Primates' brains make visual maps using triangular grids

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Primates' brains see the world through triangular grids, according to a new study published online Sunday in the journal *Nature*.

Scientists at Yerkes National Primate Research Center, Emory University, have identified grid cells, neurons that fire in repeating triangular patterns as the eyes explore visual scenes, in the brains of rhesus monkeys.

The finding has implications for understanding how humans form and remember mental maps of the world, as well as how neurodegenerative diseases such as Alzheimer's erode those abilities. This is the first time grid cells have been detected directly in primates. Grid cells were identified in rats in 2005, and their existence in humans has been indirectly inferred through magnetic resonance imaging.

Grid cells' electrical activities were recorded by introducing electrodes into monkeys' entorhinal cortex, a region of the brain in the medial temporal lobe. At the same time, the monkeys viewed a variety of images on a computer screen and explored those images with their eyes. Infrared eye-tracking allowed the scientists to follow which part of the image the monkey's eyes were focusing on. A single grid cell fires when the eyes focus on multiple discrete locations forming a grid pattern.

"The entorhinal cortex is one of the first brain regions to degenerate in Alzheimer's disease, so our results may help to explain why disorientation is one of the first behavioral signs of Alzheimer's," says senior author Elizabeth Buffalo, PhD, associate professor of neurology at Emory University School of Medicine and Yerkes National Primate Research Center. "We think these neurons help provide a context or structure for visual experiences to be stored in memory."

"Our discovery of grid cells in primates is a big step toward understanding how our brains form memories of visual information," says first author Nathan Killian, a graduate student in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. "This is an exciting way of thinking about memory that may lead to novel treatments for neurodegenerative diseases."

In the experiments in which rats' grid cells were identified, the cells fired whenever the rats crossed lines on an invisible triangular grid.

"The surprising thing was that we could identify cells that behaved in the same way when the monkeys were simply moving their eyes," Buffalo says. "It suggests that primates don't have to actually visit a place to construct the same kind of mental map."

Another aspect of grid cells not previously seen with rodents is that the cells' responses change when monkeys are seeing an image for the second time. Specifically, the grid cells reduce their firing rate when a repeat image is seen. Moving from the posterior (rear) toward the anterior (front) of the entorhinal cortex, more neurons show memory responses.

"These results demonstrate that grid cells are involved in memory, not just mapping the visual field," Killian says.

Consistent with previous reports on grid cells in rats, Killian and Buffalo observed "theta-band" oscillations, where grid cells fire in a rhythmic way, from 3 to 12 times per second. Some scientists have proposed that theta oscillations are important for grid cell networks to be generated in development, and also for the brain to put together information from the grid cells. In the monkeys, populations of neurons exhibited theta oscillations that occurred in intermittent bouts, but these bouts did not appear to be critical for formation of the spatial representation.

Vision is thought to be a more prominent sense for primates (monkeys and humans) compared with rodents, for whom touch and smell are more important. While grid cells in rodents and primates were detected in different types of experiments, Buffalo says that it doesn't mean grid cells necessarily have a different nature in primates.

"We are now training a monkey to move through a virtual 3-D space. My guess is that we'll find grid cells that fire in similar patterns as the monkey navigates through that space," she says.

Buffalo says future experiments could examine how monkeys navigate in real space, including changes in head or body orientation, to determine how grid cells respond.

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