The brain's multi-track road to long-term memory

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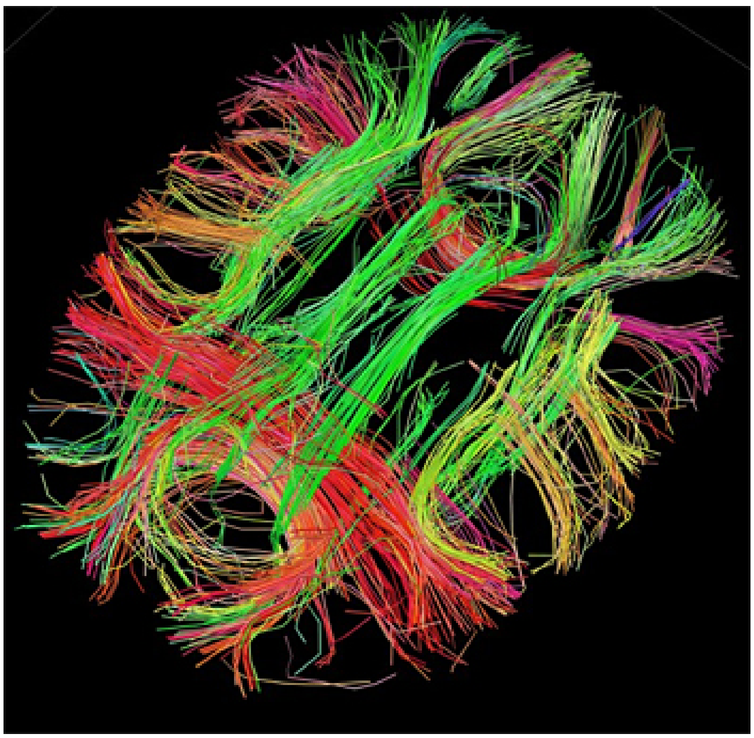

White matter fiber architecture of the brain. Credit: Human Connectome Project.

Our brain has a tough task every time we experience something new – it must be flexible to take in new information instantly, but also stable enough to store it for a long time. And new memories may not be allowed to alter or overwrite old ones. The brain solves this problem by storing new information in two separate places – the hippocampus, a short-term storage site with high plasticity and capacity that can absorb information quickly; and in a part of the cerebral cortex, the neocortex. This is slower to take in the information, but protects it for the long term and does not allow it to be overwritten. Researchers from the Institute of Medical Psychology and Behavioral Neurobiology at the University of Tübingen have been working with colleagues from Munich to discover how these two systems work together as we learn. Their findings have been published in the latest issue of *PNAS*.

The hippocampus has been the focus of intense scrutiny by memory researchers since the late 1950s, when it was surgically removed from a patient known as H.M. – who was thereafter unable to form new memories. It was largely unknown what role the neocortex played in memory or how the two regions interacted. In their experiments, the Tübingen researchers placed test subjects at a computer screen and into a virtual maze, where they had to find hidden objects. The longer the test persons moved through the maze, the better they became at understanding how it was set out and where the hidden objects were. While the test subjects were carrying out the task, their brain activity was recorded by an MRI scanner.

In order to identify the brain region responsible for spatial memory, the researchers had a special trick. During one part of the experiment the maze did not change. This enabled the participants to slowly build up a spatial representation of it in their memories. In another part of the experiment, the maze changed constantly, so that the test subjects could not recognize it or learn a set path around it. "The comparison of the MRI images from the two mazes reveals which brain regions were specifically contributing to the formation of spatial memories," says Svenja Brodt, a doctoral candidate at the Graduate Training Center of Neuroscience and lead author of the study. "We were suprised that the activity of the precuneus, a region at the back of the neocortex, steadily increased, while the activity in the hippocampus steadily fell," Brodt explains. And communication between the two regions also fell during the learning process, according to Brodt.

"These results enable us to demonstrate that the long-term, neocortical traces of memory are formed right when the information is first gathered," says Dr. Monika Schönauer, who supervised the study. She said the pace of this process was astounding. Researchers had always assumed that the process took place very slowly, lasting weeks or months. Professor Steffen Gais explains: "The astonishing thing is that the hippocampus ceases to participate in learning after such a short time." The number of repetitions appeared to have a key influence on how quickly a long-term, stable memory was formed in the neocortex.

"An independent representation of the memory is formed in the precuneus," according to Brodt. "When the MRI showed activity in the precuneus of a test subject, we could predict whether the per-son would find one of the hidden objects in the maze or not." These latest findings provide important information about which regions store long-term memory. This could help doctors in the future to come up with better treatments for patients with dementia or disorders of the hippocampus. "But even for school situations, these results are important when it comes to learning straightforward material, such as vocab or times tables, both quickly and for the long term. According to our findings, there is no getting around the frequent repetition of material to be learned," Brodt says.

More information: Rapid and independent memory formation in the parietal cortex. *Proceedings of the National Academy of Sciences* (PNAS), DOI: 10.1073/pnas.1605719113

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