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The Connection Between Mental Performance and Sleep

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Abstract: Although our understanding of sleep physiology is increasing, and many of the mechanisms of sleep have been explained, studies have mainly focused on the effect of sleep on learning and memory processes due to the increase in sleep after learning. However, it remains unclear what kind of information processing occurs in the brain during sleep and what effects information processing-related events have on sleep that are transferred from wakefulness. Research suggests that sleep has a positive impact on memory function. However, it is unclear whether specific sleep stages, such as NREM and REM, are exclusively dedicated to certain types of memory, such as semantic or event memory. It can be concluded that information processing occurs during sleep. However, it is important to note the limitations of studying information processing during sleep due to the challenges of conducting research in this state. Despite spending a third of our lives asleep, our understanding of the benefits of sleep remains limited. It is a fact that information processing occurs during sleep. However, studies investigating this phenomenon are limited. Research on sleep, memory, and information processing can aid in the comprehension of learning, consciousness, and memory processes during sleep, as well as the function of sleep neurophysiology. ©2024 NTMS.

Keywords: Sleep; Learning; Information Processing; Memory.

1. Introduction

On average, we spend eight hours a day sleeping, which amounts to 2920 hours a year. Therefore, it is important to get enough sleep to ensure optimal cognitive function. This means we sleep for 121.7 days a year, or roughly a third of our lives. During this time, our eyes close, our muscles relax, and we become unresponsive to sound, light, or touch of any intensity. From an external perspective, it may seem like we are doing nothing for a third of our lives. However, despite the significant amount of time we spend sleeping, our understanding of the benefits of sleep is limited [1,2]. Recent studies [3-5] have shown that sleep has both physical and psychological benefits. It was previously believed that the brain slows down or stops working during sleep, allowing it to rest. However, after the 1950s, it became clear that this was not the case [6]. After the discovery of REM sleep, it was observed that the brain continues to function during sleep and can even be more active than during the day. Sleep consists of various stages during which the brain alternates between slowing down and speeding up. These phases occur in a complex control system throughout the night and are accompanied by instant changes in hormone levels and fluctuations in body temperature. During REM sleep, which occurs every 90 minutes and makes up almost 20% of all sleep, the brain is highly active. Although cerebral blood flow decreases by up to 20% during sleep, brain cells compensate by increasing the number of signals. Furthermore, brain cells continue to function during deep sleep, also known as NREM, despite the complete loss of consciousness [7-9].

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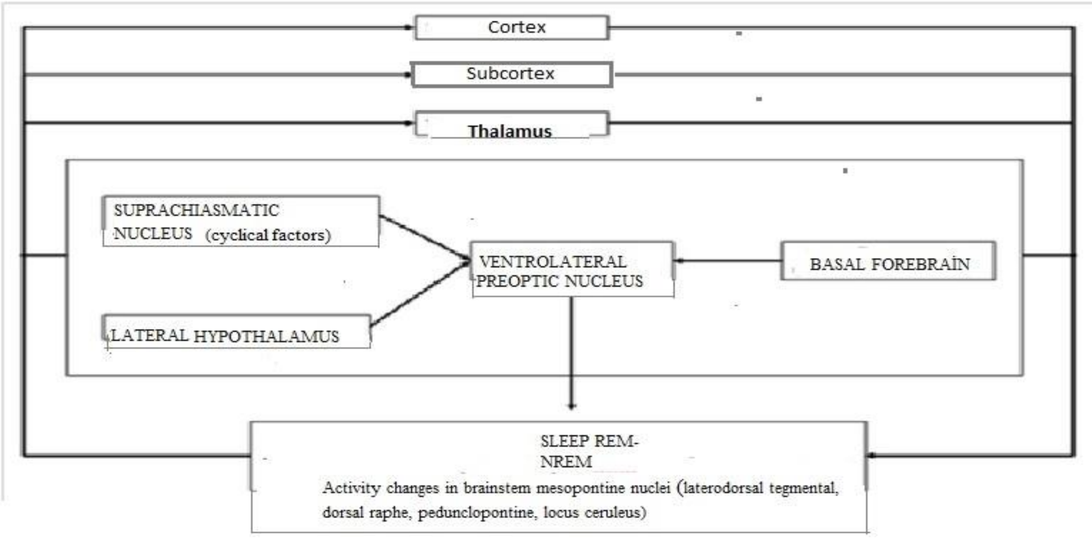

Figure 1: Brain activity during sleep.

Studies have shown that sleep is a cycle consisting of both REM and N-REM stages. This discovery highlights the functional aspect of sleep, which is shared by many species [10, 11]. The brain undergoes different speeds during different stages of sleep, which are sequential and part of a highly complex control system (see Figure 1 and Table 1).

Table 1: Characteristics of NREM and REM Periods.

	Characteristics of Nonrem and Rem Periods	
	NREM Period	**REM Period**
Neurotransmıtter levels in the Brain	Decrease in norepinephrine, serotonin, cholinergic and histaminergic agents	Increase in cholinergic agents and decrease in noradrenergic, serotonergic and histaminergic agents.
Changes in brain metabolism and local blood flow	Widespread decline	Decrease in dorsolateral prefrontal cortex and increase in paralimbic and limbic regions
Characteristics of the EEG	Delta and sigma waves, sleep spindles, K complex and slow oscillations	Low wavelength fast activity, theta waves

Fluctuating hormone levels and body temperature accompany these phases. In the first few hours of sleep, brain waves slow down, and during slow-wave sleep, muscles relax, and eye movements cease. This period is characterized by a decrease in heart rate, blood pressure, and body temperature. Individuals who awaken during this phase typically report seeing images but not experiencing a dream. After the stage of slow brain waves, brain activity begins to increase between [12-14]. During REM sleep, brain waves speed up to a level similar to that of wakefulness. Eye movements increase, the body fully relaxes, and most muscles, except for the respiratory muscles, become almost paralyzed. This is the stage when dreams are most common, and blood pressure, body temperature, and heart rate fluctuate. This stage lasts approximately 15 minutes, followed by the slow-wave phase. Sleep stages alternate throughout the night and are repeated every 100 minutes. The slow-wave phase gradually becomes shallower, and the REM phase becomes longer until waking up. The timing of sleep stages varies throughout a person's life. For example, babies typically sleep for 18 hours a day, while adults usually sleep for 6-7 hours a day, with most of this time spent in deep, slow-wave sleep. Although only a small portion of this time is spent in slow-wave sleep [15-17], research suggests that sleep has a positive impact on the learning process [18-20]. Studies in various mammals have shown that sleep improves learning and task performance. The thalamus sends impulses to the cortex during sleep, which is responsible for consciousness. These impulses cause changes in brain waves, resulting in the formation of wakefulness waves. The system responsible for maintaining wakefulness is referred to as the 'red pathway', while the 'blue pathway' is another system that also contributes to wakefulness. In this system, messenger molecules such as norepinephrine and serotonin stimulate the cerebral cortex. Additionally, other messenger molecules, including histamine, dopamine, serotonin, and MCH, which are secreted from various centres in the lower parts of the thalamus and

brainstem, help to maintain our consciousness [21-23]. When we are awake, certain molecules are continuously secreted, sending alerts to the brain. During the slow-wave phase of sleep, both systems slow down and the neurons that secrete messenger molecules stop firing. In contrast, during REM sleep, acetylcholine stimulation continues, but norepinephrine and serotonin firing ceases completely. The hypothalamus is another centre that controls sleep. Two groups of neurons in this region secrete messenger molecules that control our ability to fall asleep. The secretion of the messenger substance GABA in this region induces sleep by suppressing the centres responsible for keeping us awake [24,25]. Conversely, the second group of neurons located on the side of the hypothalamus secrete stimulatory molecules, hypocretin (orexin) and dynorphin, which activate the centres responsible for keeping us awake. The mechanisms that trigger the onset of sleep are not yet fully understood. According to some theories, the sleep process is initiated by a molecule called 'adenosine', which accumulates in the brain over time. It is suggested that coffee, containing caffeine, may suppress this molecule, which could explain why it delays sleep. Additionally, a mechanism known as the 'on-off' system, based on a molecule called 'orexin', has been discovered to facilitate the transition between sleep and wakefulness. During wakefulness, the 'VLPO nucleus' is suppressed, which prevents its suppressive effect on the orexin molecule. Orexin stimulates the cerebral cortex to maintain wakefulness. When the suppression of the VLPO nucleus is lifted, this centre is activated, suppressing orexin and inducing sleep [26-29].
The regulation of sleep is controlled by the SCN nucleus, a specific biological clock located in the brain. This centre is activated every 24 hours and is sensitive to both daylight, which is perceived in the retina at the bottom of the eye, and the hormone melatonin, which is secreted by the pineal gland at night. The SCN nucleus influences the VLPO nucleus through several centres, controlling the daily transition between sleep and wakefulness. The VLPO nucleus is activated through GABAm molecules by stimuli from the Department of Mental Health (DMH) region, allowing the transition to sleep. Meanwhile, the SCN nucleus remains active as long as there is light. In some animals, such as bats, this cycle is reversed, allowing the VLPO nucleus to become active during the day. This mechanism that rhythmically controls sleep can be reversed in experimental animals [30, 31].

The Purpose of rem sleep

Sleep duration is determined by signals sent by nerve cells in the lower centres of the brain. It is interesting to note that the size of these centres does not correlate with sleep duration; in fact, it is almost inversely proportional. For instance, elephants with very large brains have very short sleep periods, while mice with very small sleep centres have longer sleep periods. Although the relationship between sleep duration and function is not fully understood, it is believed that REM sleep plays a crucial role in this process. Models used to study the purpose of sleep are typically based on the principle of depriving animals of sleep for extended periods. Long-term sleep deprivation in mice results in skin lesions, fluctuations in body temperature, increased food consumption, and ultimately death [32]. Similar outcomes are observed when the thalamus and hypothalamus regions of the brain are damaged. These experiments demonstrate the critical role of sleep in maintaining bodily functions. Sleep serves the important purpose of conserving energy, similar to hibernation in some animals. Humans conserve energy by sleeping every night [33, 34]. Recent studies have shown that NREM sleep, characterized by slow waves, promotes protein synthesis and the formation of new nerve cells in certain parts of the nervous system. Specifically, new nerve cells are formed in the olfactory cells, inner cavities of the brain, and hippocampus within 3-4 weeks. Regular exercise has been found to increase nerve cell production, while stress has been found to decrease it. Additionally, sleep deprivation has been found to reduce the formation of new neurons. In summary, sleep has a positive impact on brain cell regeneration [35, 36]. Babies have a high metabolic rate and spend most of their day sleeping to support their growth. Research indicates that there is a correlation between metabolic rate and sleep duration, with smaller animals requiring more sleep due to their higher metabolic rates. Conversely, larger animals with lower metabolic rates require less sleep. These observations indicate that sleep has a role in regulating metabolism. Cells produce significant amounts of free oxygen radicals as a by-product of metabolism when the metabolic rate is high [37, 38].

The importance of rem sleep

Sleep is considered a vital survival mechanism for early humans. It provides necessary rest and serves as an energy-saving system during times of food scarcity when early humans needed to conserve energy to survive. Additionally, sleep functions as a defence mechanism to prevent people from wandering and falling prey to their enemies during dangerous and dark nights, a trait that has survived to this day. In addition, REM sleep is vital for physical and mental health as it strengthens and forms new connections between nerves while eliminating unnecessary ones. To summarise, REM sleep plays a crucial role in restructuring the brain's connections and facilitating memory and learning. Inadequate REM sleep can result in poor memory and learning abilities. Furthermore, REM sleep is closely linked to dreaming, with approximately 95% of individuals reporting dreams upon waking from this stage of sleep. Dreaming is considered significant due to its strong association with REM sleep, which is crucial for optimal brain function. REM sleep is the stage where dreams occur, and the brain remains metabolically active despite the person being asleep. During this stage, heart and breathing rates fluctuate, and there are rapid eye movements and small movements of limb muscles. While REM sleep uses less energy than wakefulness, it saves less energy than NREM sleep. The reason why not all sleep is non-rapid eye movement (NREM) is currently unknown [33] The duration of rapid eye movement (REM) sleep primarily depends on the development of the nervous system at birth. Animals with a well-developed nervous system at birth experience shorter REM sleep as adults. For instance, certain rodents with a well-developed nervous system at birth, even those born with teeth, experience no more than one hour of REM sleep in total as adults. For instance, some rodents have a well-developed nervous system and teeth at birth, but as adults, they experience no more than one hour of REM sleep in total [34]. In humans, the duration of REM sleep varies depending on age and other factors. It is important to note that the text already adheres to the desired characteristics and is free from errors. In contrast to humans, who experience longer periods of REM sleep as they age due to their less developed nervous system, the duration of REM sleep decreases with age. However, it is important to note that this stage of sleep is present from birth, and infants actually spend more time in REM sleep than adults. These observations demonstrate the significant role that REM sleep plays in brain development. Specifically, during REM sleep, the brain eliminates faulty nerve connections and creates new connections between nerve cells. During infancy and childhood, the programmed development of the nervous system is a crucial process [37].

The benefits of this stage of sleep in adulthood remain uncertain. It is believed that REM sleep readies the individual for wakefulness, preventing a sudden transition from NREM sleep, which is characterized by deep sleep, to a state of wakefulness. Being alert, even while asleep, is crucial for protecting animals from external threats. Animals that wake up from deep NREM sleep are more vulnerable to predation than those that wake up from REM sleep or wakefulness. Furthermore, animals awakened from NREM sleep experience negative effects on their daily bodily functions. It is worth noting that the longest period of REM sleep occurs just before waking up [38]. The initial REM phase lasts for 10-15 minutes. The phase of REM sleep that occurs just before waking up lasts for approximately 25 minutes. During this phase, changes in eye movement, breathing, and heart rate become more pronounced. These findings suggest that REM sleep prepares the body for the transition from sleep to wakefulness. Additionally, REM sleep is believed to maintain activity in the brain stem, which regulates vital internal organs and experiences continuous stimulation during this stage. REM sleep is thought to have existed before the development of the cerebral cortex, which is responsible for the brain's intellectual and fine-tuning abilities. This system affects the brain stem. Additionally, REM sleep plays a vital role in the re-synthesis of messenger molecules, whose levels decrease throughout the day [39].

1.3. Sleep, memory and information processing learning and memory

The environment primarily affects behaviour through learning and memory. Learning is the process of acquiring information, while memory is the internal system used to retain, encode, store and retrieve acquired information for later access [40, 41].

Informatıon processing

After an organism perceives a stimulus, it undergoes cognitive evaluations known as information processing. These evaluations involve the sensory, attentional, and memory systems. During sleep, the relationships between previously perceived experiences or events are evaluated, meaning is assigned to objects or events, and cognitive-motor preparation of responses takes place. Meanwhile, individuals discover details in their experiences and encounter new and seemingly impossible events [43].

N-REM and REM periods

During the NREM period, the body undergoes physical rest and renewal while biological functions mediate the somatic and autonomic systems. During the NREM period, the body undergoes physical rest and renewal while biological functions mediate the somatic and autonomic systems. This period involves organizing the events of the past day and preparing for the new day. In contrast, REM regulates cognitive functions and is when most information processing occurs. The brain is highly active during this stage, and operations are performed without external stimulation, unlike during wakefulness. However, these cannot be translated into motor expressions, except in some sleep disorders [44].

2. Discussion

The sympathetic nervous system does not receive feedback due to the inability to execute the actions. As a result, spatiotemporal control disappears [46]. Some researchers have argued that REM is a new and unknown state, similar to waking perception and thought. During REM sleep, the brain experiences arousal that stimulates the occipital region, which is associated with vision, and activates visual events or recordings. The volunteers' increased activity in areas that also showed increased activity during the waking task demonstrates the importance of sleep in memory consolidation [45].

Recent studies support the notion that REM and REM deprivation can hinder learning, corroborating early research findings. Additionally, these studies suggest that sleep and wakefulness processes are continuous, with wakefulness processes being reflected during sleep [46]. Experiments [46, 47] have shown that there is little difference in the performance of learning tasks presented before and after REM periods following wakefulness in humans and mammals. The first striking result of such experiments is the similarity between wakefulness and REM in terms of information processing. One of the first links established between

REM and learning is the increase in protein synthesis at the cellular level in both states. Inhibition of protein synthesis during wakefulness (e.g. problem solving) and REM sleep disrupts the learning of a task. The language used is clear, objective, and value-neutral, with a formal register and precise word choice. The sentence structure is simple and logical, with causal connections between statements. The text is free from grammatical errors, spelling mistakes, and punctuation errors. This means that sleep is disturbed, while learning is slowed down or prevented. No changes in content have been made [48].

Table 2: Studies on Information Processing Processes in Sleep.

The Researches	Purpose of the Study	Methodology of the Study	The Result of the Study
Miraglia, F., Tomino, C., Vecchio, F., Gorgoni, M., De Gennaro, L., & Rossini, P. M. (2021). The brain network organization during sleep onset after deprivation. *Clinical Neurophysiology*, *132*(1), 36-44. (51)	The objective of this study is to investigate the differences in brain networks during pre- and post-sleep onset conditions following 40 hours of sleep deprivation (SD) and normal sleep onset in 39 healthy participants.	Cortical sources of electroencephalographic (EEG) current density were used to perform functional connectivity analysis. The small world (SW) index was evaluated in all EEG frequency bands, including delta, theta, alpha, sigma, and beta.	Sleep deprivation (SD) can affect the architecture of the brain's functional network. Further research is necessary to identify changes associated with SD during wake resting states and to mitigate potential harm to behavior and brain function during wakefulness.
Menicucci, D., Piarulli, A., Laurino, M., Zaccaro, A., Agrimi, J., & Gemignani, A. (2020). Sleep slow oscillations favour local cortical plasticity underlying the consolidation of reinforced procedural learning in human sleep. *Journal of Sleep Research*, *29*(5), e13117. (52)	This study examines the impact of procedural learning supported by reinforcement learning on slow wave activity at night and slow oscillations during sleep, as well as the relationship between these changes and behavioural outcomes.	During the experimental phase, participants were instructed to adjust their cursor movements to align with a visual target. In contrast, the control phase did not involve any angular bias. The task was repeated at 13:00, 17:00, and 23:00 before going to bed, as well as at 08:00 after waking up. The deflection angle was initially set at 15° during the first two sessions and was then increased to 45° during the last two sessions. High-density electroencephalogram sleep recordings were taken from 23:30 to 19:30 on both experimental and control nights.	The study found that slow oscillations during sleep significantly aid the consolidation of procedural memories. These oscillations consist of several parts that represent network activations linked to procedural visual-motor reinforcement learning. The areas where there was a relationship between the percentage of slow oscillations during sleep and the ensuing improvement in task performance were significantly affected by the treatment. To maintain objectivity, any subjective assessments have been excluded. The language used is clear, concise, and value-neutral, with a formal register and precise word choice. The text adheres to standard citation and footnote styles, as well as standard formatting and organization. The punctuation, grammar, and spelling have all been corrected. No new content has been added.
Borragán, G., Urbain, C., Schmitz, R., Mary, A., & Peigneux, P. (2015). Sleep and memory consolidation: motor performance and proactive interference effects in sequence learning. *Brain and cognition*, *95*, 54-61. (53)	Using a proactive interference paradigm, the study examined how well visual-motor sequence learning is consolidated in memory while you sleep.	On Day 1, thirty-three young adults received training on sequence A. The following night, they were either allowed regular sleep (RS) or were sleep deprived (SD). After two nights of rest, the participants were required to learn a new, potentially competitive sequence B before taking another test using sequence	The study results indicate that sleep enhances the consolidation of motor skills, specifically for sequence A, resulting in faster reaction times for RS participants overnight. No changes have been made to the content. The language is objective, concise, and clear, avoiding biased or ornamental language and

		A. The study hypothesized that proactive interference effects on sequence B would be stronger in the RS condition due to prior learning of sequence A. Proactive interference is an indirect indicator of the resilience of sequence A. It should be more consolidated during post-training sleep.	adhering to a formal register. The information is presented logically with a good sentence structure. There are no typographical, grammatical, or punctuation errors in the text. On Day 4, the proactive interference effects on learning new material were similar for participants from both SD and RS. Technical terms are defined when first used, and subject-specific vocabulary is employed where appropriate. The study's results indicate that sleep after training enhances performance in the sequential domain of visuomotor sequence learning, but not in the motor domain.
Cousins, J. N., van Rijn, E., Ong, J. L., Wong, K. F., & Chee, M. W. (2019). Does splitting sleep improve long-term memory in chronically sleep deprived adolescents?. *npj Science of Learning*, *4*(1), 8. (54)	However, research has not yet established how learning is affected when sleep is divided between periods of nighttime and daytime sleep during a typical sleep-restricted school week.	The study compared the long-term memory of 58 teenagers who underwent two school weeks of suboptimal continuous (6.5 hours of night sleep opportunity) or divided sleep (5 hours of night sleep + 1.5 hours of day sleep at 14:00) simulations. After two nights of sound sleep, participants were tested on Day 5 in the late afternoon after encoding pictures during the first week. During the second week, participants learned about six different amphibian species in the morning and six different amphibians in the late afternoon for three consecutive days. The studies were conducted in the evening after a one-night break.	During the first week, the group with a split sleep schedule was able to identify more pictures. In the second week, they were able to recall more details about the species they had studied in the afternoon. However, there was no discernible difference between the groups for the species covered in the morning. This study demonstrates that a split-sleep schedule can improve learning after a nap opportunity, even when sleep is restricted, without compromising morning learning. The split-sleep schedule has been shown to be beneficial for students who experience chronic sleep deprivation, although it may not fully replace a full night's sleep.
Stiver, J., Fusco-Gessick, B., Moran, E., Crook, C., & Zimmerman, M. E. (2021). Variable objective sleep quality is related to worse spatial learning and memory in young adults. *Sleep Medicine*, *84*, 114-120. (55)	The aim of this study is to investigate the potential correlation between the learning and memory abilities of young adults in verbal and visuospatial domains and the objective intra-individual variability in sleep quantity and quality.	The study recruited 218 young adult college students from a university in the Eastern United States. Of these, 187 participants (mean age = 20.5, SD = 1.5; 70.6% female) provided full actigraphy and cognitive performance data. The study used wrist actigraphy to objectively measure the intraindividual means and variabilities of sleep quantity (total sleep time) and quality (percent wake after sleep onset) over a period of one to two weeks.	In young adults, there was a significant correlation between intraindividual variability in objective sleep quality and visuospatial learning and memory, beyond the impact of mean sleep quality.

		The study employed the Cogstate computerized test battery's International Shopping List and Groton Maze Learning tests to assess verbal and visuospatial learning, as well as memory.	
Smith et. al., 2004 (56)	To investigate changes in sleep following training.	The study compared students who were in the intensive exam period with those who did not have an exam.	It has been reported that there is an increase in the intensity of rapid eye movement (REM) sleep and associated eye movements.
Mednick SC et. al., 2013 (57)	The aim of this study is to determine which sleep period is associated with learning.	The subjects underwent a tissue discrimination test.	It has been reported that combining these two variables improves test performance by 79 percent.
Frank et. al., 2001 (58)	To investigate the relationship between neurons in the visual cortex and sleep.	For the initial 30 days of life, one eye remained closed.	The increase in primary visual cortex neurons has been linked to NREM sleep. Additionally, it has been demonstrated that plasticity increases after six hours of sleep when one eye is closed.
Best J et. al., 2007 (59)	To determine the relationship between nerve firing patterns and sleep.	Hippocampal cells firing in relation to the physical location of the rat were recorded.	They discovered that in both REM and NREM, the place cells that had fired during the initial entry remained active.
Stickgold R, et. al., 2000 (60)	It is aimed to determine which learning is affected by REM sleep deprivation.	After REM sleep deprivation was applied to the subjects, some tests were performed.	Associative learning has been found to negatively impact motor learning and have no effect on conscious learning, such as verbal learning.

Synaptic Plasticity

Synaptic plasticity is the fundamental mechanism underlying sleep, learning, and long-term memory formation. It refers to the strengthening or weakening of synapses in the connections between neurons. This process involves changes in receptor proteins, post-synaptic signalling mechanisms, and even alterations in the number and distribution of synapses between pairs of neurons. Sleep contributes to the synthesis of biomolecules that help retain information acquired during wakefulness [48].

Effects of sleep on synaptic plasticity

It has a positive effect on learning and memory processes that depend on synaptic plasticity. Conversely, sleep deprivation has a negative effect on these processes. Genes and proteins required for synaptic plasticity are synthesized during sleep. Both sleep and sleep deprivation affect synaptic connection structures and strength [49].

Differences between ınformation processing during sleep and wakefulness

Information processing during sleep is characterised by internal arousal, as opposed to external stimuli which are the basis for waking information processing. Therefore, to understand information processing during sleep, it is necessary to consider the internal functioning of sleep phenomena. Viewing information processing during sleep solely from the perspective of the waking state can result in inconsistent and disjointed results. Two fundamental questions arise regarding information processing during sleep. First, what kind of information processing does the brain allow during sleep? Second, what kinds of residues or effects of information processing events are carried over from wakefulness to sleep? During information processing in sleep, there is a cellular response to incoming information (at a later time and intensity than during wakefulness) and an active preparation of some information networks (especially cerebral structures) according to the brain's activity level [49]. To determine if information processing occurs during sleep, two conditions must be tested: 1. Recognition of a stimulus or task learned during wakefulness should also occur during sleep 2. Formation of new associations during sleep should be observed. It is important to note that subjective evaluations should be avoided and the language used should be clear, objective, and value-neutral. If we define learning as 'the process by which stimuli produce a change in behaviour', it is not possible to discuss this process during sleep. Therefore, instead of using the term learning, it would be more appropriate to use the term 'information processing during sleep'. The initial source on this subject is dream analysis. According to these analyses, a significant number of dreams revolve around a few common themes. Individuals experience the source of a particular pathology through symbolic images in their dreams, where repressed experiences, emotions, or thoughts are reprocessed through various symbols. It has been reported that these individuals bring their subconscious to the level of consciousness during sleep and dreams, activating a recall and retrieval process, even if only temporarily [50]. A study was conducted on a group of children aged 5-13 over a period of five years, comparing their dream content and mental development with their level of mental development. A linear relationship was found between the participants' ability to represent and express their dream content, their symbolization methods, their ability to make sense of symbols, and their ability to reveal their dreams with logical expressions, and their mental development processes. The study suggests that information processing abilities, which develop accordingly as people get older, are reflected in their dreams up to a certain age, specifically 50. The study emphasises the correlation between dream content and cognitive functions, specifically memory functions. Rapid Eye Movement (REM) is associated with changes in emotion and thought, which make up the dream. The REM stage, during which most dreams occur, appears to aid in forgetting certain memories and experiences while enhancing the retention of others. During REM sleep, memory appears to be reprocessed [51]. The relationship between acetylcholine (Ach), REM sleep, and memory is suggested by the fact that Ach accelerates the stimulus-memory relationship during wakefulness and leads to the onset of REM. However, the function of other chemicals, such as norepinephrine, in REM sleep can make the processing of information appear strange and incomprehensible. This is a common feature of information processing. This fragment of text already meets the desired characteristics. Therefore, no changes have been made.

General results of studies on information processing during sleep

Studies on information processing during sleep can be categorised in various ways. Some studies have explored the impact of sleep stage deprivation on pre-sleep learning, while others have investigated the correlation between sleep stages and types of memory. Current research has analysed the content of dreams to identify differences between sleep stages and the intensity of information processing. Learning is the process by which a stimulus elicits a response in an organism. 'Sleep learning' is not supported by current research. Therefore, the aim of this study is to evaluate information processing during sleep. Although information processing during sleep and wakefulness share similarities, a fundamental difference is that wakefulness relies on external stimuli, whereas sleep relies on internal stimuli. Research on information processing during sleep consistently shows that it is closely linked to memory function and can even have a positive impact on it. Both human and animal studies have produced significant and similar results indicating that sleep deprivation has a detrimental effect on information processing while awake. Sleep deprivation negatively affects both targeted learning immediately following deprivation and general information processing the day after. This includes difficulties in remembering, an increased perception threshold, and distraction. Studies on sleep deprivation have shown that the timing and stage of sleep during which the deprivation occurs are crucial factors. This is because deprivation during different stages of sleep and at different times can have varying effects on information processing. Research suggests that although certain sleep stages, such as REM and NREM, are not specialized for specific types of memory, they are more closely linked to certain types of memory function. Sleep stages differ in terms of information processing and other characteristics that distinguish them from one another. Cognitive functions are supported by the integrity of sleep and its stages. Research has shown that the type of cognitive task presented before sleep, such as motor tasks, perceptual threshold, and memory tasks, affects the impact of sleep deprivation. It is important to note that sleep deprivation has varying effects on different cognitive tasks.

3. Conclusions

Sleep is closely linked to memory function and has a positive effect on it. Sleep deprivation has been shown to have a negative impact on information processing, as demonstrated by both human and animal studies.

Limitations of the Study

Limited generalizability, lack of precision and reliability, and limited exploration of heterogeneity when interpreting and updating research.

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Conflict of Interests

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Author Contributions

All authors contributed equally to the article.

Ethical Approval

None.

Data sharing statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Consent to participate

None.

Informed Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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