NEUROPHYSIOLOGY

Want a better memory? More REM sleep could be the solution

Sleep has previously been identified as a critical period for consolidation of memory. A research team spanning labs in both New York and Peking recently identified one mechanism that only occurs during one specific stage of sleep: REM sleep. This mechanism is the pruning of dendritic spines.

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Dendritic spines are tiny attachment points on brain cells that help create connections with other brain cells. The more dendritic spines there are on a neuron, the more easily neurons are able to talk to it. Not only have dendritic spines been linked to memory, but researchers have also found that dendritic spine populations change during sleep after learning a new task.[1,2] Furthermore, sleep disruption has been shown to decrease the amount of spines in brain areas associated with memory.[3] The present study published in *Nature Neuroscience* continued this research by specifically targeting the part of sleep associated with dreaming, REM sleep.[4] In their research, the team found that REM sleep that followed new motor skill learning, selectively prunes some dendritic spines while strengthening others. While the mechanism requires further research, the implications for this paper are already translatable to health information: getting sleep is important for memory, but the quality of sleep is just as important.

The brain is a fascinating but unbelievably complicated organ. The process of memory formation has been linked in part to a specific brain region (the hippocampus), but where that memory is stored and how it is converted from short to long-term storage is not fully understood.[5] Part of what is known about memory consolidation is that synapses undergo changes in strength.[6] Synapses are the connections between two brain cells. If you think of the brain as a computer that can rewrite its own circuitry, changing synaptic strength allows the processing of information to become more efficient. Through these changes, multiple sensations, ideas, concepts, and temporal information can be associated: conceptually this is the formation of a memory. Dendritic spines may not all behave the same way, but their change in location and size has been correlated with changes in synaptic strength, which suggests dendritic spines help with memory formation and long-term storage.[7] It is known that dendritic spines change morphology during sleep, but our knowledge has gone deeper thanks to the present study.

Methods

A fascinating part of this study is the fact that it was multi-modal: it used behavioral treatments, but the measures were anatomical on a cellular scale. This links activity (learning a motor task) to specific changes in parts of brain cells (dendritic spines). The genesis of new synapses and dendritic spines occur at the fastest rate early in development, though most of these connections are later pruned. As such, the research team used young mice that would have a fast rate of spine formation. Using a high-powered microscope, the team looked at new and old dendritic spines in the area of the brain controlling conscious muscle control, the motor cortex. They then took a subgroup of those same mice and disrupted the REM portion of sleep, while the other mice had normal sleep. This sleep treatment was followed by a second microscope session to see how many new and old dendritic spines survived. After finding that disturbing REM sleep slowed the rate of dendritic spine pruning, the researchers formed a second experiment. They took a new group of adolescent mice and had them learn how to balance on a rotating bar. This is known to stimulate the growth of new dendritic spines as they improve at the task. After the mice learned how to balance, they performed a live recording of the mouse REM sleep. They specifically observed calcium concentration in neurons of the motor region to see if calcium-regulated spine pruning and strengthening.

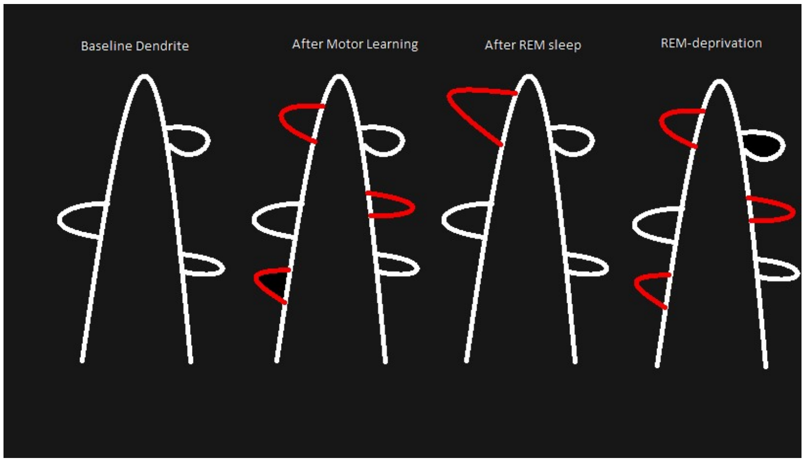

Figure 1: Dendritic spine pruning and selective strengthening occur in REM sleep. The figure differentiates spine populations as generating pre (white) and post (red) a motor learning task. Many new spines are generated after learning. The REM sleep that follows prunes most of these new spines and strengthens the others, pre-existing spines are not affected. If REM sleep is disturbed, this pruning and strengthening simply does not occur.

Results

The primary takeaway from the two experiments in this study was the finding that interrupting REM sleep inhibited dendritic spine pruning (Figure 1). The analysis goes further than this. Firstly, in the adolescent group, only newly formed dendritic spines were affected; dendritic spines in the motor area of the brain that had been established before the motor learning task were not affected by REM disruption. This suggests REM sleep may be involved with learning and consolidating new information, but possibly not involved in the maintenance of stored memories. Another finding from this study was that REM sleep not only prunes newly formed dendritic spines, but it also strengthens the populations of newly formed dendritic spines that remain intact. It's as if learning involves forming many new connections but REM sleep chooses which of those new connections are most beneficial to keep. It was also found in this study that newly formed dendritic spines were most vulnerable to REM modulation during the first 36 hours after formation, after which they were not affected during REM. Another mechanism other than REM must underlie the pruning of more permanent dendritic spines. The final experiment with the live recording of REM sleep found that calcium surges occurred during REM sleep. These calcium transients correlated with the modulation of dendritic spines, both with pruning and strengthening.

Discussion

Many substances are known to inhibit REM sleep, but not many studies have found a relationship between REM and behavioral or cognitive outcomes. Some anti-depressant drugs that are known to disrupt REM sleep were reported in one study to have no effect on memory and in some cases actually improved memory.[8] A case study described REM sleep impairment in a patient who had brain-stem lesions, but again the patient suffered no significant impairment in memory function.[9] This has stoked discussion that centers on sleep's purported function in memory facilitation.[10] This discussion does not remove the importance of the present study's findings, it just suggests a nuanced view may be needed to interpret them. Studies in which REM sleep is impaired but memory is not may suggest that dendritic spines are involved but are not the sole regulator of memory consolidation. This idea of redundant mechanisms seems to be the rule rather than the exception in biological systems, especially for systems as important to an organism's survival as memory. Another interpretation is that dendritic spines regulate a specific type of memory, or rather a specific quality of memory. Perhaps people without REM sleep have seemingly normal memory, but the ability to relate and compare different memories may be affected. Much more research is needed to be done in the field to truly understand the role of REM sleep, but this research shows that it is doing something. REM sleep exists for a reason, but the question of its utility and function currently remains unanswered.

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