PHYS.ORG

A peek inside a flying bat's brain uncovers clues to mammalian navigation

July 8 2021

Credit: Unsplash/CC0 Public Domain

When driving up to a busy intersection, you probably pay more attention to where you will be in the near future than where you are at that moment. After all, knowing when you will arrive at the intersection—and whether you need to stop or slow down to avoid a collision with a passing car, pedestrian or cyclist—is usually much more important than knowing your current location.

This ability to focus on where we will be in the near future—rather than where we are in the present—may be a key characteristic of the mammalian brain's built-in navigation system, suggests a new study appearing online Thursday, July 8, in the journal *Science*.

Neuroscientists at the University of California, Berkeley, wirelessly tracked the brain activity of Egyptian fruit bats as they flew throughout a custom flight room. When the researchers compared the bats' flight paths with their neural readings, they found that the activities of the bats' "place cells"—special type of neurons responsible for encoding an animal's spatial position—were often more closely correlated with where the bats would be in the near future, rather than where they were in the moment.

"We wanted to find out: Does the neural activity at the present moment do a better job at representing a past or future position than it does the actual present position? And we found that, for some neurons, the neural activity actually does a much better job of representing a future position," said lead author Nicholas Dotson, who conducted the research as a postdoctoral scholar at UC Berkeley. "The finding shows that neural activity in this region is representing more than the bat's present position—it's tentatively representing a full flight trajectory."

Place cells, located in a region of the brain called the hippocampus, work together to form an innate "GPS system" for a variety of land animals, including humans. As an animal explores a new environment, different place cells activate at different positions, creating an internal map of the territory that can be saved and stored.

"If you had access to neural activity in my hippocampus while I walked around a room, you'd be able to decode where I was in the room based on this neural activity," Dotson said.

The discovery of place cells in rodents was awarded the 2014 Nobel Prize in Physiology or Medicine, and many of the foundational experiments were conducted in the 1970s and '80s. However, a number of questions still remain about how this region of the brain operates during rapid movement and how it works to represent "nonlocal" positions.

"Because the hippocampus is involved in navigation, there have been several studies looking at coding in this brain region and asking: How does neural activity represent things that are going to happen in the future or that have happened in the past? And can this brain region exhibit activity that doesn't represent where we are right now, but actually represents a position that is far away?" said study senior author Michael Yartsev, an assistant professor of neurobiology and bioengineering at UC Berkeley.

Earlier experiments have been unable to conclusively answer this question, Yartsev said. This is likely because they were conducted using relatively slow-moving animals, like rats, that, in experimental enclosures, will only move about an inch or two in a second—and also because when comparing the activity of individual neurons with an animal's position over time, a shift of a fraction of an inch will not make a huge difference.

Bats, however, are extremely speedy in flight.

"Bats move really, really fast. They fly at speeds of about 30 to 50 kilometers per hour in the laboratory, which is a huge advantage, because in the same fraction of a second, a rat might move a few centimeters, while a bat would move a few meters," Yartsev said.

To conduct the experiments, Yartsev and Dotson used wireless neural recording devices to monitor bats' brain activity as they flew freely throughout a custom-built room that had been outfitted with cameras to track the bats' precise flight paths. In one set of experiments, they recorded bats' position and brain activity while humans encouraged the animals to explore the full 3D volume of the room. In another set of experiments, the bats were left alone with a set of automatic feeders, located at different locations in the room, to entice the bats to fly around.

When Yartsev and Dotson compared the timing of neural activity with the bats' flight paths, they found that when shifting the bats' positions forward in time—by comparing the neural activity with the locations where the bats would be in a few hundred milliseconds, or in a second—suddenly, the neural activity correlated much more strongly with spatial position.

"Based on the data, you might assume that some neurons don't encode spatial information at all, because there is no correlation with the position at time zero or the present moment," Yartsev said. "But if you compare their activity to a position a second in the future, suddenly the correlation is incredibly sharp."

The findings suggest that place cells' activity doesn't just represent a single current position, but actually a trajectory that stretches into the near future, and into the past, as well.

"We can imagine walking down a hallway and picturing where we just were and where we will be shortly. What does that activity look like in the brain?" Dotson said. "Our findings suggest that as the bats are flying, they're representing in their mind not just where they are, but where they are along the path."

Though place cells and the basic components of this navigational system have been identified in a wide variety of mammals, it's not yet clear whether this ability to project a path up to a second into the future is unique to bats and their rapid flight pattern, or is shared by a wider variety of animals. However, the discovery opens up a variety of interesting questions about how we humans process our movement through time and space, Yartsev said.

Because the hippocampus is also a locus of many diseases, such as Alzheimer's, where a person's sense of location and memory is often disrupted, uncovering these basic neural computations could also give scientists a better understanding of disease-related impairment and help them devise more effective treatments.

"Terrestrial creatures may not need to project as far into the future as a bat, but, even for humans, it could vary by situation. If you're walking, you are probably content with knowing what's going to happen just ahead of you. But when you're driving, you want to know what's going to happen three meters or more away from you, because you're moving at a very high speed," Yartsev said. "Now that we know that there is some neural representation of future position in bats, we can go and ask: What are the shared components between different animals? And in what ways, and to what extent, do humans exhibit this ability?"

More information: "Nonlocal spatiotemporal representation in the hippocampus of freely flying bats" *Science* (2021).
science.sciencemag.org/lookup/ … 1126/science.abg1278

Provided by University of California - Berkeley