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## Chaotic Neurons Enhance Brain's Processing

Scientists may have finally discovered why the neurons in the human brain seem to fire in utterly random ways. In the latest issue of *Nature Neuroscience*, University of Rochester researchers show how 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 power.

The new work 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 appears to be integral to making those calculations possible. "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," said Rochester brain boffin, Alex Pouget.



Rather than being analogous to a traditional digital computational model, Pouget explained how the reality of brain function 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. 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 in the background.

"[The brain is] excellent at taking various bits of probability information, weighing their relative worth, and coming to a good conclusion quickly," Pouget continued. "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, Pouget began questioning the function of the "noise" inherent in neuron function and began to realize that what looked like noise, might 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 a "Poisson distribution," and the neural noise, Pouget noticed, looked suspiciously like this optimal distribution.

Pouget and his team then investigated whether neuronal noise fitted this Poisson distribution, and found that it fitted extremely well. "The cortex appears wired at its foundation to run Bayesian computations as efficiently as can be possible," he said.

"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," he added.

"Variability" may be a better word than "noise" to describe such neuron responses, according to Pouget. The 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."

Source: University of Rochester

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## Neurons Mix Digital And Analog Functionality

The longstanding belief that each of the brain's 100 billion neurons communicate strictly by a digital code looks to be incorrect. Writing in *Nature*, Yale neurologist David McCormick reported that communicating brain cells use a mix of analog and digital coding at the same time. "This study reveals that the brain is very sophisticated in its operation, using a code that is more efficient than previously appreciated," said McCormick.

The brain's neurons receive input from other cells through synaptic contacts which release neurotransmitters that cause the voltage inside the neuron to fluctuate continuously. Once this voltage reaches a threshold, an action potential is generated, which causes a specialized waveform to travel down the axon and create an output signal. It was previously believed that this specific waveform was the only output signal that axons were capable of transmitting.

But McCormick and his co-researchers demonstrated that the analog signal present in the cell body *also* propagates down the axon and influences synaptic transmission onto other neurons. It seems that as the voltage on the sending cell becomes more positive, the amplitude of the subsequent transmission to the receiving cell,



mediated by an action potential, is enhanced. Hence, the waveform generated in the receiving neuron is not just determined by the digital pattern of action potentials generated, but also by the analog waveform occurring in the sending neuron.

"This has widespread implications, not only for our basic understanding of how the brain operates, but also in our understanding of neuronal dysfunction," said McCormick. "It's as if everyone thought communication in the brain was like a telegraph, but actually it turned out to be more similar to a telephone."

The discovery may help explain epileptic seizures and migraine headaches, which both involve large voltage changes in neurons. These abnormal patterns of activity could be directly communicated to nearby neurons - even in the absence of the generation of the usual communication waveform.

The finding will also impact scientists trying to understand how consciousness and intelligence manifest in the human brain, as any investigation into neuronal operation will now need to take into account the mixed analog-digital nature of neuron communication.

Source: Yale University