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Experiments support alternative theory of information processing in the cortex

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Neurons in the sound-processing part of the brain's cortex are experts at timing. With remarkable precision, they fire electrochemical pulses or "spikes" in sync with the cues they receive from other neurons, even when these cues are separated by very small time intervals.

A team of neuroscientists at Cold Spring Harbor Laboratory (CSHL), studying this phenomenon in rats, has demonstrated that "spike timing" in cortical neurons can influence behavior even at minuscule time intervals, more precise than previously imagined. Experiments focusing on the auditory cortex revealed that animals in the midst of decision-making have the ability to distinguish incoming signals separated by as little as three milliseconds.

Probing the relation of neuronal firing rates and behavior

The finding, published ahead of print October 12 in the online edition of *Nature Neuroscience*, adds to the current understanding of how neuronal activity in the brain's cortex modulates behavior. According to the standard model of cortical activity, behavior is thought to be determined by the rate of spiking -- the number of spikes occurring within a given interval. The CSHL team, led by Professor Anthony Zador, Ph.D., wanted to determine whether spike timing had any impact on decision-making and measure the shortest decision-driving interval between spikes.

Zador's group designed an experiment in which rats were trained to behaviorally distinguish between two sounds. When placed in a cage with two water outlets, the rats were trained to turn either to the left or to the right waterspout depending on the sound. The sounds were then replaced by electrical impulses delivered directly to two spatially separated groups of neurons in the auditory cortex. The animals were then re-trained so that simultaneous stimulation of both groups of neurons spurred the animal toward the left waterspout, whereas sequential stimulation of the neuron bundles led the animal to the right waterspout. The rats consistently homed to the right waterspout until the timing between the two sequential stimuli narrowed to below 3 milliseconds. "This suggests that the cortex is capable of 'reading out' very precise nuances in spike timing to drive behavior," says Zador.

Deciphering the "Neural Code"

The group's discovery helps make the case for an alternate theory of how the brain processes information. Neuroscientists have made vast leaps in understanding how neurons communicate with each other in the brain. But they are still in the dark about what the neuron-to-neuron message actually consists of and how it's processed. Known as the "neural code," this blueprint for the brain's information-processing language has proved to be much more elusive than language that is encoded in our genome, which was deciphered decades ago.

The prevailing theory behind the neural code is based on the observation that neurons spike faster when they are transmitting information. This supports a "rate" code model, which stipulates that information is contained within the spiking rate of the neuron. But the CSHL team's new data suggest that the neural code might actually be a "timing" code, where information is encoded within the precise pattern of spiking – something that can be deduced by examining how the spikes are distributed over time.

Zador explains the difference between the two possibilities by likening the brain to an office and neurons to the people working in the office. "If lots of people are talking within each department in a company, you might get a good idea of what's going on in the company by just measuring how loudly people are talking within a given department, which is what the classical 'rate' model predicts," he says.

But as Zador also observes, conversation is not just about loudness; it's also about the identity of the speakers, their speech patterns, etc. "Our results demonstrate directly that there is more to this 'office' than just how loudly people are talking, and motivate us to try to figure out what that extra dimension is," he says. He and his CSHL team will continue to probe for the answers as their work on this and related mysteries about neural communication continues.

Citation: "Millisecond-scale differences in neural activity in auditory cortex can drive decisions" appeared October 12, 2008 as an advance online publication in Nature Neuroscience. The complete citation is: Yang Yang, Michael R DeWeese, Gonzalo Otazu, Anthony M Zador. The paper is available online at www.nature.com/neuro/journal/v … ent/abs/nn.2211.html

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