Discovery gives insight into brain 'replay' process

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The hippocampus, a part of the brain essential for memory, has long been known to "replay" recently experienced events. Previously, replay was believed to be a simple process of reviewing recent experiences in order to help consolidate them into long-term memory. However, University of Minnesota Medical School researcher A. David Redish, Ph.D., along with his colleagues from the Center for the Neural Basis of Cognition at Carnegie Mellon University and the University of Minnesota, have discovered that the replay function of the hippocampus is actually a much more complex, cognitive process.

This discovery gives insight into the decision-making process and Redish hopes that this insight will help researchers learn more about what is happening in the brain when this decision-making process goes wrong.

By studying brain activity in rats, Redish, Gupta, and colleagues discovered that the information played out during this replay process depends on the task the animal is facing. They found that it was not the more recent experiences that were played back in the hippocampus, but instead, the animals were most frequently playing back the experiences they had encountered the least. They also discovered that some of the sequences played out by the animal were ones they had never before experienced. These observations suggest that this hippocampal process plays an important role in an animal's active learning process and may also play a role in maintaining the animal's internal representation of the world, or its cognitive map.

"The point of the cognitive map is flexibility. It gives animals the ability to plan novel paths within their environment," said Redish. "This replay process may be an animal's way of learning how the world is interconnected, so it can plan new routes or paths."

Redish and his team have been studying decision-making in rats by putting electrode "hats" on the animals and recording their brain activity. The hats detect when individual neurons in the brain fire. Certain neurons, called place cells, fire in response to the animal's current physical location and create the animal's internal, cognitive map of their environment. Through their study of the animal's brain activity, Redish and his team can identify where the rat is located simply by observing which place cells are firing.

This mapping process was key to the team's understanding of the animal's replay process. During replay, neurons fire indicating other locations on the maze rather than the location the rat actually is, indicating that the animal is processing information about other locations. On a task with two behavioral sequences, A and B, the researchers found that the animals would replay sequence B more often, even when they spent most of their time running sequence A. In other words, the researchers found that the rats were most likely to replay the path they had experienced less often. This suggests that replay is not just a function of helping an animal remember what it has experienced most frequently or most recently, but an important function in helping it map its whole environment.

During the replay process, Redish, Gupta, and colleagues also were able to observe the animal making connections between paths that it had never physically traveled before. For example, if the animal had physically traveled from point A to point B, and from point B to point C, but never from point A to point C, they observed the single sequence A to B to C during the replay process, implying that the rat's brain was able

to make the connection between points A and C on its internal map. This further indicates that replay plays a role in helping an animal learn and maintain the entire map of its environment and make connections within it. The rats were not just reviewing recent experience to move it to long-term memory.

This is important because brain cognition and the human decision-making process are poorly understood.

"Before we can understand how this process goes wrong in people with diseases such as addiction or Alzheimer's, we first need to understand how cognitive connections are made in the brain and how humans make decisions in relation to their internal, cognitive map. Once we have an understanding of how things work in normal brain processing, we can understand where they can break. And then we can understand what we can do to try to fix them," Redish said.

The discovery of this mechanism in rats gives important insight into their decision-making process and through more research, Redish hopes to further understand how this mechanism works.

More information: The study, "Hippocampal replay is not a simple function of experience," was published in the March 11 issue of *Neuron.*

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