Study breaks ground in revealing how neurons generate movement

April 24 2008

When the eye tracks a bird's flight across the sky, the visual experience is normally smooth, without interruption. But underlying this behavior is a complex coordination of neurons that has remained mysterious to scientists. Now, UCSF researchers have broken ground in understanding how the brain generates this tracking motion, a finding that offers a window, they say, into how neurons orchestrate all of the body's movements.

The study, reported in the April 24 issue of *Neuron*, reveals that individual neurons do not fire independently across the entire duration of a motor function as traditionally thought. Rather, they coordinate their activity with other neurons, each firing at a particular moment in time.

"Scientists have known that neurons that connect to muscles initiate movement in a coordinated fashion. But they have not known how the neurons we are studying – which coordinate these front-line neurons -- commit the brain to move the eyes," says co-lead author David Schoppik, PhD, who conducted the study while a doctoral candidate in the laboratory of senior author Stephen Lisberger, PhD, at the University of California, San Francisco.

"For decades, scientists have been asking, 'Do the signals involve a handful of neurons or thousands" What is the nature of the commands"' The classical understanding has been that one class of neuron is responsible for one movement, such as generating eye movement to the left, and that it remains active across the entire duration of a behavior," he says.

“The new findings suggest a totally different way of looking at how movement is controlled across time,” says Lisberger, a Howard Hughes Medical Institute Investigator at UCSF, where he is professor of physiology, director of the W.M. Keck Foundation Center for Integrative Neuroscience, and co-director of the Sloan Center for Theoretical Neurobiology.

The findings, the researchers say, could inform efforts to develop neural prosthetics to treat paralysis and motor dysfunctions, such as those resulting from stroke. “The brain’s messages don’t reach the muscles in these conditions,” says Schoppik, “so it’s critical that the drive to these prosthetics reflect what the brain is trying to do to move muscles. Understanding how multiple neurons work together could influence the type of software created to drive these devices.”

The investigation of how neurons give rise to motor behaviors has been stymied until now, says Schoppik, by the difficulties inherent in studying more than one neuron in action at a time during the course of a behavior. In the current study, the scientists overcame this obstacle in a study of macaque monkeys that had been trained to track a moving object with their eyes.

Basing their approach on two key pieces of information -- first, that when a neuron responds to a stimulus there is always a slight variation in its performance, a phenomenon that neuroscientists traditionally refer to as “noise,” and, second, that each attempt of the eye to pursue a moving target is also unique – they proposed that some aspects of neural variation may reflect behavioral variation.

They used this inherent variability as a probe. Using a formula from financial securities market analysis that looks at how individual stocks behave at a given time within the context of fluctuations in the larger financial market, they explored how individual neurons would behave relative to their neighbors.

They compared the deviations from the average spiking activity of single neurons and simultaneous deviations from the mean eye velocity. They also measured the degree to which variation shared across two pairs of concurrently active neurons.

The data demonstrated that individual neurons encode different aspects of behavior, controlling eye velocity fluctuations at particular moments during the course of eye movement, while the population of neurons collectively tiles the entire duration of the movement.

The analysis also revealed the strength of correlations in the eye movement predictions derived from pairs of simultaneously recorded neurons, and suggests, the researcher say, either that a small number of neurons are sufficient to drive the behavior at any given time or that many neurons operate collectively at each moment.

The finding, says Lisberger, underscores the importance of recording for more than one neuron at a time. “There is a lot that we can learn from how multiple neurons interact.”

Source: University of California - San Francisco