

Emotional Memory: Selective Enhancement by Sleep

Never go to sleep on an argument: an old wives' tale or a scientifically proven technique for controlling the memories you store? Recent findings show that sleep selectively enhances emotional memories, creating a long-lasting and potentially traumatic representation of distressing experiences.

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We know that new memories can be strengthened by sleep, but uncertainty remains regarding the specific types of memory for which this applies. Sleep-dependent consolidation of procedural skills such as the ability to ride a bicycle or play the piano is now well established [1]. Sleep-dependent consolidation of memories for specific events, called episodic memory, seems to be a bit trickier to pin down. Some investigations have shown improvements in episodic memory after sleep, but a number of others have failed to find this effect, leading to a controversy about its reliability [2,3]. Two recent studies, by Wagner *et al.* [4] and Hu *et al.* [5], have shed new light on this issue by demonstrating that sleep-dependent consolidation of episodic memories is specific to poignant events, and does not happen for events with no emotional relevance. These findings not only explain the inconsistencies of earlier studies, they also have important implications for the role of sleep management in treatment of psychological illness.

Wagner *et al.* [4] showed that sleep can provide a long-lasting enhancement of emotional memories. They asked subjects to memorise brief texts with either emotional or neutral content. Topics included the sexual problems of a paraplegic man, the killing methods of a child murderer, techniques for bronze sculpting and patterns for a fashion show. After studying the texts, one group of subjects had three hours of sleep and another group remained awake. Four years later those who slept remembered significantly

more about the emotional texts than those who stayed awake. There was no difference between sleep and wake groups for neutral memories (Figure 1A).

Hu *et al.* [5] found that emotional memories are consolidated in preference to neutral memories when we sleep. They showed subjects a series of pictures, including both negative emotional items, such as images of human injury and surgical slides, and neutral items, such as images of furniture and natural scenes. They then waited 12 hours before showing the pictures again and testing for recognition. Subjects were divided into two groups: half of them were trained in the morning and tested in the evening so that no sleep occurred during the consolidation period; the other half were trained in the evening and tested the next morning, having been encouraged to sleep normally during the overnight consolidation. There was no significant difference between sleep and wake groups in memory for neutral pictures, but emotional pictures were remembered 42% better by the sleep group (Figure 1B).

Interestingly, this facilitation was only observed for pictures which subjects found familiar but could not recall fully, suggesting that sleep strengthens the familiarity of emotional memories without improving detailed recollection.

These data provide clear evidence that memories are enhanced during sleep, but how does this facilitation actually occur? The authors speculate that rapid eye movement (REM) sleep may provide an ideal physiological environment for enhancement of the neural connections underpinning emotional memory. Earlier work by Wagner and colleagues [6] provides further support for this suggestion by demonstrating selective enhancement of memory for emotional texts following REM-rich but not REM-poor sleep.

The involvement of REM sleep in memory consolidation is thought to be linked to increased levels of acetylcholine, a neurotransmitter which is important for memory consolidation [7]. Acetylcholine is dramatically elevated during REM sleep and this elevation is particularly marked in the amygdala and hippocampus [8] (Figure 2), brain structures whose interactions are critical for emotional memory [9]. Recent work [10] has shown that the synchronization of neural activities in these structures is altered during REM sleep, suggesting a change in the way they interact. A temporary change in the

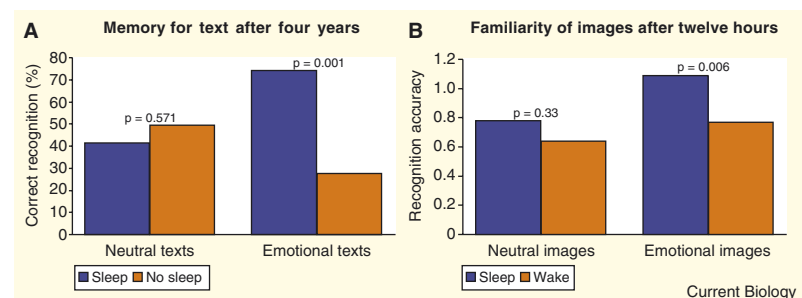


Figure 1. Sleep-enhancement of emotional memory.

(A) Data from Wagner *et al.* [4] show enhanced retrieval of information about emotional texts in subjects who slept for three hours after exposure to the texts as compared to subjects who were not allowed to sleep. Retrieval of neutral texts was not influenced by sleep. (B) Data from Hu *et al.* [5] show an enhancement of familiarity for emotional pictures after a night of sleep as compared to an equivalent period of wakefulness. No such enhancement is shown for neutral items.

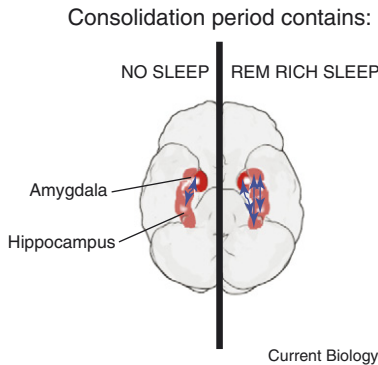


Figure 2. Locations of amygdala and hippocampus in the brain.

Connectivity between these structures is critical to emotional memory [9] and is thought to be enhanced by REM sleep [10].

connections between amygdala and hippocampus, in combination with local elevation of acetylcholine, might well lead to long-term alterations in connectivity, thus underpinning the selective facilitation of emotional memories.

The suggestion that facilitation of emotional memories by sleep occurs as a result of changes in connectivity between amygdala and hippocampus is not only physiologically plausible, it is also easily testable. One potential experiment would use an emotional memory task and compare the connectivity between amygdala and hippocampus in a group of subjects who slept between training and testing with the connectivity in a group who did not sleep. Any enhancement of connection strength in the sleep group, in comparison with the wake group, could then be correlated with the extent of memory facilitation and with the percentage of REM sleep obtained in order to elucidate the relationship between connectivity and memory.

An understanding of precisely how sleep enhances emotional memories will do more than just add to our knowledge of the physiology of memory. The potential to selectively strengthen, or for that matter selectively prevent the strengthening of, specific types of memory has clear clinical implications and could improve the way we deal with sleep in psychological disease.

Post-traumatic stress disorder, a persistent pathological anxiety caused by the stress of a frightening event, is a dramatic example of the harm which can be caused by inappropriate emotional memories. Many of the symptoms of post-traumatic stress disorder, such as flashbacks and nightmares, are thought to be caused by the over consolidation of negative memories [11]. The observation that short periods of immediate sleep can enhance emotional memories for years suggests that sleep patterns after a traumatic event may be closely linked to the likelihood of developing these symptoms. This research therefore suggests that a period of sleep deprivation immediately after trauma may help to prevent post-traumatic stress disorder, and that prescribing patients with sedatives at this time may be harmful.

Patients with post-traumatic stress disorder are not the only ones in whom strongly negative memories can reinforce pathological states of mind. Wagner *et al.* [4] raise the possibility that the insomniac tendencies of people with anxiety and depression disorders may be a natural mechanism for preventing the over consolidation of negative memories. The difficulty we all experience in falling asleep when feeling strong emotions such as fear or anger could be an everyday extension of this.

On a related point, antidepressant drugs are known to inhibit REM sleep, sometimes by as much as 100% [12]. Although this is not considered to be their main physiological action, REM inhibition might disrupt the consolidation of negative memories, an action which would partially explain the ability of these drugs to alleviate depression. There is a lag time of several weeks between the main physiological action of antidepressants and their eventual influence on mood [13]. Work on the processing of facial expression has suggested that this delay may occur because these drugs act by altering subtle aspects of social interaction, thus providing an indirect influence on mood [14].

The reduction of negative memories via alterations in sleep patterns could provide an alternative mechanism for the delayed impact of antidepressants.

Of course, emotions are not all unpleasant. In some cases it is just as adaptive to strengthen positive memories as it is to weaken negative ones. This is particularly obvious in pair bonding, when people form strongly positive representations of their romantic partners. It is easy to fall asleep when you are relaxed, and sexual activity has a known soporific effect.

Until recently we have been unaware of the way our brains use sleep to filter memory. The findings of Wagner *et al.* [4] and Hu *et al.* [5] make it clear that a more complete understanding of how emotional memories consolidate during sleep offers potential for both prevention and treatment of some psychological diseases. Before such treatment can become reality, a number of interesting and novel experiments are called for. One thing is for certain, the proverb "never go to sleep on an argument" is more than just an old wives' tale.

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DOI: 10.1016/j.cub.2006.12.033