neurophysiology of sleep.

Theoretical foundation

Regulation and homeostasis

There is a brief tendency to interpret sleep as a kind of bodily "shutdown", due to the perception of being temporarily in a state of reduced responsiveness. This thought turns out to be partly mistaken, because while we sleep, we actually have a decrease in our sensitivity to external stimuli, however, the brain continues in an extremely variable activity throughout the evolution of the sleep phases and counteracts this, therefore, the idea of being disconnected.[5]

In fact, the complexity linked to sleep consists of the adaptive capacity in which your temporary, periodic and cyclical state of consciousness manages to adapt to the demands of both the organism itself and the environment around it. In this way, we can observe that, at the same time that sleep regulates bodily events, the body itself also modulates the act of sleeping. Therefore, before delving into the effects of sleep deprivation itself, we need to understand how the neurophysiology occurs that allows this intimate homeostatic relationship between body and sleep.[5]

In order to carry out an analysis and identification of the particular characteristics inherent to each phase of sleep, the electrical brain waves, the degree of eye movement and muscle contractility will be the main physiological variables evaluated, respectively, by the electroencephalogram (EEG), electrooculogram(EOG) and electromyogram (EMG) of the jaw muscles. When carrying out such exams, two patterns of body expression were observed during sleep, one marked by the absence of rapid eye movements (NREM) and the other marked by the rapid movement of the eyeballs (REM).[8] During the NREM phase, neurons acquire a slower rhythm that is expressed in the EEG in the form of slow waves and, concomitantly with this decrease in brain activity, muscle fibers enter a state of relaxation with relative maintenance of vagal tone and, As already mentioned, there is an absence of rapid eye movement. This phase represents the longest moment of sleep with an average duration of 90 minutes and can be divided into 3 stages (N1, N2 and N3) according to a progressive increase in the recording of slow brain waves.[1,9]

Stage N1 is extremely important as it marks the transition from a waking posture to a state of drowsiness, in which the brain progressively begins to reduce its brain waves typical of when awake to begin producing less active waves characteristic of the NREM phase. Thus, in stage N1, there is a process of progressive and gradual reduction in brain activity, in such a way that, even at the same stage, the mind passes from a superficial sleep to a deeper sleep. Stages N2 and N3 represent levels that continue the deepening of sleep.[1,6]

The REM phase follows the NREM phase and reveals itself to be the stage in which sleep is in its deepest condition. REM sleep has a short duration that can vary from 5 to 10 minutes, which is a period of intense brain activity with the occurrence of dreams. An interesting factor about this phase is that it presents a somewhat paradoxical character, because, although the body is sleeping during REM sleep, characteristics similar to those found in the waking state can be visualized during this specific moment of sleep.[1,3] When entering REM sleep, the electrical brain waves, which were in a more lethargic state during NREM sleep, begin to have a more active and desynchronized character. Such waves acquire a fast rhythm with low voltage, which, when represented in encephalography, represent an image with a serrated appearance and, therefore, can be called serrated waves. This desynchronized finding can also be seen on the EEG when we are awake.[1,3]

However, the REM phase is not only similar to the waking state in terms of the character of its waves, other characteristics inherent to the period in which we are awake can also be observed in this part of sleep. As a protective measure for the body so that movements performed in dreams are not physically reproduced, a condition of muscular atony is found in this stage of sleep. However, despite the muscles being in a state of intense relaxation, it is possible for there to be a phasic release of muscle activity of varying location. There is a brief explosion of the muscles which, in addition to causing rapid movement of the eyes, often happens in an unpredictable and random manner, which explains the movement, for example, of limbs and facial muscles, even allowing the babbling of certain sounds. REM sleep, therefore, would be another factor that proves in practice that sleep is far from being a condition of brain shutdown, even presenting similarities with the waking state.[1]

The main importance of sleep is the fact that several physiological events, necessary for the organic maturation of the body, occur as the aforementioned cyclical phases progress. It is when we sleep that the brain acquires a broad plastic capacity to generally reorganize its synapses and cellular structures, allowing the development of its neurocognitive functions. This dynamic ability of the nervous system to improve its parts is called neuroplasticity and will be better explored, as well as the issue of memory and learning, during the development of current scientific production.[10] In addition to the contributions of sleep related to cognitive processes such as memory, we can also find multiple physiological actions that happen when we sleep. It is in the NREM phase of sleep that hormonal regulation issues occur, for example, such as the release of GH and testosterone, which are important, respectively, for growth and sexual development. REM sleep continues the process of consolidating memories started in the previous phase. During a healthy night's sleep lasting an average of eight hours, the body goes through approximately six sleep cycles. Each cycle comprises the moment of the beginning of NREM sleep and the end of REM sleep and it is common that, between the end of one cycle and the beginning of another, there are micro awakenings. If there is some external stimulus, such as an alarm clock ringing, or some internal stimulus, such as the urge to urinate, these cycles can be interrupted without having been completed.[1]

However, the ability to sleep is not limited to the simple act of lying in bed and closing your eyes, as sleep does not prove to be a passive process. In fact, the body needs to find active ways to modulate sleep, in such a way that it is possible to induce the desire to sleep and the need to stay awake. In this context, a notable cycle deserves to be highlighted because it is precisely responsible for this sleep regulation process: the sleep-wake cycle. It is worth noting that several structures of the central nervous system participate in this cycle, however, the hypothalamus and the brain stem deserve to be highlighted because they are closely related to the alternation of brain activity through their participation in this process. Therefore, our approach will be focused on exploring these two structures.[1,3]

The reticular formation is found in the brain stem and is structurally composed of the reticular substance, which contains neurons that generate diverse gradual signals, whose axons, with significant extension, have the capacity to secrete numerous neurotransmitters. The Magnocellular zone corresponds to a specific area of the reticular formation, where we can find a system of neuronal bundles that transmit information upwards towards the cerebral cortex, influencing its cortical electrical activity.[3,11]

This ascending reticular activating system has reticular nuclei of specialized neurons, which release neurotransmitters related to the induction and maintenance of a state of wakefulness and alertness, such as histamine, dopamine, norepinephrine, serotonin and acetylcholine. Such substances cause an excitatory state in the cortex that allows it to remain active, consequently generating the desynchronized waves typical of the waking state. Communication between this system and the cortex is mediated by the thalamus.[3,11] However, the ascending reticular system does not prove to be the only means of regulating the sleep-wake cycle, after all, it has great relevance for maintaining a state of alertness, however, it alone does not have a broad capacity to induce drowsiness. Because of this, another neuronal circuit, governed by the hypothalamus, comes into activity, which influences both the establishment of the state of wakefulness and the induction of sleep, and may even influence the activation of the ascending reticular system. Faced with a mixed functionality, the hypothalamus has a region that promotes wakefulness, located in the tuberomandibular nucleus (NTM), and a region responsible for inducing sleep, present in the ventrolateral preoptic nucleus (POVL).[3,11]

Two main neurotransmitters are linked to the sleep-wake cycle, histamine and gamma-aminobutyric acid (GABA). Histamine, secreted by the previously mentioned ascending reticular activating system, is also released by the NTM and, when it binds to postsynaptic H1 receptors in the cortex, activates a system of second messengers that promote wakefulness. GABA is released by the POVL and has a potential reducing action on neuronal activity in several areas of the central nervous system such as the prefrontal cortex, as, when binding to its GABAa receptor, it causes a tonic or phasic inhibitory neurotransmission, which reduces synaptic activities, inducing a more lethargic state that can trigger drowsiness.[11]

However, after all this explanation about the sleep-wake cycle, in which we understand that this cycle has the function of inducing the body to a state of alert or a state of rest, the following question arises: how does the sleep-wake mechanism know When is it necessary to induce sleep and when is it necessary to suppress it, in order to optimize the physiological functions influenced by the body's routine? As surprising as it may seem, the answer lies in the hypothalamus itself, showing how complex its functionality is. There are two hypothalamic mechanisms that will govern the balance between the activation of the NTM and the POVL.[1]

One of them is said to be the region of the lateral hypothalamus, which has neurons that secrete a peptide neurotransmitter known as orexin or hypocretin. Two types of orexin receptors can be found in the central nervous system: orexin 1 receptor and orexin 2 receptor. In general, it is the orexin 2 receptor that is in fact related to the sleep-wake cycle, as it is the main receptor found in hypothalamic regions directly related to this cycle.[10,11]

Orexin has the ability to regulate the release of histamine by the hypothalamic wakefulness-promoting center, NTM, when it binds to orexin 2 receptors found with certain abundance in this region. An important point is that histamine, when released, in addition to exciting the neural synapses of the cortex, also has the ability to inhibit POVL. In other words, indirectly, orexin, through its control over histamine secretion, also regulates the activity of the sleep-promoting hypothalamic center.[10,11] However, despite the lateral hypothalamus acquiring a significant role in creating stability between the antagonistic centers of the hypothalamus itself, the participation of some process that enables the adaptation of sleep to external stimuli from the environment is still necessary. It is in this context that the other mechanism that influences sleep-wake regulation comes into operation. The hypothalamic structure responsible for this important homeostatic functionality turns out to be the suprachiasmatic nucleus (SCN).[11,12]

The SCN, through its communication with the retina, via the hypothalamic retinal beam, becomes sensitized to photic stimuli. In other words, the SCN allows the body to identify, according to ambient lighting, when it is night and when it is day, establishing another cycle capable of adapting the body's physiology to the daily routine. This new cycle, made possible by the SCN, is called the circadian cycle or rhythm.[11,12]

The circadian rhythm turns out to be an internal timer system that lasts approximately 24 hours and allows the adjustment of body physiology according to environmental stimuli, such as light and ambient temperature. Since the SCN is the main promoter of this rhythm, it becomes understandable why this hypothalamic portion is called the body's master clock. The circadian cycle occurs from the moment in which the SCN remains in line with the environment and studies state that this master clock receives neural extensions from at least 35 different areas of the brain.[13] This explains the fact that the circadian rhythm influences a series of centers that regulate homeostatic patterns, and is therefore not limited to just regulating the sleep-wake cycle. Thus, the circadian cycle affects, in a widespread way, metabolic, hormonal and neural events, in addition to being extremely relevant for gene expression, as certain genes, called circadian genes, have their expression linked to circadian progression.[13]

Thus, it is understood that from the moment the SCN receives information from afferent pathways, such as the retinohypothalamic bundle, it modulates cyclical biological responses that make up the circadian rhythm. This makes it clear that the circadian rhythm is extremely relevant for the activation or inhibition of sleep-wake mechanisms, depending on the adaptive needs of the environment. However, not all stimuli that help the SCN to understand when it is day and when it is night come from the external environment, in fact, one of the main signs of nighttime comes from an endogenous pathway. This signal, in fact, turns out to be a lipophilic, sleep-inducing hormone produced by a small gland located in the roof of the diencephalon. This gland is called pineal and its hormone is the famous melatonin.[3,14]

Melatonin, produced by pineal gland cells called pinealocytes, acts on three distinct receptors called M1, M2 and M3, however, the M3 receptor is not involved in sleep physiology. The other two receptors have a strong relationship with the circadian and sleep-wake cycle, as they are present in the SCN and have the ability to induce sleep when linked to melatoni.[10,11] Furthermore, an important factor to be commented on is that certain hormones, also influenced by the circadian rhythm, present an antagonistic synthesis and release to melatonin, that is, while melatonin production is high, the production of this other hormone is low, or vice versa. A classic example of this relationship can be observed with the synthesis and secretion of cortisol. Cortisol is a hormone produced by the adrenal glands and is related to a series of physiological effects, such as renal and inflammatory activities. This hormone has an antagonistic relationship with melatonin, precisely because they have opposite functions, as while melatonin participates in the deactivation of wakefulness mechanisms, cortisol has the ability to keep us alert, amplifying energy mobilization mechanisms and stimulating different systems such as the cardiovascular system. This is just one example of the intriguing hormonal relationship inherent to the circadian cycle (Reinhardt, 2013).[15]

Many of the substances influenced by sleep regulatory processes, despite having their release linked to this entire homeostatic apparatus involved with the habit of sleeping, have multiple effects, the extensions of which go far beyond their relationship with sleep and affect a series of events corporeal at the most diverse physiological levels, events that modulate who we are. Many of the neurotransmitters and hormones mentioned have effects on reward circuits, cognition, sense perception, learning, memory and so on.[10] Therefore, it is hoped that, with this brief general exploration of the neurophysiology of sleep, its intimate relationship with the body's homeostasis has been clarified, in such a way that, even before we delve into sleep deprivation itself, the notion How harmful this private process can be can already be deduced only with the physiological notions worked on so far.[10]

Sleep habits and routine

It is undeniable that, in contemporary times, the search for productivity has become something intrinsic to the social imagination of those who seek, mainly, academic and professional success. Therefore, in this imperative search for maximum efficiency, many individuals, in their stressful routines, normalize the increased use of electronic devices to perform these tasks. This expansion in the use of electronics means that individuals are exposed to a prolonged period of lighting during the night. Therefore, this new habit harms the sleep-wake cycle, as photons from computer, tablet and cell phone screens stimulate the suprachiasmatic nucleus, which inhibits the secretion of melatonin, a hormone that induces a state of deep relaxation, by the pineal gland.[16]

Furthermore, the hormonal accumulation of cortisol, due to the routine stress caused by self-demanding academic and professional commitment, also contributes to changes in this cycle, given that it has been proven that the low amount of this hormone in the bloodstream is what causes the occurrence of cortisol stage N3 of NREM sleep. This phase is extremely important as it is part of deep sleep and is when hormones are released, such as growth hormone (GH). Furthermore, it is worth mentioning that stress itself leads to a cycle of insomnia, as sleep fragmentation leads to an increase in serum cortisol, becoming a new stressful factor and causing hyperactivity of the hypothalamic-pituitary-adrenal axis, responsible for controlling physiological aspect of this hormonal activity.[17] Therefore, it is inevitable that there will be negative consequences for these individuals, as during sleep there is a "cleaning" of adenosine residues in the nervous system, originating from ATPs (adenosine triphosphate) used during the day, which promote mental fatigue. Furthermore, the consolidation of long-term memory is also carried out during this state of body relaxation, so that sleep deprivation modulates individuals to experience memory and learning delays.

This proves the existence of a paradox in today's society, as it stops sleeping to produce more, but effectively becomes less productive, as its mental abilities deteriorate due to changes in the sleep-wake cycle.[16] A posteriori, it is worth mentioning that bad sleeping habits, and the lack of adequate hygiene, for a good night's rest, lead to the appearance of disorders that affect the quality of life, such as narcolepsy, that is, the exacerbated increase in drowsiness during the waking period. There is also the possibility of anomalies appearing, such as obstructive sleep apnea, a type of breathing difficulty that occurs when the patient is sleeping, and Ekbom syndrome, which is characterized by involuntary movement of the limbs during sleep night.[18]

Sleep in the formation of personality

From this perspective, it is worth mentioning that prolonged wakefulness is directly related to changes in dopamine signaling, given that the increase in adenosine load promotes a negative regulation in the receptors of this neurotransmitter. These changes in the dopaminergic framework influence changes in reward behavior, as there is an increase in reward sensitivity, making it difficult to distinguish the precision of the reward that a given attitude will actually generate.[19]

Therefore, as a result of this anomaly in the dopaminergic reward system, sleep deprivation contributes to the development of characteristics such as increased impulsivity and the development of addictions. It also increases the predisposition to obesity, as few hours of rest promote changes in appetite-regulating hormones such as leptin and ghrelin. It also favors the appearance of dysfunctions in dopamine receptors, causing the regions of the frontal cortex, responsible for decision-making, to have their activities reduced, which, associated with sensitivity dysfunctions in the subcortical mesolimbic region, increases the desire for food hypercaloric.[19] Furthermore, it is worth highlighting that a relevant aspect, linked to personality and perspective of life, altered by sleep deprivation is the way of making decisions, since few hours of rest contribute to the increase in the recurrence of apprehensive thoughts, questions about one's own competence, thus intensifying self-criticism. This provides changes in the way circumstances are deliberated, in addition to the fact that changes in the sleep-wake cycle are correlated with a decrease in short-term memory and learning, factors that also influence the judgment about certain situations.[20] Added to this, the irregularity linked to the circadian cycle, that is, the lack of constancy in the number of hours to sleep and fixed times to regulate this act, of an individual who is not diagnosed with anxiety promotes the intensification of an anxiogenic state. Therefore, it is unquestionable that sleep is capable of modulating personality and behavior, as deprivation of hours of rest increases the propensity of a human being to make wrong decisions, induces anxiety and impulsive behaviors, in addition to being related to obesity.[21]

Impacts of sleep deprivation on attention

Attention acts as a filter, through which some items gain greater prominence to the detriment of others, according to Kandel.[22] This ability is essential for the individual's experience, considering that it is impossible, without it, to participate in a complex cognitive process where there is diverse information, from which the most important ones must be filtered for decision making and effective understanding of the situation at hand, that the individual is subjected to. The ability to selectively direct attention is a fundamental pillar of cognitive functioning, allowing the brain to focus its limited resources on what is relevant and meaningful at a given moment. However, the capacity for attention and alertness, which are mainly responsible for satisfactory performance in tasks, are part of the cognitive abilities affected by sleep deficit.[23] This phenomenon is mediated by a dose-dependent mechanism in relation to the amount of time spent awake, that is, the longer the duration of sleep deprivation, the greater the accumulated attention deficit.

The attention deficiency described is known as "lapses", which can be characterized as an increase in slow responses, approximately more than twice the average response time in normal sleep conditions. Thus, during the Psychomotor Vigilance Test (PVT), the "gold standard" for evaluating the effects of sleep deprivation, it was noted that the sleep-deprived individual's performance is interrupted by moments of reduced arousal that prevent a quick and effective response effective to the task.[24] The implementation of this theory of lapses allows a concise explanation of the interrelationship between sleep deprivation and the large number of errors and accidents experienced in reality.[25]

Reductions in functional magnetic resonance imaging (FMR) signal have been described in the dorsolateral prefrontal cortex during attention-demanding tasks and in the intraparietal sulcus, in addition to reduced connectivity with other regions. The prefrontal cortex is responsible for regulating our thoughts, actions and emotions through connections with other brain regions, being able to inhibit interference from external or internal distractions and promote operations relevant to the tasks assigned to the individual at that time.[26] More recently, another important change was found to explain the attention-sleep deprivation relationship: the Default Mode Network. This network is characterized by a set of brain areas that often deactivate when an individual stops performing a certain task. This mechanism is functional so that areas appropriate to task X are mobilized and, thus, successful behavior directed towards the objective is obtained.[26]

Under normal sleep conditions, the inhibitory mechanism between the activity of the Fronto-Parietal Network, of which the dorsolateral prefrontal cortex and intraparietal sulcus are part, and the Default Mode Network is reciprocal, supported by the excitation of the thalamus. In this way, there is stability in the alternation between these two networks, which promotes consistent attention and working memory performance.[19]

In conditions of prolonged wakefulness, when the homeostatic impulse is high, caused by sleep deprivation, that is, when there is an accumulation of adenosine in the postsynaptic receptors in the brain, the interaction between the Fronto-Parietal Network and the Mode Network Pattern is impaired, resulting in state instability as you fluctuate between wakefulness and sleep rapidly. As a consequence, there will be variable attention due to decreased activity of the fronto-parietal network (part of the cortex and intraparietal sulcus) related to the task and, sometimes, increase or decrease, without any pattern, of the Default Mode Network during task engagement.[24]

Relationship of sleep with memory and learning

Currently, there is a general consensus in the academic community about the relationship between sleep and its influence on cognitive performance and the consolidation of long-term memory. Therefore, new studies seek to understand which mechanisms govern this interaction and which factors are capable of intensifying learning processes. Therefore, it is important to associate these concepts, since the same region is responsible for both the acquisition of new knowledge and the storage of what is learned, the temporal lobe, where most of the limbic system is located. In this sense, it is possible to notice a marked drop in information retention in people with sleep disorders, this occurs due to the physiological repair mechanisms that act in the brain while the person sleeps. Therefore, if the minimum number of hours of rest is not respected, or if this sleep is still lacking quality, mental fatigue is generated. Such tiredness can also be achieved through very intense study routines, which harm rather than increase performance.[27]

However, it is necessary to understand the differences between the two types of sleep and how they act in a particular way on learning, which in turn is only effective if there is retention of the assimilated content, that is, if a long-term memory is formed. Firstly, slow wave sleep - called NREM - is important because it is a precursor to REM sleep; At this time, cholinergic activity and the release of glucocorticoids are minimal, favoring spontaneous activity of the hippocampus and its flow of information with the neocortex. This phase is essential because this region has so-called place cells, which have special properties and use a combination of reference points to create space representations. Therefore, according to Araújo[28] there is long-lasting potentiation, activated by this cascade signaling and which improves signal transmission from excitatory synapses, persisting for extended periods after induction.

In a second analysis, it is during REM sleep (the deepest and where dreams occur) that there is greater brain activity, which characterizes an intense mnemonic reverberation from both the electromagnetic waves existing in this stage, and the expression of genes that help to perpetuate newly used synaptic connections. That is, memories evoked by electrical reverberation during slow wave sleep are consolidated by genetic reactivation during REM sleep. Consequently, changes in gene expression are observed during this process, causing different stimuli, for example: increase in the number of dendritic spines, release of pre-synaptic neurotransmitters, increase in synaptic surface area and post-synaptic sensitivity; thus ensuring better performance in the active analysis of new memories, problem solving and deduction of new information.[28]

Benefits of a nap: A study carried out by the National Medical Research Council of Singapore, with a group of adolescents between 15 and 19 years old, proved that adding a few minutes of sleep during the day brings benefits for learning. Two groups were evaluated, one with 8 hours of sleep at night and the other with 6.5 hours at night and 90 minutes during the day. Students who napped during the day demonstrated greater performance in the applied activity, demonstrating a greater capacity to retain learning. This result is due to the dissipation of homeostatic sleep pressure in this group, associated with improvements in the processes of accommodation and

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message assimilation in the brain. The neural mechanism responsible for these results consists of the transmission of electrical impulses between the prefrontal cortex and the medial part of the hippocampus during sleep, capable of generating memories that are more resistant to forgetting. Furthermore, the research explored the fixation of content associated with an existing memory and entirely new content, concluding that it is possible to optimize the learning process when new information is acquired with information already known by the individual. Therefore, the link between a nap and a schema with previously learned information is an effective method for using sleep as a resource to enhance learning.[29]

Another similar survey conducted with school-aged students by the University of Pennsylvania and the University of California, published in the journal Sleep, demonstrated similar results. However, it has been proven that the time of day in which the nap is implemented makes a difference, and after lunch around noon is the optimal time to enjoy this benefit. Higher levels of self-control, verbal IQs and academic performance were observed.[30] Finally, the Non-Governmental Organization "Sleep Foundation" states that the ideal duration of a nap is around 15 to 30 minutes and that it should be taken at least 8 hours before sleeping at night. It is also suggested that they not be late - after 3 pm - as this can impact the sleep routine. Furthermore, the institution argues that regularity is capable of optimizing the quality of sleep, that is, it is possible to intensify its benefits by incorporating this practice into daily habits.

Determinants for neural reactivation and memory formation: Sleep may also be responsible for benefiting the reactivation of some memories at the expense of others based on a pre-established reward system. In other words, there is a neurological mechanism influenced by the individual's life experiences that can determine whether information will be retained or not. This theory was studied by scientists in Switzerland who, using magnetic resonance imaging, identified patterns in brain activity permeated by some codes. These codes, in turn, demonstrated that there was communication between the hippocampus (responsible for memory consolidation) and the ventral tegmental area (region involved with reward mechanisms). In this sense, during stage N3 of NREM sleep the same sites involved in the experiments carried out during wakefulness were reactivated; thus, there is a privilege in the reprocessing of rewarded information during sleep.[31]

Another mechanism explored from the neurophysiology of sleep is the dissociation between two types of memories, those intentionally acquired and recalled (explicit) and/or information acquired incidentally and recovered involuntarily - implicit. In this sense, sleep directly influences the consolidation of explicit memories, allowing them to have greater expression during this period; and implicit memories are translated into explicit ones to be absorbed. The researchers also point out, based on neuroimaging analyzes on the volunteers, that the hippocampal, cortical and subcortical regions are activated during this process. In this way, it is possible to understand learning as an active process that has well-defined patterns regarding the stabilization and selection of information during sleep.[32]

Neuroplasticity and neural regeneration

Initially, neuroplasticity is characterized by the brain's ability to adapt its learning and behavior patterns in order to adapt to new skills and intellectual capacity. Similarly, the brain works like a device that resembles a computer, that is, it processes information and issues appropriate responses to such stimuli. This allows for organized connections and enables the formation of complex neural systems. Furthermore, neural regeneration represents the partial recovery of lost functions that, even incomplete, demonstrate the nervous system's ability to adapt to adverse situations.[28,33,34]

Delving into the functioning of the brain, neurons, the best-known cells in the nervous system, do not work alone. Glial cells function in several ways to contribute to the complex performance of this system. We can therefore mention astrocytes, responsible for organizing neurons and readapting processes that involve neurotransmitters; microglia, which act as defense cells; the ependymal cells, which produce the mechanical protection barrier of the nervous system, the cerebrospinal fluid and, finally, the oligodendrocytes, responsible for producing the myelin sheath in the central nervous system. Furthermore, signal transmission begins through electrical impulses through the neuron until it reaches the axon. However, communication with another neuronal cell is mostly chemical, carried out through neurotransmitters through synaptic clefts, which will bind to receptors on the postsynaptic membrane, a process called excitation-secretion coupling.[11,35,36]

Initially, sleep is understood as a dynamic and important process for the healthy development of the individual. Furthermore, such activity contributes to the consolidation of memory, neural circuits and neural regeneration. Studies have been carried out relating the two topics, from newborns to adulthood, as well as the influence of REM and NREM sleep on the consolidation of information and brain plasticity. Thus, from these data, it was noted that, in newborns, REM sleep occupies 50 to 80% of sleep time, however, this percentage is reduced until 12 months of age, reaching 25 to 30%, when NREM sleep begins to predominate. REM sleep contributes to the development of the brain and neurais networks, which consequently allows adaptation to learning patterns and experiences. Thus, from the first months of life, sleep establishes a crucial importance for the rest of the individual's life, that is, if well consolidated in early childhood, brain neuroplasticity will present a greater capacity to adapt to new skills, taking into account given the more effective development of neural circuits at the appropriate age.[37]

In cases of sleep deprivation, REM sleep, which is characterized by a cascade of reactions, is impaired and, conresequently, neuroplasticity undergoes changes in physiology. Firstly, REM sleep phenomena occur, predominantly, in the lateral portion of the oral pontine reticular nucleus, which is ventral to the peri-locus-ceruleus area, a region in the superior angle of the floor of the fourth ventricle. The neurons present in this area stimulate cells that inhibit cellular motoneurons, causing temporary loss of muscle tone. This network of neurons uses acetylcholine and glutamate as neurotransmitters. Acetylcholine is related to learning and memory processes, glutamate, in turn, is an excitatory neurotransmitter and acts on neural and synaptic development and plasticity. It is clear, therefore, that, in cases of unfulfilled sleep, this cascade of reactions generates, as a consequence, difficulties in brain regeneration and neuroplasticity.[1]

Results

Homeostasis

Thus, it is notable that, with the advent of encephalography, it was possible to deepen the study of neurophysiology as a whole. The EEG, when done in conjunction with other means of analyzing physiological variables, such as EOG and EMG, makes it possible to record a series of body parameters that favored the development of sleep medicine. Through the emergence of a medical area focused on the study of sleep, the multiple phases and stages of this phenomenon, as well as its physiological effects on the body's homeostasis, could be better explored.[1,7,8,38]

Therefore, with the possibility of unraveling the homeostatic mechanisms behind sleep, two phases could be observed while we sleep. One marked by non-rapid movement of the eyes, NREM, and the other with rapid movement of the eyeballs, REM. Each of the phases presents its own characteristics representative of brain activity, as well as its functions and neurotransmitters are also distinct, something that is greatly emphasized in the psychopharmacology work of renowned psychiatrist and neurologist Stephen Stahl. As explained by Gomes,[3] depending on which phase of sleep we are treating, the consolidation of distinct physiological events involving hormonal, cognitive and behavioral issues can be observed Krieger.[3,4,11] Furthermore, it became possible to reach the result that sleep is far from being a passive process, as the act of sleeping encompasses multiple regulatory cycles. Of these cycles, two of them deserve to be highlighted because they are closely related to sleep: the sleep-wake and circadian cycles. The first works as a kind of switch capable of activating the excitatory centers of wakefulness or inhibiting them when encouraging the centers that promote the resting state.

The second, also called circadian rhythm, is responsible for signaling when it is necessary to turn the switch on or off. In other words, it was possible to perceive that the circadian cycle, as emphasized by Alves[13] and Viegas,[14] through its communication with stimuli from the external environment, plays a crucial role in regulating the sleep-wake cycle. As a general result of deepening the neurophysiology of sleep, a mutual homeostatic regulation has become notable, in which, at the same time that sleep regulates the body, the body modulates sleep.[13–15]

Sleep habits and routine

Thus, it appears that the increase in hours of use of electronic devices, a characteristic habit of contemporary times, disrupts the correct functioning of the sleep-wake cycle, since this exposure reduces the secretion of melatonin, a substance responsible for inducing deep relaxation. Added to this, the increase in self-demand for greater academic or professional performance leads to high levels of stress and cortisol. A factor that also provides poor quality of sleep, given that high serum levels of this hormone prevent stage N3 of NREM sleep, in addition to feeding back into the cycle of poor sleep, as the very fact of having a bad night's sleep increases cortisol levels of the organism.[16,17]

Therefore, it can be concluded that the new habits of contemporary times hinder the development of a good night's sleep. Consequently, the mental performance of individuals is compromised, since it is during sleep that the residues of ATPS used during the day are cleaned and the consolidation of memory and learning occurs. This poor sleep hygiene also leads to the emergence of disorders such as narcolepsy, obstructive sleep apnea and Ekbom syndrome.[16,18]

Sleep deprivation and personality

Regarding this aspect, it is inferred that sleep deprivation favors an increase in impulsive behaviors, making individuals more predisposed to developing addictions, due to the dysregulation of the dopaminergic system. Furthermore, due to homeostatic dysfunctions related to few hours of rest, including changes in dopamine receptors, there is an increased tendency to develop diseases such as obesity.[19] In this way, it is clear that individual decision-making itself is compromised, as sleep deprivation compromises mental health, due not only to dopaminergic imbalance, but also leads to an anxiogenic state and self-critical thoughts in individuals.[20,21]

Impacts of sleep deprivation on attention

The investigations identified the fundamental role of attention as a filter to select relevant information in a scenario of stimuli, in addition to establishing that the need to selectively direct attention is important for cognitive processes, which can be complex or simple. With all this, the magnitude of the negative consequences of sleep deprivation in tasks that require attention and alert skills was emphasized through the experiments carried out, especially through the Psychomotor Vigilance Test (PVT).[23]

The presence of the phenomenon of "lapses", which is characterized by slow and ineffective responses, was evidenced as being a prominent response to adequate sleep deficiency. From the Psychomotor Vigilance Test (PVT), a fragmentation of the sleep-deprived individual's performance in tasks can be observed, with moments of reduced neural excitation, which impairs effective and quick responses; in addition to changes in brain functioning, including areas associated with attention regulation, verified through Functional Magnetic Resonance Imaging (FMR).[26] It is undoubted that sleep deprivation compromises the development of a complex cognitive state, given that there is a lag in attention proportional to the time spent awake. This lag occurs in the form of lapses, that is, increased slow responses to everyday stimuli, which are consequences of decreased task-related fronto-parietal network activity.[24]

Relationship of sleep with memory and learning

The relationship between sleep and memory and learning is undeniable, since it is during sleep that both occur in the same brain region: the temporal lobe (Nogaro, 2012). Therefore, it is valid to differentiate the stages of sleep and the relationship with brain activities: slow wave sleep - called NREM - is important because it is a precursor to REM sleep, in which it favors hippocampal activity and the flow of information to the neocortex. The other stage is known as REM (deeper and where dreams occur), in which the memories evoked in slow wave sleep are built and stabilized by the process of gene reactivation. Thus, it is concluded that poor sleep quality directly compromises the consolidation of memory and learning.[28]

From this perspective, the role that sleep plays in emotional well-being is evident, through the stabilization of information stored in the human mind. This balance prevents brain collapse, since forgetting is as important as memorizing; This mechanism prevents system overload through the selection, storage and disposal of everything that is absorbed. Therefore, there are three types of forgetting: incidental, motivated and intentional. However, other factors that directly influence learning are also affected by this mechanism, such as the ability to concentrate, access to complex cognitive functions and mental performance.[39] Therefore, the individual's formation, trajectory and perspectives are forged directly by the neurophysiology of sleep.

Neuroplasticity

Neuroplasticity reveals itself to be the adaptive means found by the nervous system to adapt to the diverse nature of the most distinct stimuli. This dynamic attribute is made possible, as neurons change their behavior, modify their synaptic responses and generally change their organization. However, for the expected result of this neuroplasticity to be achieved, the neuron has a series of auxiliary cells around it. Therefore, to understand brain plasticity, an analysis limited to the study of neurons is not enough. The astrocyte, for example, turns out to be one of these support cells, helping neuronal reorganization and the readaptation of the response to neurotransmitters.[39]

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Therefore, many of the intellectual advances linked to sleep, such as learning and memory, are made possible by the brain plasticity inherent to the period in which we sleep. During REM sleep, for example, the neuroplasticity provided by this phase allows for an expansion of informational circuits and an adaptation to learning and experience patterns. This structural flexibility of the nervous system is so efficient that in addition to providing intellectual advancement, it is also capable of generating a process of neural regeneration, in which damaged areas of the nervous system can partially have their functionality restored. Thus, it becomes clear that any habit harmful to sleep quality, such as sleep deprivation, will directly affect the adaptive restructuring of the brain and cause losses of the most diverse nature, mainly in the cognitive aspect.[11,35,36]

Discussion

During the deepening of the neurophysiology of sleep, it became notable that the existence of the sleep-wake cycle would be irrelevant if there were no regulatory means capable of adapting the alternation of states of wakefulness and rest according to the daily needs of human beings. Therefore, the circadian rhythm, provided by the SCN, exerts such a regulatory function on the sleep-wake mechanism. One of the main endogenous stimuli that assists the SCN in its function as a master clock is melatonin, which proves to be an important biological signal for a series of physiological phenomena in the body, which includes its relationship with sleep mechanisms. However, some studies showed some divergence regarding the focus given to the nature of the effects provided by melatonin.[10,11]

According to Reinhardt,[15] melatonin would not exactly be a sleep-inducing substance, as its main function would be more linked to the stabilization of the circadian rhythm. This regulatory process on the circadian rhythm would be linked to melatonin's ability to make the body prone to sleep, but not to induce it itself. In other words, this hormone would have a relevant role in inhibiting wakefulness mechanisms, allowing sleep-promoting centers to gain space. Thus, melatonin would prove to be, in fact, not an efficient sleep inducer, but rather a hormone that would allow the rest mechanisms associated with sleep induction to operate. This would explain why melatonin has its peak release at the beginning of the night, as it is at this time that the wakefulness mechanisms are at their peak and mental arousal and body temperature are intensified. Therefore, given the secretion of melatonin during this period, it would end up inhibiting the continuity of this intensified state of alert. Therefore, it is clear that Reinhardt emphasizes the action of melatonin on the propensity to sleep and not on its induction itself.[15]

According to Alves,[13] melatonin would be the hormone produced by the body with the exact purpose of inducing sleep, acting to reduce the time needed to fall asleep and also allowing an extension of sleep duration. This ability to induce sleep makes the administration of melatonin agonists positive for individuals who have difficulty sleeping. Thus, the quality of melatonin as an inducer of drowsiness is observed, opposing Reinhardt's idea of starring this hormone as a stabilizer of the circadian rhythm and leaving its function as a sleep inducer in the background.[13,15]

Neurologist and psychiatrist Stephen Stahl, in his work Psychopharmacology: neuroscientific bases and practical applications, emphasizes a mixed approach to melatonin. Depending on the receptor to which melatonin binds, it can be either a stabilizer of the circadian rhythm or a sleep inducer. Thus, melatonin proves to be an effective natural hypnotic in inducing the onset of sleep, however, its function as a sleep inducer occurs when this hormone binds to its MT1 receptor, generating in response the inhibition of neurons in the SCN, the main regulatory center of the circadian cycle, and this allows the appearance and induction of sleep signals. The action as a stabilizer of the circadian rhythm and regulation of its effects on the sleep-wake cycle would occur from the moment melatonin binds to the MT2 receptor.[11]

However, not all authors who sought to understand the relationship between melatonin and body physiology focused on its relationship with sleep. Viegas,[14] when writing his monograph presented to the Faculty of Medicine of Coimbra and entitled "The Circadian System and the Metabolic Syndrome" (2020), was concerned with exploring the general metabolic effects of melatonin not necessarily linked to sleep. It emphasizes the influence of melatonin on anti-inflammatory, antioxidant, immunomodulatory and vasomotor processes. This effect of melatonin on various metabolic events can be explained by the fact that melatonin has receptors in the most diverse tissues and organs of the body, such as the central nervous system, the retina, the cardiovascular system, the liver and adipocytes. However, for reasons of affinity and thematic limitation, current scientific production was restricted to the participation of melatonin in the neurophysiology of sleep and, therefore, the general physiological impacts of melatonin unrelated to sleep were not highlighted in this literature review article.

It is also noteworthy that learning and memory are interdependent, with the memory process being dynamic, through neuronal extensions that form the logical memory circuits. In this sense, it is possible to address the brain's growth capacity, which does not occur through an increase in neurons, but rather through the addition of neuronais connections. Furthermore, it is extremely important to understand the role of corticosteroid hormones in regulating these brain functions, acting on neuronal excitability, release of neurotransmitters and modulation of neurogenesis, mechanisms that directly affect learning and memory. These substances act on the hypothalamic-pituitary-adrenal axis and are secreted by the adrenal glands, determining the appropriate beginning and end of the stress response. Given this process, the increase in glucocorticoid levels in the hippocampus and consequent overactivation of their receptors generates inhibition of learning and memory.[28]

However, there is no consensus among scholars about how long is adequate to enjoy the benefits of short periods of sleep during the day. According to Aghayan Golkashani,[29] 90 minutes were essential for the dissipation of homeostatic sleep pressure. However, Sleep Foundation researchers recommend taking just 15 to 30 minutes of naps, with this average being more compatible with being applied to the majority of the economically active population. Finally, Liu et al.[30] states that in addition to the number of minutes, doing it in the middle of the work day is the best alternative.

However, the factors that determine the content that will be consolidated during sleep were also addressed. In this way, neurophysiology dissociates explicit memories, that is, those intentionally acquired and recalled, and implicit memories, which were acquired incidentally and recovered involuntarily. From this perspective, the related mechanism is the greater expression of explicit memories during sleep, as implicit memories are translated into explicit ones to be absorbed. Therefore, it is clear that learning is an active process and has defined patterns.[32]

However, such patterns are not yet clear enough to agree on what is the greatest determinant of neural reactivation during learning sleep. However, according to Sterpenich,[31] the reactivation of some memories at the expense of others is influenced by a pre-established

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reward system. This is due to the stimulation of the same locations during stage N3 of NREM sleep that were encouraged in the experiment during wakefulness.

In relation to sleep habits and routines, a different but complementary approach can be seen in relation to the articles cited, as there is a focus on different hormones related to the sleep-wake cycle. In relation to this, Costa; Guimarães; Schirmer,[16] focus on how the increased use of electronic devices influences the melatonin cycle and, consequently, favors insomnia. Palma[17] exposes the hormonal interference of cortisol in this cycle, highlighting the feedback effect exerted by this hormone, as stressful routines cause an increase in serum cortisol levels, thus hindering the occurrence of stage N3 of NREM sleep. A factor that is also stressful for the body, as it impedes homeostasis, making it even more difficult to sleep. Furthermore, Cruz,[18] adds new consequences of these bad sleeping habits, highlighting pathological aspects, such as Ekbom Syndrome, in relation to Guimarães; Schirmer; Costa,[16] which focus the consequences more on the lag in memory and learning.

Furthermore, regarding the way that sleep shapes an individual's personality, there is also a complementarity between Krause[19] and Domingue.[20] From this perspective, the first highlights how the accumulation of bad nights of rest causes changes in dopaminergic receptors, which encourages the development of more impulsive behaviors, addictions and even the tendency to diseases, such as obesity. The second highlights as a consequence the greater recurrence of negative and self-critical thoughts. Furthermore, Almondes & Araújo[21] also mention that individuals, even if they do not previously have anxiety and have poor quality of sleep, can be induced into an anxious state. Therefore, everyone, in different but integrative ways, highlights how poor sleep quality negatively affects individuals' personality and decision-making.

Current research highlights the findings of how sleep deprivation negatively impacts the formation of individuals' decision-making process, making it later and more vulnerable, considering that, according to theories of memory lapses, there is an increase in slow responses and failures in the instantaneous reaction to stimuli that sleep-deprived individuals are subjected to. The main process that demonstrated this phenomenon is the Psychomotor Vigilance test, which in several studies obtained similar results, which consisted of interrupted performance and instability of neuronal activities and their connections, impairing the effective response to stimuli.[25] The interaction between the Fronto-Parietal Network and the Default Mode Network is impaired by sleep deprivation, leading to instability in the state of attention and fluctuations between wakefulness and sleep. This may be the reason behind the perceived change in the time intervals it takes an individual to respond to a task.[24]

In this sense, it is possible to note the implications of the relationship between sleep deprivation and attention deficiency in various areas and situations experienced in everyday life. In work and educational environments, sleep deprivation can trigger a high probability of errors and accidents, as these individuals have difficulty maintaining concentration, remembering information and, consequently, making correct decisions in the face of the situation. The effects generated by this deprivation negatively affect both productivity, which is characterized as hypocrisy in a world in which people stop sleeping to be more productive, as well as the personal and public safety of citizens. Understanding all these mechanisms and effects of sleep deprivation cited in the literature, it is possible to see the importance of promoting sleep hygiene and the balance between work and rest as essential steps to mitigate the negative impacts on cognitive performance and attention.[25]

Furthermore, sleep deprivation, when related to neuroplasticity and neural regeneration, plays an important role. In cases of impairment, REM sleep, responsible for brain development and neural circuits, undergoes changes in the individual and, consequently, in activities that require learning, memory and behavioral adaptation. Studies have shown that, from early childhood, sleep has effects on neuroplasticity, due to the greater predominance of vibrating wave sleep in the full sleep interval and, if poorly consolidated, will have long-term consequences for the individual. It is clear, therefore, that, in cases of unfulfilled sleep, this cascade of reactions generates, as a consequence, difficulties in brain regeneration and neuroplasticity.[1]

Other studies indicate that sleep has the function of regulating and promoting changes in early childhood, since neurodevelopment does not require such changes, which are structural, rapid and intense. Therefore, since sleep deprivation and neuroplasticity are entirely interconnected, it is necessary to have a comprehensive view of what can cause harm to sleep, such as family, neurobiological and environmental aspects. Such activity aims not only at neuroplasticity, but also at memory and personality formation.[40]

Final considerations

Given the considerations presented in this article on the neurophysiology of sleep, the relevance of this topic is evident, as it discusses a process inherent to the human being and the structures that govern its functioning, such as the limbic system and the hypothalamic-pituitary-adrenal axis. In this sense, the factors by which sleep is responsible for impacting the formation of personality were analyzed, based on memory, learning and regeneration of the nervous system. Another aspect analyzed was sleep deprivation, in a society where this is the reality of the majority of the population who undergo intense work hours and studies in search of an unattainable ideal of productivity.

In this way, it is evident that the correlation between brain regions and activities of the nervous system with the physiology of sleep, as well as the identification of hormones and neuroreceptors that are involved in this regulatory mechanism. Thus, this topic has been the target of constant discoveries within the scope of science as it represents a factor of utmost importance for the performance of any individual in the society in which they are inserted, with these studies playing a fundamental role in contributing to a deeper understanding of this subject and, thus shedding light on the important neurocognitive and physiological implications involved.

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Conflicts of interest

The authors declare no conflicts of interest.

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