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Mysterious 'Neural Noise' Actually Primes Brain for Peak Performance

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Researchers at the University of Rochester may have answered one of neuroscience's most vexing questions—how can it be that our neurons, which are responsible for our crystal-clear thoughts, seem to fire in utterly random ways?

In the November issue of *Nature Neuroscience*, the Rochester study shows that the brain's cortex uses seemingly chaotic, or "noisy," signals to represent the ambiguities of the real world—and that this noise dramatically enhances the brain's processing, enabling us to make decisions in an uncertain world.

"You'd think this is crazy because engineers are always fighting to reduce the noise in their circuits, and yet here's the best computing machine in the universe—and it looks utterly random," says Alex Pouget, associate professor of brain and cognitive sciences at the University of Rochester.

Pouget's work for the first time connects two of the brain's biggest mysteries; why it's so noisy, and how it can perform such complex calculations. As counter-intuitive as it sounds, the noise seems integral to making those calculations possible.

In the last decade, Pouget and his colleagues in the University of Rochester's Department of Brain and Cognitive Sciences have blazed a new path to understanding our gray matter. The traditional approach has assumed the brain uses the same method computation in general had used up until the mid-80s: You see an image and you relate that image to one stored in your head. But the reality of the cranial world seems to be a confusing array of possibilities and probabilities, all of which are somehow, mysteriously, properly calculated.

The science of drawing answers from such a variety of probabilities is called Bayesian computing, after minister Thomas Bayes who founded the unusual branch of math 150 years ago. Pouget says that when we seem to be struck by an idea from out of the blue, our brain has actually just resolved many probabilities its been fervently calculating.

"We've known for several years that at the behavioral level, we're 'Bayes optimal,' meaning we are excellent at taking various bits of probability information, weighing their relative worth, and coming to a good conclusion quickly," says Pouget. "But we've always been at a loss to explain how our brains are able to conduct such complex Bayesian computations so easily."

Two years ago, while talking with a physics friend, some probabilities in Pouget's own head suddenly resolved.

"One day I had a drink with some machine-learning researchers, and we suddenly said, 'Oh, it's not noise,' because noise implies something's wrong," says Pouget. "We started to realize then that what looked like noise may actually be the brain's way of running at optimal performance."

Bayesian computing can be done most efficiently when data is formatted in what's called "Poisson distribution."

And the neural noise, Pouget noticed, looked suspiciously like this optimal distribution.

This idea set Pouget and his team into investigating whether our neurons' noise really fits this Poisson distribution, and in his current Nature Neuroscience paper he found that it fit extremely well.

"The cortex appears wired at its foundation to run Bayesian computations as efficiently as can be possible," says Pouget. His paper says the uncertainty of the real world is represented by this noise, and the noise itself is in a format that reduces the resources needed to compute it. Anyone familiar with log tables and slide rules knows that while multiplying large numbers is difficult, adding them with log tables is relatively undemanding.

The brain is apparently designed in a similar manner—"coding" the possibilities it encounters into a format that makes it tremendously easier to compute an answer.

Pouget now prefers to call the noise "variability." Our neurons are responding to the light, sounds, and other sensory information from the world around us. But if we want to do something, such as jump over a stream, we need to extract data that is not inherently part of that information. We need to process all the variables we see, including how wide the stream appears, what the consequences of falling in might be, and how far we know we can jump. Each neuron responds to a particular variable and the brain will decide on a conclusion about the whole set of variables using Bayesian inference.

As you reach your decision, you'd have a lot of trouble articulating most of the variables your brain just processed for you. Similarly, intuition may be less a burst of insight than a rough consensus among your neurons.

Pouget and his team are now expanding their findings across the entire cortex, because every part of our highly developed cortex displays a similar underlying Bayes-optimal structure.

"If the structure is the same, that means there must be something fundamentally similar among vision, movement, reasoning, loving—anything that takes place in the human cortex," says Pouget. "The way you learn language must be essentially the same as the way a doctor reasons out a diagnosis, and right now our lab is pushing hard to find out exactly how that noise makes all these different aspects of being human possible."

Pouget's work still has its skeptics, but this, his fourth paper in Nature Neuroscience on the topic, is starting to win converts.

"If you ask me, this is the coming revolution," says Pouget. "It hit machine learning and cognitive science, and I think it's just hitting neuroscience. In 10 or 20 years, I think the way everybody thinks about the brain is going to be in these terms."

Not all of Pouget's neurons are in agreement, however.

"…but I've been wrong before," he shrugs.

Source: University of Rochester

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