

# What does the sleeping brain think about?

July 15 2021

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During deep sleep, the brain replay important events of the previous day. It reactivates spontaneously the memories associated to reward. Credit: UNIGE, Virginie Sterpenich

We sleep, on average, one third of our time. But what does the brain do during these long hours? Using an artificial intelligence approach capable of decoding brain activity during sleep, scientists at the University of Geneva (UNIGE), Switzerland, were able to glimpse what we think about when we are asleep. By combining functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), the Geneva team provides unprecedented evidence that the work of sorting out the thousands of pieces of information processed during the day

takes place during deep sleep. Indeed, at this time, the brain, which no longer receives external stimuli, can evaluate all of these memories in order to retain only the most useful ones. To do so, it establishes an internal dialog between its different regions. Moreover, associating a reward with a specific information encourages the brain to memorize it in the long term. These results, to be discovered in the journal *Nature Communications*, open for the first time a window on the human mind in sleep.

In the absence of tools capable of translating [brain](#) activity, the content of our sleeping thoughts remains inaccessible. We however do know that sleep plays a major role in [memory consolidation](#) and emotional management: when we sleep, our brain reactivates the [memory](#) trace built during the day and helps us to regulate our emotions. "To find out which brain regions are activated during sleep, and to decipher how these regions allow us to consolidate our memory, we developed a decoder capable of deciphering the activity of the brain in [deep sleep](#) and what it corresponds to", explains Virginie Sterpenich, a researcher in the laboratory of Professor Sophie Schwartz in the Department of Basic Neurosciences at UNIGE Faculty of Medicine, and the principal investigator of this study. "In particular, we wanted to see to what extent positive emotions play a role in this process."

During deep sleep, the hippocampus—a structure of the temporal lobe which stores temporary traces of recent events—sends back to the cerebral cortex the information it has stored during the day. A dialog is established which allows the consolidation of memory by replaying the events of the day and therefore reinforce the link between neurons.

## **Combining MRI, electroencephalography and artificial intelligence**

To conduct their experiment, the scientists placed volunteers in an MRI in the early evening and had them play two video games—a face-recognition game similar to 'Guess Who?' and a 3D maze from which the exit must be found. These games were chosen because they activate very different brain regions and are therefore easier to distinguish in the MRI images. In addition, the games were rigged without the volunteers' knowledge so that only one of the two games could be won (half of the volunteers won one and the other half won the second), so that the brain would associate the game won with a positive emotion.

The volunteers then slept in the MRI for one or two hours—the length of a sleep cycle—and their brain activity was recorded again. "We combined EEG, which measures sleep states, and functional MRI, which takes a picture of brain activity every two seconds, and then used a 'neuronal decoder' to determine whether the brain activity observed during the play period reappeared spontaneously during sleep", Sophie Schwartz explains.

## **Even when asleep, the brain likes rewards**

By comparing MRI scans of the waking and sleeping phases, the scientists observed that during deep sleep, the brain activation patterns were very similar to those recorded during the gaming phase. "And, very clearly, the brain relived the game won and not the game lost by reactivating the regions used during wakefulness. As soon as you go to sleep, the [brain activity](#) changes. Gradually, our volunteers started to 'think' about both games again, and then almost exclusively about the game they won when they went into deep sleep", says Virginie Sterpenich.

Two days later, the volunteers performed a memory test: recognizing all the faces in the game, on the one hand, and finding the starting point of the maze, on the other. Here again, more the [brain regions](#) related to the

[game](#) were activated during sleep, better were the memory performances. Thus, memory associated to reward is higher when it is spontaneously reactivated during [sleep](#). With this work, the Geneva team opens a new perspective in the study of the sleeping brain and the incredible work it does every night.

**More information:** Virginie Sterpenich et al, Reward biases spontaneous neural reactivation during sleep, *Nature Communications* (2021). [DOI: 10.1038/s41467-021-24357-5](https://doi.org/10.1038/s41467-021-24357-5)

Provided by University of Geneva

Citation: What does the sleeping brain think about? (2021, July 15) retrieved 16 August 2024 from <https://medicalxpress.com/news/2021-07-brain.html>

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