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The brain's neural thermostat

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As we learn and develop, our neurons change. They make new pathways and connections as our brain processes new information. In order to do this, individual neurons use an internal gauge to maintain a delicate balance that keeps our brains from becoming too excitable.

Scientists have long theorized a larger internal system monitors these individual gauges, like a neural thermostat, regulating average firing rates across the whole brain. Without this thermostat, they reasoned, our flexible neurons would fire out of control, making bad connections or none at all. The result of a faulty neural thermostat could be an epileptic seizure, catatonia or autism.

This thermostat-like control of neuron firing has never been observed in a live, complex animal—until now.

Brandeis University scientists observed in vivo that neocortical neurons, cells that control higher functions such as sight, language and spatial reasoning, have a set average firing rate and return to this set point even during prolonged periods of sensory deprivation. Furthermore, the average firing rate is so well regulated by this neural thermostat that the rates do not change between periods of sleep and wakefulness.

The study, led by professor Gina Turrigiano in collaboration with the labs of Don Katz and Stephen Van Hooser, was the cover story in the Oct. 16 issue of the journal *Neuron*.

There is a time in early development across mammalian species when the brain does most of its wiring, affected largely by the environment in which the animal is being raised. This study demonstrated that during this period, neurons are constantly "self-tuning" to adjust for changes in environmental inputs, says postdoctoral fellow Keith Hengen, the paper's first author.

"If something is disturbed during that critical period of early childhood development, functioning neurons can self-adjust and return to their set-point average firing rate," Hengen says.

In this study, Turrigiano's team studied young rats that temporarily lost vision in one eye. In the first 48 hours, the neuronal firing rates dropped significantly from lack of external stimuli. But within the next 48 hours, those neurons rebounded back to their set-point rate—like a cold house heating up.

Soon, the neocortical neural firing rates were the same in both hemispheres, one with visual data and one without. Turrigiano's team studied the animals awake and asleep—and found that although the pattern of neural firing changed, the rate of firing stayed exactly the same.

This homeostatic mechanism keeps neurons on an even keel even as they change in response to learning, development and environmental factors.

"The homeostatic rule can control average activity across periods of sleep and wakefulness," Hengen said. "The other rules in the brain have to play out in the context of this tightly regulated system of locked-in average firing rates."

A demonstrated neural firing-rate set point opens up a whole new approach to thinking about neurological disorders such as epilepsy, in which the brain is too excited, and autism, in which the brain is not excited enough.

"If we can figure out how these set points are built, we may be able to adjust them and bring the brains of people suffering from such disorders back into balance," Turrigiano says.

Provided by Brandeis University

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