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REVIEWS

Sleep Strengthens Memories

UMA DEVI P, MURUGAN S, SENAPATHY J G

ABSTRACT

Sleep has been identified as a state that optimizes the consolidation of newly acquired information in memory. Many evidences prove that both procedural and declarative memories are improved during sleep. Sleep does this through neurotransmitters and neurohormone secretion between its stages. While we sleep, our bodies secrete hormones that affect our mood, energy, memory and concentration. There occur two stages of sleep that include NREM (Non-Rapid Eye Movement) and REM (Rapid Eye Movement) sleep. Hippocampus-dependent memories benefit primarily from slow-wave sleep (SWS), whereas memories not depending on the hippocampus, show greater gains over periods containing high amounts of Rapid Eye Movement sleep. During sleep, the brain rewires its circuits to make sure that all newly gained knowledge is stored for future use. The parts of the brain that we use to learn a task become active again during sleep. This activity, scientists suggest, could be the brain transferring memory from short-term to long-term storage.

Key Words: Sleep, memory, neurotransmitters, hormone

School of Biotechnology,
Karunya University,
Coimbatore -641 114(India)
Corresponding Author:
Dr. Uma Devi Pongiya*,
Assistant Professor (SG),
School of Biotechnology and
Health Sciences,
Karunya University,
Coimbatore-114,
Mobile: +91 9994583372
E - mail: umadevipongiya@rediffmail.com

Introduction

Sleep Isn't Just a Form of Rest

Sleep plays a critical physiological function and is indispensable for your intellectual development. Those who do not respect their sleep are not likely to live to their full mental potential. By cutting down on sleep, we learn less, we develop less, we are less bright, we make worse decisions, we accomplish less, we are less productive, we are more prone to errors and we undermine our true intellectual potential. Yet, some dramatic facts related to sleep deprivation slowly come into light [1]. Many studies make it clear that sleep deprivation is dangerous. Sleep-deprived people who are tested by using a driving simulator or by performing a hand-eye coordination task perform as badly as, or worse than those who are intoxicated. Sleep deprivation also magnifies alcohol's effects on the body and so a fatigued person who drinks, will become much more impaired than someone who is well-rested. Driver fatigue is responsible for an estimated 100,000 motor vehicle accidents and 1500 deaths each year, according to the National Highway Traffic Safety Administration [2]. Since drowsiness is the brain's last step before falling asleep, driving while drowsy can – and often does – lead to disaster. Caffeine and other stimulants cannot overcome the effects of severe sleep deprivation [3].

Sleep Enhances Memories

A good night's sleep triggers changes in the brain that help to improve memory. New memories are formed within the brain when a person engages with information to be learned (for example, memorizing a list of words or mastering a piano concerto). However, these memories are initially quite vulnerable; in order to "stick", they must be solidified and improved. This process of "memory consolidation" occurs when connections between the brain cells as well as between different brain regions are strengthened and for many years, it was believed to develop merely as a passage of time. More recently, however, it has been demonstrated that the time spent in sleep also plays a key role in preserving memory [4].

Procedural and Declarative Memory

Memory is possibly a person's most distinctive characteristic: it defines who we are and acts as a guide to our present and future. Psychologists have classified normal human memory into procedural and declarative memory. Procedural memory is used for skills such as riding a bike; while declarative memory is more concerned with knowing that a bicycle is called a bicycle [5].

By using functional magnetic resonance imaging (f-MRI), we can actually see which parts of the brain are active and which are inactive while subjects are being tested, thus enabling us to better understand the role of sleep in memory and learning. Fenn et al [6] of Harvard Medical School pointed out that the MRI results of the selected population have shown some areas of the brain were distinctly more active after a period of sleep and other areas were noticeably less active. But together, the changes brought about by sleep resulted in improvements in the subjects' motor skill performance.

"The cerebellum which functions as one of the brain's motor centers in controlling speed and accuracy, was clearly more active when the subjects had had a night of sleep," he explains. At the same time, the MRIs showed reduced activity in the brain's limbic system, the region that controls emotions such as stress and anxiety. "When you're asleep, it seems as though you are shifting memory to more efficient storage regions within the brain. Consequently, when you awaken, memory tasks can be performed more quickly and accurately and with less stress and anxiety"[4].

In the new work, researchers studied the influence of sleep on declarative memory in healthy, college-aged adults. The results demonstrated a robust effect: As compared to participants who did not sleep during the trials, those who slept between learning and testing were able to recall more of the original words that they had learned earlier. They demonstrated that sleep does not just passively and transiently protect memories; rather, sleep plays an active role in memory consolidation [7].

Physiology of Sleep

The human brain seems to be the highest achievement of biological evolution. It all started from a simple ability to conduct impulses. The hippocampus acts as the central switchboard that can easily store short-term memory patterns for the brain. During sleep, the brain works as hard as during SAT or GRE exams. It rewires its circuits to make sure that all newly gained knowledge is optimally stored for future use. Due to the physiological function of sleep, which is the rewiring of the neural network of the brain at the synapse level, we can naturally expect that the demand for sleep be associated with the amount of learning on the preceding days.

At the time when we usually go to sleep, there is a substantial circadian increase in melatonin released from the pineal gland. Melatonin is one of strong contributors to drowsiness. However, it

is possible to sleep against the melatonin-serotonin cycle, which clearly indicates that it is not the only sleep regulator. At the same time, there is a significant drop in ACTH and cortisol, which are our alertness hormones. Similarly, the levels of serotonin drop and so does the body temperature. Once we rest in an undisturbed place, we drift into a dreamland. Actually, this is only the case in a well regulated sleeping cycle. People who cannot succumb to natural body rhythms will often be unable to follow the above scenario [1].

In the course of the night, we alternately enter two phases of sleep,

- NREM sleep (named for non-Rapid Eye Movement)
- REM sleep (named for Rapid Eye Movement)

Using EEG measurements, scientists were able to identify four phases of NREM sleep which correspond to progressively deeper sleep. As we close our eyes, it takes 3-15 minutes to enter Stage 1 NREM sleep (in a healthy and well-regulated individual). In this stage, we often experience little jerks associated with the impression of falling. Minor disturbances will wake us up and often we will even deny that we were asleep. Once State 1 NREM solidifies, we move towards Stage 2 NREM sleep which is still relatively light. After that, we move to Stage 3 and Stage 4 NREM (also called slow-wave sleep or deep sleep). One cannot learn effectively if your sleep gets cut short in the morning or if it gets interrupted during the night. Even if you try to sleep 15 hours per day in short pieces of interrupted sleep, your learning results will be dismal.

After 60-90 minutes of NREM sleep, there is a gradual increase in the activity of cells in the pontine tegmentum which is responsible for triggering REM sleep. During REM sleep, the cortex behaves as if you were awake. You experience dreams that seem to be generated by a random impulsation sent from the brainstem to the cortex. The cortex produces the best possible and most coherent imagery that it can. You experience connected events, real people, realistic scenery, all put together in the most improbable configurations. Yet, you cannot act upon your dreams (except for people with a disorder called *violent sleeping*). You often want to act in sleep (e.g. to escape a ferocious dog), yet you remain motionless. You feel as if mired in molasses. Only your eyes move rapidly and the muscles in your middle ear twitch. REM sleep is philogenetically younger than NREM sleep. Fish, amphibians or perhaps most reptiles do not show typical REM sleep. Yet, interestingly, REM sleep is present in both mammals and birds. This made some evolutionists hypothesize that REM sleep has been invented twice by evolution! The conclusion is that REM sleep plays a critical role for the survival of creatures with bird-mammal IQ levels. REM sleep is characterized by intense neural activity, increase in blood circulation and the use of oxygen, as well as an increase in the uptake of amino acids by the brain tissue. The brain in REM sleep is a hard-working brain that has little to do with the notion of energy-conservation and rest in sleep. A typical night will see you go five times through NREM-REM cycles, with each cycle lasting around 90 minutes and getting slightly shorter as the night progresses. Light impulses from the retina travel to the hypothalamus and SCN to produce a stop signal for the release of melatonin. Instead another neurohormone, serotonin were released,which in high level is responsible for what we feel as the morning sunshine happiness. It is also serotonin that is boosted by the popular antidepressant- Prozac. Unless you suffer from sleep phase advancement, always make sure the sunshine streams into your sleeping room in the morning to wake you up.

Role of Enzyme Mitogen-Activated Protein Kinase

Long-lasting memories are stored in the brain through strengthening of the

connections or synapses between neurons. Researchers have known for many years that neurons must turn on the synthesis of new proteins for long-term memory storage and synaptic strengthening to occur, but the mechanisms by which neurons accomplish these tasks have remained elusive. The MIT (Massachusetts Institute of Technology) research team, led by Nobel laureate Susumu Tonegawa, director of the Picower Center for Learning and Memory, has now identified a crucial molecular pathway that allows neurons to boost their production of new proteins rapidly during long-term memory formation and synaptic strengthening. There is a direct activational signal from the synapse to the protein synthesis machinery, "The central component of this pathway, an enzyme called "mitogen-activated protein kinase" (MAPK), which effectively provides a molecular switch that triggers long-term memory storage by mobilizing the protein synthesis machinery. The synaptic stimulation normally activates MAPK and the activated form of MAPK in turn activates several key components of the protein synthesis machinery. This direct regulation of the protein synthesis machinery helps explain the observation that the activation of MAPK enhanced the production of a broad range of neuronal proteins [8].

Which Memories Are Restored In Sleep

Memories that are lost during the day may actually come back after a good night's sleep. But new research suggests that not all memories are equal and that some may be more likely to be forgotten than others. Researchers say that the task was like learning to understand someone speaking in a foreign language. The study showed that the performance declined over the span of a day, but completely recovered after a night's sleep and protects memories from decay; sleep also appears to restore memory.

In the second study, the short-term memory of the first exercise was lost in the process of immediately learning a second exercise. Sleep enhanced the memory of the exercise, but only of the second learned task and not the first. This is because the memory of the second learned exercise was not interfered with. But when the second exercise was learned six hours after the first, it did not interfere with the processing of the first and the performance and the memories of both were enhanced by sleep. Researcher Matthew P. Walker and colleagues of Harvard Medical School say that the findings showed that when memories are recalled, they shift back to an unstable state. Once reactivated, these memories may either be restored or lost if this process is interfered with [6].

Memory Consolidation during Rem and Nrem (Or Slow Wave Sleep) Sleep

Sleep causes memory consolidation by establishing a different pattern of neurotransmitters and neurohormone secretion between sleep stages. Another central role for consolidating memories is played by the slow oscillation, that is, the oscillating field potential change dominating SWS. The emergence of slow oscillations in neocortical networks depends on the prior use of these networks for encoding of information. Via efferent pathways, they synchronize the occurrence of sharp wave ripples accompanying memory reactivations in the hippocampus with thalamocortical spindle activity. Thus, hippocampal memories are fed back into neocortical networks at a time when these networks are depolarized and because of concurrent spindle activity, can most sensitively react to these inputs with plastic changes underlying the formation of long-term memory representations [9].

One of the functions of rapid eye movement (REM) sleep is to help memory processing. A research team headed by Pierre Maquet used positron emission tomography (PET) and brain blood flow measurements to assess brain function when people were

learning a reaction time task and when they were sleeping. In the experiments, people were trained to press buttons when they saw certain symbols on a computer screen. The performance of these people on the reaction time task improved with practice and improved even more after they got a night's sleep. Dr. Maquet and his co-workers found that many of the brain areas that were activated when people performed the reaction time task were the same as those activated during REM sleep. During REM sleep, the visual cortex, premotor cortex, and some parts of the thalamus were more active in trained subjects than in untrained subjects. These were the same areas that showed significant activation during the reaction time task. These data suggest that areas of the brain which are important for learning the reaction time task are "reactivated" during REM sleep. The researchers believe that this reflects the importance of REM in memory processing, perhaps by strengthening memories [10].

Why Infants Need More Sleep

A good night's sleep may help your brain permanently file away lessons learned during the day. "Sleep appears to play a key role in human development," These findings may explain why children and teenagers need more sleep than adults and in particular, why infants sleep almost round the clock. They have an immense amount of new material to consolidate and consequently, this intensive period of learning may demand a great deal of sleep" [4].

Even More Reasons to Get Good Night's Sleep

As though improved memory isn't enough incentive, there are many other reasons why getting plenty of shut-eye is a wise move. When we sleep:

- Muscle tissue is rebuilt and restored
- Growth hormone is secreted (this is important for kids but also for rebuilding tissue in adults)
- Mental energy is restored

And a good night's sleep is important for everything, from improving your mood and mental alertness to giving you energy and stamina to get through the day.

On the other hand, if you don't get the sleep you need:

- Your immune system may become impaired, leaving you less able to fight off disease
- You may feel irritable and have poor memory, poor concentration and mood swings
- You're more likely to feel angry, pessimistic and sad
- Your coordination, reaction time and judgment may all be negatively affected, which is particularly dangerous while driving

Conclusion

All of us need sleep to help reinforce memories and keep them from fading away. The researchers found that those who slept between learning and testing were able to recall what they have learned, more efficiently. The brain is more active during sleep to convert short-term to long-term memory storage. But some memories which are learned immediately and others are elapsed based on main concern. Sleep does not just passively and transiently protect memories; rather sleep plays an active role in memory consolidation. If you really want to remember something, study until bedtime. But don't stay up all night. You may learn less, but you'll remember a whole lot more. Some scientists say that sleep isn't essential for storing memories. Until that is settled, it's probably still better to be on the safe side, getting plenty of sleep.

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