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Sleep On It - Why Sleep is Important for Optimizing Learning and Memory

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Why is this topic important for public health?

At some point, most of us have sacrificed valuable hours of sleep to study for an exam, meet a project deadline, or put final touches on preparations for an important event. Sacrificing sleep often seems like a small price to pay for checking items off the to-do list. However, short sleep actually impairs performance, interferes with learning, and disrupts memory formation – making it much more difficult to complete tasks. This essay summarizes some of the science that explains sleep's role in learning and memory and why getting a good night's sleep is critical for achieving peak performance.

What do we currently know?

Kinds of memory. There are 3 different types of memory: working, short-term, and long-term. Working memory is what you are remembering in the present moment. Working memory is very brief and fragile, meaning it doesn't last long. An example of working memory is remembering a phone number long enough to dial it.

Working memories can become short-term memories if something about the memory or situation is meaningful to you. For example, think back to a time when you were introduced to a group of strangers. You probably did not remember their names for more than a few seconds. However, if one of them had the same name as your mom, best friend, or favorite singer, you probably did remember that stranger's name. Because that name was meaningful to you, it stuck -- became a short-term memory. As you may have guessed, short-term memories last longer than working memories. You're able to remember short-term memories at a later time (not too much later; perhaps just later that day).

Short-term memories can become long-term memories during sleep. Sleep helps turn short-term memories into long-term memories and combines them with the information already stored in your brain. You can think of it like organizing new memories into a filing cabinet with all your other memories, so you can access them later. This process of storing short-term memories as long-term memories is called consolidation. Consolidation is critical for learning and memory, which can determine how well we function and perform tasks.

The processing of declarative memories. For a long time, we have known that short- and long-term memories are formed in a part of the brain called the hippocampus. This knowledge came from a famous patient in neuroscience history: Henry Molaison. Henry was born in 1928 and had severe seizures throughout his early life. In his mid-20's, Henry had neurosurgery to eliminate his seizures. The surgery removed his hippocampus. After the surgery, the seizures were cured, but Henry could not form new memories. He could remember events in his life before the surgery, but could not remember new people or events after the surgery. For example, if people he did not know before his surgery came to visit him, he could interact with them quite normally. But, if they walked out of the room for a few minutes and came back in, Henry could not remember them. They were again strangers.

Research with rats has helped us understand how short-term memories are consolidated into long-term memories. There is a group of brain cells in the hippocampus that fire (send a signal) when a rat is in a specific place or location. Scientists called these brain cells "place cells." Researchers recorded these place cells while rats were running in a maze. Some place cells fired when the rat was in one part of the maze, whereas other place cells fired when the rat was in another part of the maze – the researchers could tell where the rat was in the maze just by looking at which cells were firing. As the rat ran the maze, different place cells fired as the rat entered different locations along its path through the maze. Thus, a cell firing pattern was generated that represented the rat's path through the maze. After the rat completed the maze and was resting, the cells fired in the same pattern, but backwards as if the rat was remembering where he had just been. Then, the rat was left undisturbed to sleep. During sleep, the place cells fired in the same pattern as when the rat was running through the maze over and over again. The researchers believed that the rat's brain was replaying the memory of running through the maze. After looking at more complex brain activity, the researchers determined that these firing patterns (or replays of memories) in the hippocampus were eventually transferred to other regions of the brain where they could be stored.

You may be wondering how a rat's memory of its location in a maze has anything to do with human learning and memory. Well, humans also have location memory. Like rats, we use it to find our way around our environment. However, these experiments taught us more than how our brains help us remember directions. These findings helped scientists understand that as we experience things in life, our brains record these experiences as unique cell firing patterns. During sleep, these patterns are replayed and the experiences they represent are sent to other brain regions where they can be stored as long-term memories.

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The role of sleep in memory consolidation. So, what is the purpose of replaying short-term memories (brain cell firing patterns) during sleep? Do these replays help consolidate (strengthen) memories? Research in humans has helped answer this question.

In one study, researchers asked participants to remember where images were located on a grid on a computer screen. During daytime training sessions, images (for example a cat, tea kettle, and bell) popped up in different locations on the screen. When each image appeared, it was accompanied by a sound (the cat with a meow, tea kettle with a whistle, bell with a ring, etc.). While the participants were sleeping the following night, some of the sounds were played over and over. The next day, the participants were tested on whether they remembered the location of each image. Amazingly, they remembered the locations of the images that matched the sounds that were played back to them during the previous nights' sleep better than they remembered the locations of the other images. For example, if the "meow" sound was played during sleep but the "whistle" sound was not, the participants remembered the location of the cat image better than that of the tea kettle image.

A similar study was done using smells with images, rather than sounds. When each image appeared in this study, participants were exposed to a rose scent. During sleep, participants were re-exposed to either the rose scent or a different scent. The next day, the participants who were exposed to the rose scent during sleep scored better on the test than the participants who were not exposed to the rose scent.

Another similar experiment has been done with mice. In that experiment, the mice were exposed to a mild foot shock, which was a fearful experience. This experience was paired with a smell. Some mice were exposed to the smell during sleep, whereas others were not. The next day, all mice were exposed to the smell. Those who had been exposed to the smell during sleep had greater fear reactions than those who were not exposed to the smell during sleep.

All three of these experiments support the idea that when memories are replayed during sleep, they are strengthened and consolidated.

Next Steps

There is still a lot to learn about how the brain records experiences and consolidates them into memory. However, research has helped us understand that sleep is important for consolidating memories and integrating them with existing knowledge. This integration is the source of insight, creativity, and the ability to use past experiences to deal with new challenges. When considering

sleep's critical role in learning and memory, it is evident that sleep is especially important for younger people as they progress through education and gain life experiences.

Further Reading

Why We Sleep: Unlocking the Power of Sleep and Dreams. Matthew Walker. 2017. Amazon
Sleep Learning Gets Real. Kenneth Paller and Delphine Oudiette. Scientific American Nov. 2018
Secrets of Sleep Science: From Dreams to Disorders. H. C. Heller. The Great Courses.
Healthy Sleep Tips. SleepFoundation.org
Healthy Sleep Health Center. WebMD.com
Brain Basics: Understanding Sleep. NINDS.NIH.gov