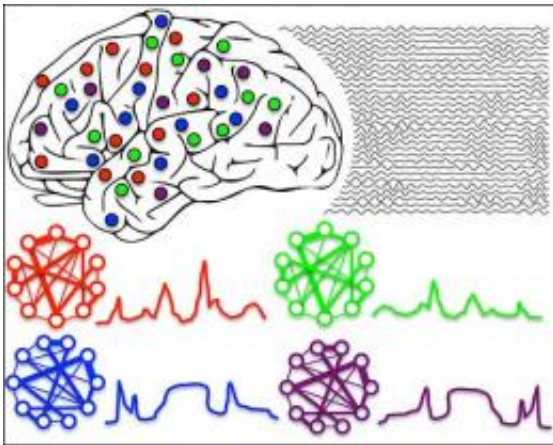


For neurons to work as a team, it helps to have a beat

September 20 2010, By Sarah Yang



This is an illustration of how brain rhythms organize distributed groups of neurons into functional cell assemblies. The colors represent different cell assemblies. Neurons in widely separated brain areas often need to work together without interfering with other, spatially overlapping groups. Each assembly is sensitive to different frequencies, producing independent patterns of coordinated neural activity, depicted as color traces to the right of each network. Credit: Ryan Canolty, UC Berkeley

(PhysOrg.com) -- When it comes to conducting complex tasks, it turns out that the brain needs rhythm, according to researchers at the University of California, Berkeley.

Specifically, cortical rhythms, or oscillations, can effectively rally groups of neurons in widely dispersed regions of the [brain](#) to engage in

coordinated activity, much like a conductor will summon up various sections of an orchestra in a symphony.

Even the simple act of catching a ball necessitates an impressive coordination of multiple groups of neurons to perceive the object, judge its speed and trajectory, decide when it's time to catch it and then direct the muscles in the body to grasp it before it whizzes by or drops to the ground.

Until now, neuroscientists had not fully understood how these neuron groups in widely dispersed regions of the brain first get linked together so they can work in concert for such complex tasks.

The UC Berkeley findings are to be published the week of Sept. 20 in the online early edition of the journal [Proceedings of the National Academy of Sciences](#).

"One of the key problems in neuroscience right now is how you go from billions of diverse and independent neurons, on the one hand, to a unified brain able to act and survive in a complex world, on the other," said principal investigator Jose Carmena, UC Berkeley assistant professor at the Department of Electrical Engineering and Computer Sciences, the Program in [Cognitive Science](#), and the Helen Wills Neuroscience Institute. "Evidence from this study supports the idea that neuronal oscillations are a critical mechanism for organizing the activity of individual neurons into larger [functional groups](#)."

The idea behind anatomically dispersed but functionally related groups of neurons is credited to neuroscientist Donald Hebb, who put forward the concept in his 1949 book "The Organization of Behavior."

"Hebb basically said that single neurons weren't the most important unit of brain operation, and that it's really the cell assembly that matters,"

said study lead author Ryan Canolty, a UC Berkeley postdoctoral fellow in the Carmena lab.

It took decades after Hebb's book for scientists to start unraveling how groups of neurons dynamically assemble. Not only do neuron groups need to work together for the task of perception - such as following the course of a baseball as it makes its way through the air - but they then need to join forces with groups of neurons in other parts of the brain, such as in regions responsible for cognition and body control.

At UC Berkeley, neuroscientists examined existing data recorded over the past four years from four macaque monkeys. Half of the subjects were engaged in brain-machine interface tasks, and the other half were participating in working memory tasks. The researchers looked at how the timing of electrical spikes - or action potentials - emitted by nerve cells was related to rhythms occurring in multiple areas across the brain.

Among the squiggly lines, patterns emerged that give literal meaning to the phrase "tuned in." The timing of when individual neurons spiked was synchronized with brain rhythms occurring in distinct frequency bands in other regions of the brain. For example, the high-beta band - 25 to 40 hertz (cycles per second) - was especially important for brain areas involved in motor control and planning.

"Many neurons are thought to respond to a receptive field, so that if I look at one motor neuron as I move my hand to the left, I'll see it fire more often, but if I move my hand to the right, the neuron fires less often," said Carmena. "What we've shown here is that, in addition to these traditional 'external' receptive fields, many neurons also respond to 'internal' receptive fields. Those internal fields focus on large-scale patterns of synchronization involving distinct cortical areas within a larger functional network."

The researchers expressed surprise that this spike dependence was not restricted to the neuron's local environment. It turns out that this local-to-global connection is vital for organizing spatially distributed neuronal groups.

"If neurons only cared about what was happening in their local environment, then it would be difficult to get neurons to work together if they happened to be in different cortical areas," said Canolty. "But when multiple neurons spread all over the brain are tuned in to a specific pattern of electrical activity at a specific frequency, then whenever that global activity pattern occurs, those neurons can act as a coordinated assembly."

The researchers pointed out that this mechanism of cell assembly formation via oscillatory phase coupling is selective. Two neurons that are sensitive to different frequencies or to different spatial coupling patterns will exhibit independent activity, no matter how close they are spatially, and will not be part of the same assembly. Conversely, two [neurons](#) that prefer a similar pattern of coupling will exhibit similar spiking activity over time, even if they are widely separated or in different brain areas.

"It is like the radio communication between emergency first responders at an earthquake," Canolty said. "You have many people spread out over a large area, and the police need to be able to talk to each other on the radio to coordinate their action without interfering with the firefighters, and the firefighters need to be able to communicate without disrupting the EMTs. So each group tunes into and uses a different radio frequency, providing each group with an independent channel of communication despite the fact that they are spatially spread out and overlapping."

The authors noted that this local-to-global relationship in brain activity

may prove useful for improving the performance of brain-machine interfaces, or lead to novel strategies for regulating dysfunctional brain networks through electrical stimulation. Treatment of movement disorders through deep brain stimulation, for example, usually targets a single area. This study suggests that gentler rhythmic stimulation in several areas at once may also prove effective, the authors said.

Provided by University of California -- Berkeley

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