Changes in brain state influence the readiness to form memories

University of Tübingen neuroscientists find that spontaneous internal fluctuations in the brain lead to brief periods of increased plasticity in memory systems.

Most everyday moments are quickly forgotten, while others stay with us for a lifetime. How the brain determines which memories are retained and which are lost remains an open question. A neuroscience team at the University of Tübingen, led by Professor Andrea Burgalossi of the Institute of Neurobiology and the Werner Reichardt Center for Integrative Neuroscience (CIN), has found that spontaneous fluctuations in the brain's internal state influence how ready the memory system is to store new information. The new study has been published in the latest edition of Nature Communications.

The researchers used mice to investigate the neural mechanisms of memory formation, focusing on the hippocampus, a region of the brain known to be essential in the formation of episodic memories. The hippocampus of mammals, including mice and humans, contains neurons called place cells that represent experiences in the brain. "In laboratory settings, we can expose mice to different environments and observe how the place cells become active," says Dr. Eduardo Blanco-Hernandez of the University of Tübingen, one of the lead authors of the study. "Different groups of place cells represent different environments. Watching their activity is like observing memories being formed or reactivated in real time."

The team recorded the activity of these memory-related neurons while also tracking the animals' internal brain state. The brain is a dynamic system, and even during immobility its state rapidly fluctuates between higher and lower levels of alertness and arousal. "The internal brain state can be estimated from pupil size," says CIN researcher and co-author of the study, Nicola Sartorato. "When we become more alert or engaged, our pupils dilate. The same is true in mice."

The researchers found that spontaneous fluctuations in internal state strongly influenced which memory neurons were active at any given moment, even when the animal was fully at rest. "A specific subset of place cells became especially active when the animals became more alert," explains Nicola, "suggesting that internal state can rapidly reshape the neuronal substrate of episodic memories." These changes were also reflected in brain rhythms: neural activity patterns known as theta oscillations – thought to reflect memory encoding processes – became stronger or weaker depending on the internal state.

Brain state and plasticity

The researchers then asked whether fluctuations in internal state reflect moments when the brain becomes more plastic and capable of change. "Plasticity is essential for memory because it is the process by which the brain physically stores experiences," says Professor Burgalossi. To form a memory, neurons must rapidly adjust their connections and reorganize their activity patterns so that new information can be encoded. "This is especially important for episodic memory, since the events we experience in life happen only once. There is no repetition, no rehearsal – so the brain must capture and store them quickly and efficiently in real time" says Burgalossi.

From this perspective, the researchers hypothesized that fluctuations in internal state might not just influence memory indirectly, but could actively control when the brain is in a state that is more ready to change. To test this, they stimulated individual memory-related neurons during these states. Remarkably, this was enough to create new memory-like activity patterns: the stimulation triggered the formation of new place-specific responses, effectively generating new "memory cells" in the network.

Taken together, the findings show that the hippocampus – the brain's episodic memory center – is highly dynamic and appears to enter brief periods in which it becomes especially ready to rewire itself. "What's exciting is that we can now study these processes in a controlled way, by focusing on moments when the brain is naturally more plastic," Burgalossi says. By identifying and potentially controlling these windows of increased plasticity, the study opens up a new way to investigate the neural mechanisms through which memories are physically formed in the brain.

Publication:

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