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Stanford scientists see the logic in the illogical behavior of neurons

Neurons in your brain trigger the physical movements of your body, but some of them seem to fire in a crazy quilt pattern just before and during the movement. But Stanford researchers say there is method in the apparent madness.

BY LOUIS BERGERON

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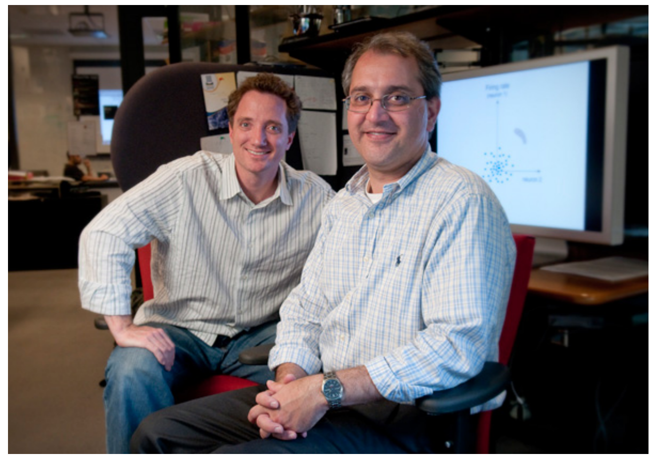

Electrical engineering postdoctoral student Mark Churchland, left, and associate professor of electrical engineering Krishna Shenoy.

You've decided to kick a soccer ball. But before your muscles even twitch, your brain has to kick into gear to direct the action.

Just what happens inside your brain during that kick-in process, though, has puzzled researchers because some of your neurons – which generate the electrical signals to trigger your muscles – sometimes work to create the opposite motion.

Now Stanford researchers have found out why, and it turns out the contrarian neurons aren't contrary at all – they just have a different way of getting to their goal.

"A classic idea is that the neurons are coded according to a sort of blueprint, in which each neuron has a movement that it 'prefers,'" said Mark Churchland, a postdoctoral researcher in electrical engineering. That means that a given neuron would be most active before and during its preferred movement. For example, if you wanted your leg to make a rightward movement, all your neurons would be active, but the rightward-preferring neurons would be the most active.

"But what we found is that a neuron could be very active before, say, a rightward movement, but then actually shut down just before the rightward movement," Churchland said. Or it could be completely inactive before a leftward movement, but then become strongly active during the leftward movement.

"If you're trying to relate the activity of a single neuron to the action that takes place, it looks crazy," he said.

Method to the 'madness'

"If you said that the neuron was effectively voting for its preferred movement, you'd say it is voting for moving left at this time and a tenth of a second later it is voting for moving right and a tenth of a second after that it is voting for something else," Churchland said. "It would not make any sense at all."

But if you compare the neuron's behavior to a pendulum in a clock, things begin to make sense, he said. In order to get a pendulum to swing to the right, you first have to pull it to the left. And as a pendulum swings back and forth, it will be moving in different directions at different times, even as all its activity is directed at keeping the proper time.

"Whereas a vote is something that should stay nice and consistent across time, a pendulum may swing different directions at different times. But a pendulum has *dynamics* that are consistent across time even though the position of the pendulum is not," Churchland said.

"It basically comes down to don't think of planning a movement as something that involves creating an explicit blueprint," Churchland said. "Think of it as getting your motor system wound up in just the right way so that when you release it, it does just the right thing."

Churchland is the lead author on a paper explaining the research in the Nov. 4 issue of *Neuron*. Krishna Shenoy, an associate professor of electrical engineering, is the senior author.

Shenoy and Churchland conducted their research with rhesus macaque monkeys. The monkeys were connected to a computer that monitored their neural activity.

Video game test
While the monkeys were monitored, they played a video game that required them to move their hand from an initial point on the screen to a small square that appeared elsewhere on the screen. "The square initially jiggles onscreen, sort of like a buzzing fly. Then it stops jiggling, which we call landing, and then the monkey's job is to swat the fly," Churchland said.

"The important thing is that the tasks allowed us to record neural activity not just during the movement, but also during the period when the monkeys are getting ready to make the movement," Churchland said.

So if there is no blueprint for your brain to follow each time you decide to move a muscle, does the brain have to figure everything out from scratch, starting at the beginning each time?

"That is an excellent question," Churchland said. "We do know that the brain has difficulty winding up its 'neural pendulum' exactly the same way every time. That is probably part of what makes golf so challenging. However, we really don't have a full answer to that question yet. It is very much an avenue for future research."

John Cunningham, formerly a postdoctoral researcher in electrical engineering and now a fellow at the University of Cambridge; Matthew Kaufman, a graduate student in the neurosciences program at Stanford; and Stephen Ryu of the Palo Alto Medical Foundation are also authors of the paper in Neuron*.*

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