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Neural 'synchrony' may be key to understanding how the human brain perceives

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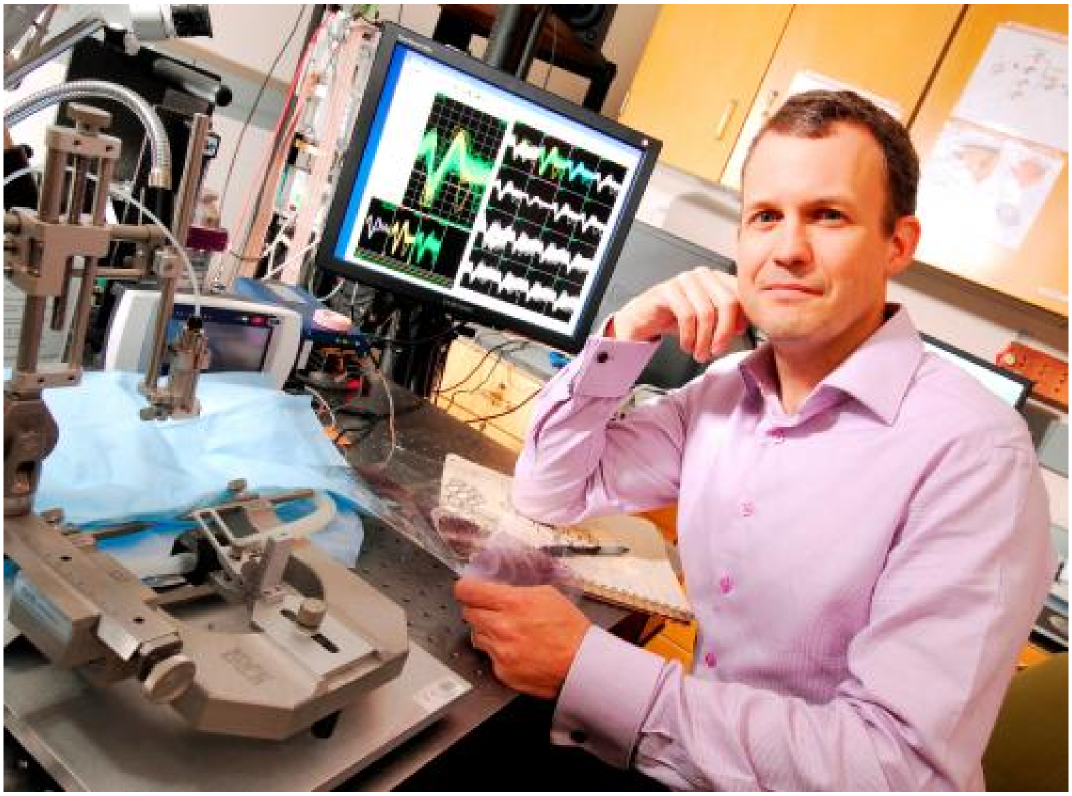

Garrett Stanley, a Georgia Tech/Emory University biomedical engineering professor, has published almost 40 articles related to "reading and writing the neural code." In his latest perspective article, he wrote that the specific timing of electrical pulses may be key to understanding how the human brain perceives what we see, feel and hear. Credit: Georgia Tech Photo: Gary Meek

Despite many remarkable discoveries in the field of neuroscience during the past several decades, researchers have not been able to fully crack the brain's "neural code." The neural code details how the brain's roughly 100 billion neurons turn raw sensory inputs into information we can use to see, hear and feel things in our environment.

In a perspective article published in the journal *Nature Neuroscience* on Feb. 25, 2013, biomedical engineering professor Garrett Stanley detailed research progress toward "reading and writing the neural code." This encompasses the ability to observe the spiking activity of neurons in response to outside stimuli and make clear predictions about what is being seen, heard, or felt, and the ability to artificially introduce activity within the brain that enables someone to see, hear, or feel something that is not experienced naturally through sensory organs.

Stanley also described challenges that remain to read and write the neural code and asserted that the specific timing of electrical pulses is crucial to interpreting the code. He wrote the article with support from the National Science Foundation (NSF) and the National Institutes of Health (NIH). Stanley has been developing approaches to better understand and control the neural code since 1997 and has published about 40 journal articles in this area.

"Neuroscientists have made great progress toward reading the neural code since the 1990s, but the recent development of improved tools for measuring and activating neuronal circuits has finally put us in a position to start writing the neural code and controlling neuronal circuits in a physiological and meaningful way," said Stanley, a professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

With recent reports that the Obama administration is planning a decade-long scientific effort to examine the workings of the human brain and build a comprehensive map of its activity, progress toward breaking the neural code could begin to accelerate.

The potential rewards for cracking the neural code are immense. In addition to understanding how brains generate and manage information, neuroscientists may be able to control neurons in individuals with epilepsy and Parkinson's disease or restore lost function following a brain injury. Researchers may also be able to supply artificial brain signals that provide tactile sensation to amputees wearing a prosthetic device.

Stanley's paper highlighted a major challenge neuroscientists face: selecting a viable code for conveying information through neural pathways. A longstanding debate exists in the neuroscience community over whether the neural code is a "rate code," where neurons simply spike faster than their background spiking rate when they are coding for something, or a "timing code," where the pattern of the spikes matters. Stanley expanded the debate by suggesting the neural code is a "synchrony code," where the synchronization of spiking across neurons is important.

A synchrony code argues the need for precise millisecond timing coordination across groups of neighboring neurons to truly control the circuit. When a neuron receives an incoming stimulus, an electric pulse travels the neuron's length and triggers the cell to dump neurotransmitters that can spark a new impulse in a neighboring neuron. In this way, the signal gets passed around the brain and then the body, enabling individuals to see, touch, and hear things in the environment. Depending on the signals it receives, a neuron can spike with hundreds of these impulses every second.

"Eavesdropping on neurons in the brain is like listening to a bunch of people talk—a lot of the noise is just filler, but you still have to determine what the important messages are," explained Stanley. "My perspective is that information is relevant only if it is going to propagate downstream, a process that requires the synchronization of neurons."

Neuronal synchrony is naturally modulated by the brain. In a study published in *Nature Neuroscience* in 2010, Stanley reported finding that a change in the degree of synchronous firing of neurons in the thalamus altered the nature of information as it traveled through the pathway and enhanced the brain's ability to discriminate between different sensations. The thalamus serves as a relay station between the outside world and the brain's cortex.

Synchrony induced through artificial stimulation poses a real challenge for creating a wide range of neural representations. Recent technological advances have provided researchers with new methods of activating and silencing neurons via artificial means. Electrical microstimulation had been used for decades to activate neurons, but the technique activated a large volume of neurons at a time and could not be used to silence them or separately activate excitatory and inhibitory neurons. Stanley compared the technique with driving a car that has the gas and brake pedals welded together.

New research methods, such as optogenetics, enable activation and silencing of neurons in close proximity and provide control unavailable with electrical microstimulation. Through genetic expression or viral transfection, different cell types can be targeted to express specific proteins that can be activated with light.

"Moving forward, new technologies need to be used to stimulate neural activity in more realistic and natural scenarios and their effects on the synchronization of neurons need to be thoroughly examined," said Stanley. "Further work also needs to be completed to determine whether synchrony is crucial in different contexts and across brain regions."

More information: Stanley, Garrett B., "Reading and writing the neural code," *Nature Neuroscience* (2013): dx.doi.org/10.1038/nn.3330

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