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More Than Meets the Eye

Variability in visual cortex neurons reflects input diversity

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By ELIZABETH COONEY *July 14, 2016*

We can thank neurons in the brain's cerebral cortex for the rich representation of the world we "see." In response to sensory stimuli—sights, sounds, tastes, smells, touch—neurons fire electrical spikes that collectively make up our brain's model of the world.

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To help construct that world, individual neurons are so specialized that they fire in response to specific external inputs. With vision, that could mean a neuron would respond to an upward motion but not a downward one; another neuron to a right shift but not a left one.

Yet despite their consistency in stimulus preference, cortical neurons are surprisingly messy in how they respond to repetitions of a sensory stimulus, seemingly firing or not firing randomly.

"Perhaps neurons don't play dice after all." — Gabriel Kreiman

Why, then, are the spikes so variable in the first place? The general view in the field holds that, on the spectrum of signal to noise, neurons are just noisy by nature. The brain could deal with this noise by averaging responses from many cells to produce a clear signal, engendering the reliable behavior needed for survival.

Harvard Medical School scientists now have a different interpretation.

In a paper published online July 14 in ***Neuron*,** a team led by **Richard Born**, HMS professor of neurobiology, and **Gabriel Kreiman**, HMS associate professor of ophthalmology at Boston Children's Hospital, reports that inactivating neurons in one part of the primate visual cortex caused this well-known variability to disappear in nearby cortical areas. The neurons in the neighboring areas remained active but now produced unusually regular spike patterns to repeated visual stimulation. When the researchers reactivated the silenced area, spiking became irregular again.

"This suggests that neurons are likely not intrinsically noisy." — Camille Gómez-Laberge

"This suggests that neurons are likely not intrinsically noisy," said **Camille Gómez-Laberge**, HMS research fellow in neurobiology and co-first author of the paper. Instead, said the researchers, neuronal variability seems to reflect input diversity.

“Neurons, especially those in the cortex, are both highly variable and highly interconnected with neurons from all over the brain,” Gómez-Laberge said. “We found that these ‘noisy’ neurons become unusually consistent when their connectivity is reduced during our intervention.”

The study’s results may help us understand how the connectivity of the cortex’s neurons make it such a powerful computational device, said Born, who is co-senior author of the paper.

“By manipulating some of the inputs, we’ve shown that these many inputs are a big part of the variability,” he said. “But we still need to understand how much of that variability is irreducible noise, and how much of it is due to different sources of input. What we’re thinking now is it’s the connectivity and not the firing variability of the neurons.”

To illustrate the difference, Born said, think of a blind person who hears one voice advising on how to navigate a room. That would be one source. Then imagine 100 voices yelling go right, turn left, it’s raining. The blind person’s path might become erratic in response to so many sources. Variability would decrease if those multiple voices were silenced.

Something similar may be happening in the brain when multiple inputs cause neurons to fire. The firings may appear to be noise, but they could also be providing context for the brain to make judgments, Born said.

“What the brain is trying to do is extract meaning out of those patterns of spikes that allow it to form a model of the world. How much is noise and how much is signal we don’t yet understand?” — Richard Born

“What the brain is trying to do is extract meaning out of those patterns of spikes that allow it to form a model of the world,” Born said. “How much is noise and how much is signal we don’t yet understand?”

“Perhaps neurons don't play dice after all,” Kreiman said. “Neurons are actually quite reliable once we rigorously control for changes in the external variables and internal milieu.”

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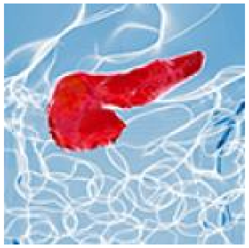

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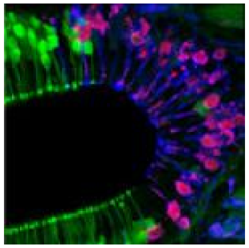

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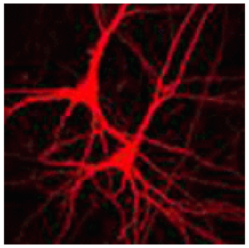

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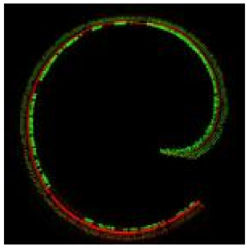

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