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Research on the relationship between episodic memory and sleep in human

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Abstract. This paper reviews and analyzes the important "memory" aspect of brain science, mainly through reading and summarizing the existing literature to explain the relationship between episodic memory and sleep. A large amount of literature on Google scholar shows that sleep plays an important role in consolidating episodic memories, and gives experiments and evidence to support this idea. The study found that slow-wave sleep is an important period for memory consolidation, and that different stages of sleep also play a part in the memory consolidation process. Various experiments have demonstrated the important link between sleep and episodic memory storage, which means that memory quality is closely related to sleep. This paper also contains two hypotheses for the process of memory Consolidation: the "Active System Consolidation Hypothesis" and the "Synaptic Homeostasis Hypothesis". In the course of research, we haven't seen much literature supporting the existence of episodic memory in animals, but they do have memories that look a lot like episodic memory, which most scientists call "episodic-like memory."

Keywords: episodic memory, human, memory consolidation, sleep.

1. Introduction

Memory can be divided into long-term and short-term memory, and long-term memory can be divided into explicit and implicit memory [1]. Episodic memory is a type of declarative long-term explicit memory that refers to a person's unique recollection of experiences, situations, and times [2]. The content of the recall is usually the details of the event, the background and the related emotions. When we usually recall, if we only evoke a sense of familiarity, but cannot describe its specific details, we cannot be considered to have episodic memory.

People take in information throughout the day but retain some of it the next day because the brain processes it and consolidates the memory. Sleep plays an important role in memory consolidation, and research into it could also lead to the future regulation of sleep quality, which may affect memory. Can the efficiency of memory during study be improved by the choice of study time and the improvement of sleep quality? This paper will explore the relationship between sleep and episodic memory in detail. This study is helpful for people to have a deeper understanding of the role of sleep and the consolidation of episodic memory, reflecting the importance of sleep.

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2. Stages of sleep

Sleep is an essential part of human survival and something we experience every day. What happens in the brain during sleep has long been a subject of inquiry. Sleep can be divided into four stages, the first three stages (N1, N2, and N3) are non-rapid eye movement (nREM), and the last stage is rapid eye movement (REM). During N1 sleep, the body is not completely relaxed. It is just falling asleep, and it is easy to be woken up. The N2 phase is accompanied by muscle relaxation, a slow heart rate, and a drop in body temperature. Brain wave monitoring at this stage of sleep shows that eye movement has stopped. Stage N3 can be referred to as slow wave sleep (SWS), during which a person enters a deep sleep state. REM sleep is close to the level of wakefulness, when the eyes move rapidly. Studies have shown that this stage of sleep is important for cognitive ability and creativity.

2.1. The cortical mechanism of memory consolidation

The consolidation of memory in sleep can be divided into two steps, the first is to process the memory of the event, and then through the brain to store and consolidate the memory [3]. They also propose that the connection between the neocortex and striatum plays an important role in the formation of long-term memories. During wakefulness, situational information is encoded in networks both in and out of the hippocampus and sorted into events that contain time. Later, during the SWS sleep phase, the encoded memory is repeatedly activated and transmitted to the striatal and neocortical networks, which facilitate communication between them and are controlled by electroencephalographic oscillations. During subsequent stages of REM sleep, encoded memories are stabilized and converted into new representations. Therefore, the two sleep stages of SWS and REM are important for memory consolidation.

2.2. Two hypothesis of the process of consolidation of memory

To explain memory consolidation from the perspective of neurons, it is thought to be a change in the strength of synaptic connections. There are two hypotheses for the process of memory Consolidation, the first is the "Active System Consolidation Hypothesis" and the other is "Synaptic Homeostasis Hypothesis" [3, 4].

In the active systems consolidation hypothesis, information that humans perceive is temporarily stored in the hippocampus, and neurons that are activated in response to new information are reactivated during sleep to perform offline replay. Subsequently, the information stored in the hippocampus is gradually transferred to the neocortex, and the synapses encoding new information in its network can undergo long-term plasticity changes, so that newly acquired information can be gradually integrated with existing long-term memories. In one experiment, the subjects were asked to learn the position of 2D images by smelling the roses before going to bed, and to see the correct rate of restoring the image position after waking up [5]. The experiment showed that the brain wave imaging of the subjects was active during the SWS during sleep, and the final accuracy was the highest. The experiment also proved that encoded memory neurons can consolidate memories when they are activated during sleep, and in this case, smell was the factor that stimulated neural activity and promoted the consolidation of memory.

In addition, the "Active System Consolidation Hypothesis" holds that memory consolidation in sleep is selective. Although a lot of information was encoded during the day, only part of the memory could be effectively stored in the brain and become long-term memory at the SWS stage. Because the repetition of neural activity during sleep involves hippocampal function, episodic memory benefits more from sleep consolidation than procedural memory. In the experiment, neutral foreground items will be paired with a negative or neutral background when coded. In the test, foreground objects were shown as cues, and participants were asked to retrieve information from source images originally paired with those objects [6]. The test included two different task conditions: the EMOTION condition and the emotion-free condition (PEOPLE). In terms of emotion, participants indicated whether the source image associated with each presented object was emotional or neutral. In PEOPLE, they indicate whether the source image contains people. Source memory performance was comparable between the sleep and wake groups after coding, indicating similar baseline memory levels and indicating that performance

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was not affected by the time of day of training or testing. However, in a subsequent delayed test, participants who slept forgot less of the source information than those who stayed awake. The results of the experiment strongly showed that there's a lot of processing of emotional memories during sleep and it's very effective in consolidating episodic memories.

In 2003, Tononi proposed the “Synaptic Homeostasis Hypothesis”, which posits that when people are awake, the number of synaptic pathways involved in receiving information increases [7]. This may lead to less available brain space and more energy consumption, thus reducing the efficiency of synaptic transmission. If the brain is kept awake for a long period of time, the brain's storage space can no longer allow synapses to continue to work, which affects memory. One experiment looked at changes in synaptic structure. In fruit flies, protein levels of the presynaptic and postsynaptic components were higher after waking and decreased during sleep. In addition, the number or size of synapses in the four different neural circuits increased a few hours after waking and only decreased when the flies were allowed to sleep. Thus, it turns out that synaptic activity is reduced only during sleep, freeing up space for the brain to learn more widely and efficiently during the day. In some studies, people who pull an all-nighter have significantly reduced brain function and learning ability compared to people who have a normal night's sleep [8]. Because if it is normal sleep, during NREM and SWS, the synaptic reference will take effect, and it will return to the original state, maintaining synaptic homeostasis, and thus increasing the efficiency of memory. Overall, the hypothesis is that memory consolidation is related to synaptic activity. However, this hypothesis also has some problems. Only NREM and SWS sleep stages are mentioned in the hypothesis, but the REM stage is not mentioned, which lacks support for the theory. Also, there were areas of the brain that did not show slow-wave activity during the SWS stage.

In studies of memory consolidation in humans, scientists have found that SWS is more effective for declarative memory storage than REM sleep [9]. Rapid eye movement is more conducive to the consolidation of procedural memory during sleep. Episodic memory, as the name suggests, is the memory of a scene. In our life, we experience different scenes every day, and different events happen in these big and small scenes.

One study showed that napping can selectively consolidate context memory, but not item memory [10]. In their experiment, there were two groups of subjects, one taking a nap and one not taking a nap. They were asked to study two lists of words and look at two different posters. Words are considered item memory, and posters are considered to be related to episodic memory, because they will convert the color, composition and other contents of the poster into images and imprint them in the brain. When they subsequently recalled the words, the group that had napped had a better and more accurate recollection of the content of the poster. But there was no significant difference in item memory between the two groups. Thus, it can be proved that sleep makes a prominent contribution to the consolidation of episodic memory.

Sleep also slows the rate of forgetting and resists distractions. The forgetting rate of temporal context is the slowest during SWS, and the consolidation of spatial context is mainly during REM.

People's emotions, as one of the factors of episodic memory, can also be consolidated during sleep, and the REM sleep cycle is particularly important. The amygdala is the part of the brain responsible for processing emotions, and the hippocampus is where long-term memories are formed and retroactively recalled. The researchers found that neural regions in the amygdala and the medial temporal lobe of the hippocampus were more active when people entered REM than when they were awake, suggesting that during sleep the brain responds more vigorously to memory than during the day, linking emotions to memory storage.

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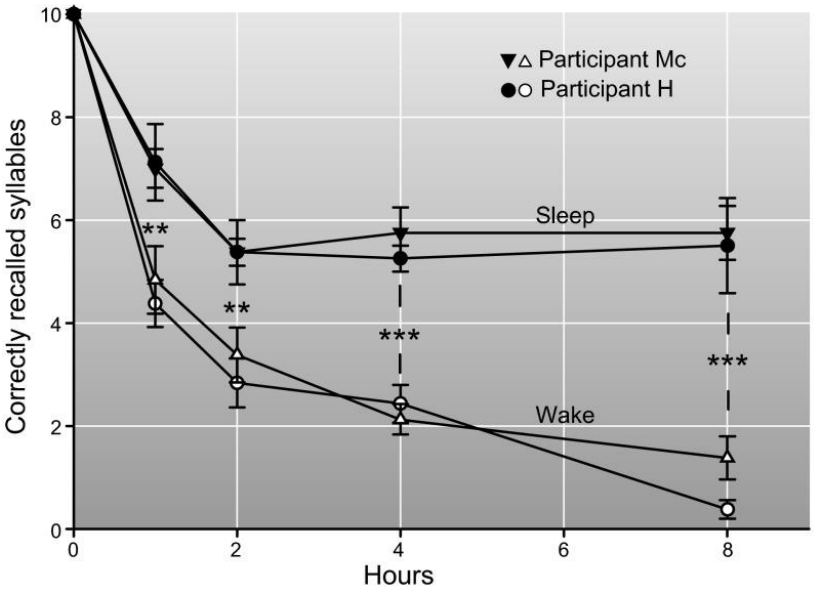

Figure 1. Effects of sleep and wake intervals of different length after learning on memory for senseless syllables.

In 1885, Ebbinghaus established the famous "Ebbinghaus forgetting curve" based on his rate of forgetting words [3]. In the experiment, he selected two groups of subjects, one group studied before going to bed at night, and the other group studied during the day while staying awake. When their memory of the words was tested 24 hours later, it was found that the group who studied the words at night before going to bed was more accurate. As can also be seen from the above graph, sleep has a significant and effective effect on memory consolidation.

3. Conclusion

In conclusion, sleep, which is very important for human beings, plays an important role in memory. Many scientists today are studying the mysteries of the brain and the role of sleep, and the results are refreshing. The academic community has also made hypotheses about the relationship between sleep and memory, which have been confirmed by experiments. It can be seen from the results of the experiment that if you want to improve the efficiency of learning, especially memorizing words, you can consider reciting before going to bed at night. Because the nerves that are activated during memorization are reactivated later in sleep, thus consolidating the memory. In addition, because the SWS phase of sleep is an important period for memory consolidation, the length and quality of sleep are also important if you want to make learning memories more profound. It can be changed the day after tomorrow to achieve the desired effect. Memory consolidation during sleep has only been discussed in humans, but less research has been done in animals. This article would be more complete if it included a discussion of animal memory.

Although there are a lot of studies on episodic memory in animals, many of the conclusions are that they have episodic-like memory, which is slightly different from the episodic memory pattern that humans have. For example, in the Scrub Jay experiment [11], scientists put peanuts and wax worms in a box, and based on the time that scrub jay returned to search for food, assessed their ability to judge time and space and their memory. But because animals can't express it directly, fewer experimental conclusions can be drawn. In the future, the scientific community may need to repeat the same type of experiment more often, the repeatability of experimental conclusions, and continue to explore the relationship between episodic-like memory in animals and human episodic memory.

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