Brain Region Draws Map for Food-Caching Birds

~ A brain region that allows birds to remember thousands of food hiding spots during the winter offers a new way to study memory, with implications for disease and AI. ~

News Release
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NEW YORK — Unlike most birds that live in cold places, the tufted titmouse doesn't fly south for the winter. It sticks around and endures subzero temperatures: thanks to a thick layer of fat, a hefty coat of feathers, and – most remarkably – an incredible memory that allows the bird to remember thousands of hiding spots for food stashed during warmer months.

Researchers at Columbia's Zuckerman Institute have now revealed a possible key to this impressive feat: a dense network of brain cells never before seen in birds, which generate a map of the bird's environment with remarkable precision.

This discovery, published today in *Science*, promises to accelerate research into how memories form, how to create artificial intelligences that learn more quickly and how to treat diseases that damage our memories.

"Memory has been an incredibly difficult thing to study," said lead author Hannah Payne, PhD, a postdoctoral research fellow who carried out this work in the laboratory of Dmitriy Aronov, PhD, at Columbia's Zuckerman Institute. "Investigating birds like the titmouse, a type of chickadee with a brain specialized for memory, could be a game changer."

Scientists have long known that titmice and chickadees have incredible memories. Scientists in the Arctic have seen wild birds stash tens of thousands of seeds in a single season, in thousands of different hiding spots – and return to these caches months later to retrieve their booty.

But Dmitriy Aronov, a principal investigator at Columbia's Zuckerman Institute, is the first to bring this behavior into the lab and study its neural underpinnings. His team spent years constructing indoor arenas for birds to explore and developing new devices for monitoring the brain activity of birds on the move, in collaboration with the Zuckerman Institute's Advanced Instrumentation team.

"No one has recorded the brain activity of titmice moving around freely before," said Dr. Aronov, an assistant professor of neuroscience at Columbia's Vagelos College of Physicians and Surgeons, who recently received the NIH New Innovator Award. "So it took a lot of effort to lay the groundwork for this research."

Discovering Place Cells

In today's study, the first research paper published by the Aronov lab, Dr. Payne watched birds collect bits of sunflower seeds while monitoring the hippocampus, the brain's memory center. She saw certain cells consistently fire when the birds were in certain locations. Those cells were especially dense in the front of the hippocampus.

Scientists know of such cells in the hippocampus of rats and other mammals. Called "place cells," they are thought to help the brain form mental maps. The discovery of these cells earned the Nobel Prize in 2014. But no one had observed place cells in birds, until now.

This finding inspired the Columbia researchers to continue monitoring the birds as the animals slept. The scientists saw cells in the same brain region fire again, as if the titmice were recalling their experiences while unconscious. This pattern of activity, called a sharp-wave ripple, has been observed in mammals – but also never before in birds.

The brains of birds look very different from ours, lacking the layers and the organization found in mammals. This has led some to argue that birds might have a totally different way of using their hippocampus to store memories.

"Not enough was known about the hippocampus of birds," said Dr. Payne. "What was known seemed to suggest that it works very differently from the mammalian hippocampus."

These new discoveries challenge that notion. They provide evidence that birds and mammals, though separated by hundreds of millions of years of evolution, navigate the world in similar ways.

"We have found that the brain area that birds use for memory has incredible similarities to the same brain area in mammals, including humans," said Dr. Aronov. "This is hugely important: It suggests that life may have evolved a fundamental mechanism for memory, and it gives us confidence that whatever we continue finding in these birds will be directly relevant to human beings."

Looking for Memory

On the heels of today's announcement, the Aronov lab has already made more discoveries expected to be published in the coming years.

The team believes that their research may be the key to understanding how you remember events that happen once, whether it's where you put your car keys or a traumatic moment from your childhood. Studying these sorts of episodic memories has been difficult because traditional experiments require training animals to do a task, over and over. The chickadee's natural instinct to hide a seed once and then go back and retrieve that seed once provides a behavior ready-made for studying episodic memory, and thus the nature of memory itself.

“Our ultimate goal is to understand what exactly these memories look like in the brain, as a pattern of electrical activity,” said Dr. Aronov.

A better understanding of episodic memory, he hopes, could provide a boost to artificial intelligence. It could help machines learn from a single exposure to information, instead of requiring extensive training, as they do today. To prepare for this future, Dr. Aronov has already partnered with the Center for Theoretical Neuroscience at the Zuckerman Institute, comprised of physicists, mathematicians and others who bring together experimentation, data analysis and theoretical modeling.

The work of the Aronov lab is also laying foundations for treating neurodegenerative disorders, such as Alzheimer’s, that damage memory by damaging the hippocampus.

“We are studying the basic mechanisms of memory,” said Dr. Aronov. “We need to understand these mechanisms if we want to have a hope of developing better treatments for brain disease.”

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This paper is titled “Neural representations of space in the hippocampus of a food-caching bird.” Additional contributors include Dr. Galen Lynch, MIT.

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