GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Review Article)

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The role of ICTs on the function of sleep and its effects on learning and brain

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GSC Advanced Research and Reviews, 2023, 16(01), 139–148

Publication history: Received on 05 June 2023; revised on 12 July 2023; accepted on 14 July 2023

Article DOI: https://doi.org/10.30574/gscarr.2023.16.1.0309

Abstract

Numerous strategies have the potential to improve learning. Since memory is a fundamental cognitive skill that underpins learning, many approaches are employed in education to enhance it. If learning is a natural process, does this mean that there is a natural mechanism that supports learning? It is confirmed in this review that sleep is such a mechanism. According to the population's age, various effects of sleep on the brain and learning are supported by the research on this topic. For proper brain development and cognition, sleep is a crucial activity. In order to effectively exploit this knowledge and create fresh educational initiatives, additional studies need be conducted.

Keywords: Sleep; Memory; Learning; Cognitive Enhancement.

1. Introduction

The majority of senses are shut off during sleep, which results in a lack of reactivity to the surroundings. Visual coordination is lost, the body is largely still, and the response to sound becomes jumbled. The pathway from short-term memory to long-term memory stops working and becomes blocked. The ability to remember recent events while falling asleep can last for three minutes and then they fade away [2]. Hypnos was the offspring of the Night and Erevos, according to Greek mythology, and Homer's Iliad refers to Hypnos specifically as the Lord of All Gods [1]. In ancient Greece, Hypnos was revered and thought to be of great importance.

Why would such a somatic state of mind and body be able to improve cognition? Does sleep aid in learning? Has the value of sleep changed from the days of the ancestors? According to research, memory processing and sleep are closely related and interact with one another. In reality, learning continues in a passive manner when you sleep [3]. The basic physiological processes of the body, such as hormone production, control of body temperature, immune system, ontogenesis, and tissue repair, are all aided by sleep. Increased blood pressure, increased glucose tolerance, increased insulin sensitivity, and diabetes are all results of inadequate sleep. Developmental, cognitive, and emotional disorders can also result from it [4], [3].

This study's objective is to discuss the findings of previous investigations into how sleep affects learning and brain function. Information on the learning process during sleep at various sleep stages and developmental stages is specifically included in the review. To learn more about the effects of sleep on learning, researchers frequently use sleep deprivation or sleep extension in their research protocols. Many studies have also shown a connection between sleep and memory consolidation. Learning requires memory, particularly when it comes to language learning and comprehension [5]. Finally, ideas are provided on recent studies as well as ways to support learning while you sleep.

The current study is a review of academic articles from 2000 to 2020 that were found on Mendeley and Google Scholar. The study was conducted in English with the aid of keywords like "Hypnopaedia," "sleep and learning," "sleep and memory," and "sleep and cognition." The majority of the time, peer group studies that have been reported in scholarly

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journals were preferred. Hypnopedia is the term used to describe the development of cognitive skills through sleep mechanisms. The findings of the study are shown in two sections: First, findings on how the brain works while we sleep are mentioned, and then findings regarding how sleep affects learning at various ages and stages follow. Finally, conclusions are arrived upon.

2. Sleep's effect on Brain Activity

The physiological state of sleep varies depending on the many cycles of brain activity. In reality, the brain experiences many periods of metabolic and neuronal alterations that separate awake from sleep [6].

The NREM state (Non- Rapid Eye Movement) and the REM state (Rapid Eye Movement) are the two states that predominate during sleep. They can be distinguished from one another by the externally visible eye movement. The electroencephalogram (EEG) also exhibits coordinated movements, sleep spindles at 12–16 Hz, K–complexes, sluggish brain wave activity, low muscle tone, and minimal psychological activity during the NREM stage. Each 90 to 100 minutes, one of four distinct stages in this state is repeated. Based on differences in brain frequencies and brain wave speed that were detected using EEG, this differentiation is made. Brainwaves of the alpha frequency precede lower frequencies of the theta band in the second stage of sleep, which begins in a non-rapid eye movement (NREM) state. The third stage of the NREM state lasts for a brief period of time, and the fourth stage quickly follows in the delta band of brainwave activity. In contrast to the previous stages, arousal is possible in the initial stage [7], [6], [2], and [8].

Then comes the REM phase of sleep. The EEG is chaotic, the muscles are toneless, there are sporadic eye movements, there are cardiovascular abnormalities, and there is a dreamy condition. The human body seems immobile, yet the brain is still working. For 1 to 5 minutes, the REM state lasts. Slow Wave during the initial half of the night's sleep In 80% of sleep, sleep frequencies are prominent. Acetylcholine, noradrenaline, and cortisol levels are decreased during this phase. REM state increases (20-25% of total sleep) in the second half of sleep and manifests earlier in stage 2 of NREM state [7], [6], [2], [8].

Sleep consists of concurrent physiological and behavioral processes of inactivity and movement that can be seen or not [2]. It has to do with synaptic homeostasis, and according to Tononi & Cirelli [9], synapses are charged during arousal, but low frequencies are used during sleep to unload synapses and stabilize them. Additionally, learning involves consistent alterations in the volume, frequency, and connection of neurons. The number of slow waves increases during sleep in direct proportion to the volume of synapses during learning in alertness. Consolidation is therefore improved. Inertia, homeostasis, and circadian rhythms are three sleep state factors that have an impact on cognitive performance and higher-order processes. Burke, et al. [10] claim that sleep inertia impacts visual attention while circadian rhythms can affect inhibition. Additionally, circadian cycles and homeostasis control motivation, mood, alertness, and motivation as well as the preservation of visual attention and working memory. Hypovigilance can also result in micro-sleeps, which can dangerously impair concentration throughout a variety of activities. The reduction of such accidents may be aided by specialized equipment and monitoring [11], [12].

A method of learning while you sleep is called hypnopaedia. It has been linked to science fiction and popular culture, in which sleep-learning is portrayed as simple and automated. In 1956, Emmons & Simons (as cited in Oghenero) [13] used EEG to evaluate the feasibility of learning while dozing off and discovered that it was ineffective. For years, there has been no scientific interest. The study of hypnopaedia has resumed as a result of advances in neurology and the wealth of knowledge provided by memory research.

3. Sleep's Effect on Learning and the role of ICTs

In particular, memory and cognitive performance on related activities benefit from sleep, which is an enhancing factor for cognitive processes. It has been researched through tests where the amount of sleep or lack of sleep has been regulated. Studies have focused on the impact of sleep deprivation prior to learning on memory tasks. The consequences of sleep after learning, the impact of treatments on sleep patterns, and the repeating of neuron expression during sleep have all been studied. The majority of these research contend that, in both people and animals, sleep is intricately linked to memory functions [7].

Neuroimaging techniques used to study the brain as you sleep reveal complex interactions in the thalamus circuits that keep electro-cortical oscillations in the NREM state. The fMRI test revealed that the left cerebellum, motor cortex, dorsomedial prefrontal cortex, and hippocampus all exhibit repetitive neuronal activity. Reduced activity is also seen in the prefrontal region, the left insula, the temporal lobes, and the parietal lobes. Changes in the thalamic and cortical systems as well as interactions between brain cells and neuron networks are what cause neuroplasticity. These findings mostly come from research done on cats [14], [15], and [3].

The aforementioned information leads us to the conclusion that sleep aids in learning and memory function. The first thorough study was carried out in 1924, despite the fact that dreams were considered to influence and alter the volume of neuron connections in the memory in 1801. According to this study, memory function improved following a night of sleep. A pertinent theory was established, and it has recently advanced with the help of neurosciences, which provide scientific justification [3]. Infants have been the subject of studies on sleep-related learning. Using a device that recorded bio-electric brain activity, Fifer, et al. [16] studied 34 neonates (10 to 73 hours old). The neonates' eyes were given a puff and a sound by the researchers. Infants in the experimental group predicted the sequence of stimuli more quickly than those in the control group did, and the EEG recordings revealed maximal, positive slow brain waves, which are associated with memory update. The cerebellar circuit function, which is different in children with autism, dyslexia, ADHD, and schizophrenia, is shown by blinking in response to a stimuli. This may make a very early diagnosis of these illnesses possible.

The impact of sleep on explicit memory was studied by Seehagen et al. [17] in groups of babies (6 to 12 months old) who had either just slept or had recently experienced sleep deprivation. After four and twenty-four hours, respectively, infants were evaluated for their performance in a learning activity involving puppets. The findings demonstrated that infants who napped remembered the activities better than those who did not, and that the first group performed better 24 hours later. This study provides the first experimental evidence of the stabilization and consolidation of explicit memory during the first year of life. It's crucial to remember that as we age, sleep and sleep functions change. Sleep in infants begins with the REM phase, which accounts for 50% of total sleep and has a short cycle of 50 minutes. REM sleep is reduced and makes around 20 to 25% of sleep till age 2. NREM sleep, which makes up 40% of total sleep during adolescence, is likewise diminished; however, this reduction occurs more slowly as people age, and this is especially true for men [2].

Lam, et al. [18] investigated the effects of a brief nap on preschoolers' cognitive abilities (N=59, 3-5 years old). For a week, they employed actigraphs, along with tests of attention, language, and reaction control, and questionnaires for parents to gauge the quality of their children's sleep. Data research revealed a negative correlation between napping and vocabulary and auditory attention span. Children with inadequate sleep had a higher tendency to act impulsively, which would have been detrimental if nighttime sleep deprivation had occurred. Additionally, they discovered that people who napped throughout the day slept less soundly at night. A night's sleep is essential for preschoolers' cognitive development, according to this study, which also found that naps at this age worsen neurobiological cognitive function while improving it for adults.

In light of this, depending on the age group, a daytime sleep may be beneficial or detrimental. According to Lovato and Lack [19], a nap only reduces drowsiness and enhances cognitive function for a period of 1 to 3 hours after it lasts for 5 to 15 minutes. Even 6 minutes of sleep after learning improves memory, as has already been established [20]. This is due to the O Process, which states that during a 10-minute nap, no activity occurs in the nucleus, and following arousal, activity occurs again and alertness increases. A snooze that lasts 30 minutes or longer is detrimental for cognitive function immediately after awakening, but it also improves for many hours immediately following. Longer sleep stages are associated to high vigilance levels of time. The ideal time for a nap is early in the afternoon, according to circadian rhythms. The effect of sleep on executive functions in preschoolers was investigated by Bernier, et al. [21]. The sleep habits of 65 children's mothers were recorded in a diary beginning in the first year of life, and a Wechsler Test (WPPSI) was administered four years later. The analysis of the data revealed that children who got enough sleep performed better in their executive functions but not in cognitive ability tests. Researchers highlighted how important sleep is for preschoolers' higher cognitive skills.

In 290 youngsters (7, 5 to 8, 8 years old), Paavonen et al. [22] investigated cognitive function and connected the outcomes to the quantity and quality of their sleep. Children's actigraphs and sleep-related questionnaires that were completed by parents were both used. In addition to two additional visuomotor and narrative-memory capacity assessments, the researchers used four WISC-III subtests to assess cognitive ability. Less sleep is associated with worse visuospatial performance, but not with worse language skills, according to the study's findings. In a different investigation, researchers [23] assessed the neuro-behavioral traits of 77 students (M=10, 6 years old) before and after sleep loss or extension for merely an hour. The kids' sleeping habits had previously been noted for five days. The quality of sleep was improved even after one hour of sleep deprivation, according to the study. On the other hand, extending sleep by an hour made sleep quality worse. Shorter reaction times and greater memory were associated with more sleep, but these abilities suffered from sleep deprivation. Executive processes appeared to be more taxed in the sleep deprivation condition, and there were generalized neuro-behavioral changes that were obvious.

De Bruin, et al. [24] conducted a systematic analysis of 16 studies on the effects of sleep deprivation or extension on cognitive function in teenagers (10 to 19 years old). No adverse impacts on adolescents' cognitive abilities were found under a partial sleep deprivation situation. Memory improved in both the sleep extension and the higher-quality sleep conditions. The consolidation of memories is improved by sleep following learning, according to research. There were several participants who had no discernible results. Numerous tests were used in these research to make a variety of measurements, and numerous individual differences were noted. In conclusion, researchers contend that teens with impaired sleep will also have improved working memory, whereas teens with inadequate sleep will have decreased ability to perform alert tasks.

The effects of sleep on children's and adolescents' cognitive skills were the subject of a meta-analysis by Arajo & Almondes [25]. Because of routines and certain habits, researchers contend that the biological need for sleep may not be satisfied. Young children are drowsy, however teenagers are accustomed to sleeping late and using the internet to watch shows. As a result of this fact, Slow Wave Sleep decreases and sleep phase delays take place. Working memory, attention, and visuospatial perception may all be hindered by these delays. Researchers have found that while some youngsters may function better with less sleep, bad sleep results in lower cognitive performance. It is a proven truth that when people lack sleep, their explicit and procedural memory suffers.

Kyle, et al. [26] used data on the sleep function that were taken from a biological bank (N= 477.529, 40 to 69 years old). 133.314 people (M=57 years old) were determined to have insomnia, according to the researchers. They contrasted their cognitive performance with that of others (344.215, M=56 years old) who did not experience sleep issues in terms of reasoning, reaction time, numeric memory, visual memory, etc. According to the findings, people who had sleeplessness frequently performed marginally better on cognitive tests. The scores of people who used sleeping pills and those who typically slept fewer (7 hours) or more (>9 hours) were lower. Last but not least, people who slept at night performed better than people who slept during the day. Sleep and cognitive function appear to be tightly related. The effects of sleep on memory, executive function tasks, and learning are the main research areas. Prior to or after studying, getting a good night's sleep improves learning outcomes. A meta-analysis, however, found that sleep deprivation, even a negative one, may have detrimental effects on executive functions, attention maintenance, and long-term memory [27]. Age, sex, sleep duration, perceived drowsiness, and sleep delay all have an impact on the aforementioned impacts.

Additionally, a number of sleep-related activities may promote learning. These methods use smells or sounds to trigger memories that were formed throughout the learning process. Electrical or acoustic stimulation, as well as medications like noradrenalin and glutamine, are typically used to achieve this. [28], [29]. In reality, sensory input may shift to becoming conditional. Due to the fact that hearing and smell are remain active while we sleep, these senses have been used extensively in research to aid in learning [30], [31], and [32]. The auditory cortex and thalamus can be twice as active in the NREM phase in response to an audio stimulation. The right amygdala and prefrontal cortex can both be stimulated by calling someone by name. Clicks during sleep can improve problem-solving skills [7].

Learning processes also have an impact on sleep. Research consistently shows that oscillations in the hippocampus and an increase in slow wave sleep, which produce consolidated information and knowledge, occur in both animals and humans. Additionally, REM sleep phases are lengthened, which improves memory consolidation in the long-term memory [33], [34]. In summary, sleep is a function that changes with age and has different effects on cognition and performance. Even when sleeping, newborns may learn. An uninterrupted night's sleep has positive effects on kids. An afternoon nap for adults might be beneficial. Poor sleep in adolescents has a negative impact on their cognitive functioning, particularly their executive skills. In terms of their cognitive capacities, those who are over 40 and have insomnia are not badly impacted, although a lack of sleep generally impairs cognition.

Finally, we emphasize the significance of all digital technologies in the fields of education and of sleep, which is highly effective and productive and facilitates and improves assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere [35-38], various ICTs applications that are the main supporters of education [39-58], and AI, STEM, and ROBOTICS that raise educational procedures to new performance levers [59-63] as well as friendly and amusable games [64-66]. Additionally, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the cultivation of emotional intelligence [67-93], accelerates and improves more than educational practices and results, especially in the domain of education for sleep improvement and its practices like assessment and intervention.

4. Conclusion

More specifically, sleep seems to be a mysterious and dynamic function. Since the development of neurosciences, multiple procedures come to light which take place in a motionless body. Why do people sleep? Is it because circadian rhythms force us to do so? Is it because the organism needs some time to be neuro-biologically balanced in order to survive? Is it because a lot of information that we come across every day must be processed and organized? Is it because some functions are manifested only during dreams? According to neuroscience, sleep is presented by oscillations, peaks, electric power, periods, time, motion, and neurotransmitters, all of which differ in individuals and each developmental stage. Babies sleep more and dream more. It is possible for them to learn during sleep and to recall better after a good sleep.

As children grow up, in preschool years, daytime becomes a field for activity and education. If a short nap mediates during this time, it can affect the vocabulary performance and the function of attention in a negative manner. In contrast, a night sleep favors the consolidation of data extracted from an interesting and explorative previous day. Children and adolescents sleep, but neither enough nor sufficiently. Their sleep is of poor quality because of everyday habits, such as overusing screens (pc, TV, mobile phones, etc.) and routines such as going to school very early. This affects their cognitive performance. Perhaps we should consider appropriate changes that could lead to sleep restoration and better cognitive performance. In addition, adolescents dream more and sleep less. Developmentally, the youth seems to need more vision and more action.

Adults benefit from a nap during the day even if it lasts for 6 minutes. A nap early in the afternoon can recharge nucleus in the brain effectively and achieve the necessary level of vigilance. People who are above 55 years old use to sleep less and gradually Slow Wave Sleep becomes less, too. They usually deal with insomnia, which nevertheless, does not affect much of their cognitive function. In general, cognitive performance may be decreased by insomnia or sleeping during the daytime, because of sleep deprivation.

Sleep appears to evolve while getting older. Is it because it may relate to maturation and neuro-plasticity? It seems that the more immature or unshaped one is, the more active one's sleep is. Also, the more mature and 'wise' one is, the shorter one's sleep is. We should consider how to utilize these results about cognitive enhancement or even about interventions in special education. Researchers have already made use of technologies which are put into action during sleep and they boost memory and learning. New research is necessary to be conducted on what, how, and for whom these interventions may upgrade learning, as well as the quality of life.

Compliance with ethical standards

Acknowledgments

The Authors would like to thank the SPECIALIZATION IN ICTs AND SPECIAL EDUCATION: PSYCHOPEDAGOGY OF INCLUSION Postgraduate studies Team, for their support.

Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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