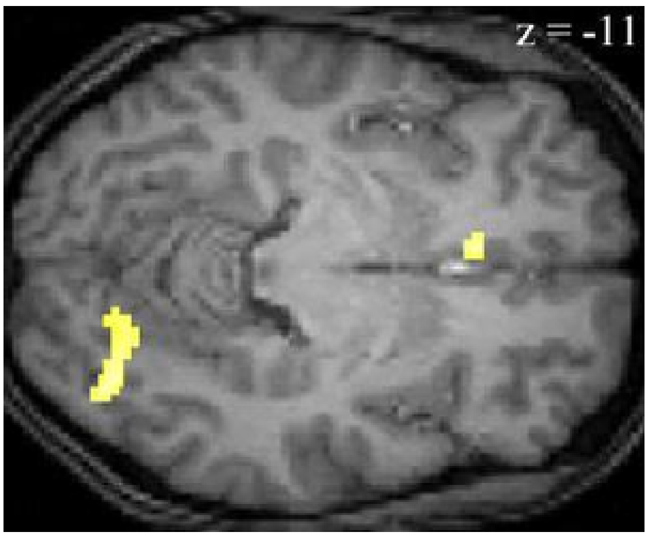
Quality of Sleep Determines Where the Brain Stores Memories

December 13 2007, By Lisa Zyga



Brain fMRI after six months of a subject who was allowed to sleep the night after learning the word pairs. Correct word recall activates the mPFC and the occipital cortex, but there is no longer significant activity in the hippocampus. Image credit: Steffen Gais, et al. ©2007 PNAS.

As time passes, our memories are transferred to different parts of the brain in order to ideally store our past experiences. While scientists have known that sleep plays an important role in helping consolidate memories, a new study investigates the role of sleep a step further, and shows how one night of sleep can lead to changes in brain activity six months after an event has occurred.

The group of researchers, from the University of Liege in Belgium, has published their results in a recent issue of the *Proceedings of the National Academy of Sciences*. Their research shows that a good night's sleep after learning word pairs enhances memory processing in the hippocampus, and also induces information transfer between the hippocampus and medial prefrontal cortex (mPFC). This transfer serves to consolidate memories, helping new memories become stable and immune to interfering stimuli.

"Our work shows how the development of a trace left by new memories depends on sleep," co-author Steffen Gais told *PhysOrg.com*. "This is the first time we could confirm in humans a number of predictions based on animal research. In particular, we could show that the hippocampus plays only a temporary role for storing new semantic information, and that other brain regions slowly take over its function."

In general, memory consolidation occurs in two forms: through molecular processes at individual synapses, and through a reorganization of storing memories within different brain systems. In the second form, memory consolidation begins in the hippocampus, and over the course of several months memories are transferred to the prefrontal cortex. Although scientists don't fully understand how this reorganization works, the Belgian study shows that getting a good night's sleep the night after learning a new fact has a direct impact on the transfer process between the hippocampus and the medial prefrontal cortex.

In the study, 18 subjects were given 90 word pairs, and then were immediately tested on how many word pairs they could recall while being monitored with an fMRI. Half the subjects were then instructed to sleep normally that night, while half were required to remain awake all night in a monitored room with TVs, music, and games. Two days after the initial learning, the subjects were again tested. Not only did the sleep-deprived forget a significantly greater number of word pairs, but the fMRIs revealed that brain activity in the right hippocampus was significantly stronger in subjects who slept than those who didn't.

"This was surprising. Our original hypothesis about the time-course of hippocampal involvement predicted an immediate decrease – not an increase – in hippocampal activity after sleep," Gais said. "Only after some studying the literature we found that we were not alone to show a similar pattern of activity."

Six months later, the results showed a different contrast between the two groups. The subjects were not told they would be tested again, and had forgotten most word pairs, with those in the sleeping group remembering slightly but not significantly more word pairs than the sleep-deprived. More significantly, however, were the brain responses in the fMRI. This time, subjects in the sleeping group had greater brain activity in the left ventral medial prefrontal cortex (but not the hippocampus) compared with the sleep-deprived, who had a more active hippocampus.

"We were very surprised to see the shift in brain activity between brain regions so clearly," Gais said. "In particular, to see an increased connectivity between the hippocampus and the prefrontal cortex early after learning, and then a decrease in hippocampal and increase in prefrontal activity during the later recall test was very exciting for us."

The researchers explained that this finding indicates that sleep deprivation after learning something new hinders the plastic changes needed for memory consolidation. Nevertheless, sleep-deprived subjects still recalled nearly the same amount of word pairs as their rested counterparts, since the hippocampal and neocortical systems store memories in a redundant way. However, long-term memories stored in the prefrontal cortex are more resistant to interference, whereas new memories in the hippocampus are more susceptible to interfering stimuli.

Analyzing the interplay between brain regions, memories, and post-learning sleep will hopefully help researchers further understand the intricate workings of the brain for a variety of medical applications.

"We believe that our findings bring us a little closer to understanding how the brain stores and processes new memories," Gais said. "This understanding might prove helpful in improving memory, for example, in conditions like Alzheimer's disease."

More information: Steffen Gais, et al. "Sleep transforms the cerebral trace of declarative memories." *Proceedings of the National Academy of Sciences*. November 20, 2007, vol. 104, no. 47, 18778-18783.