Seminar

Synchronized Neurons and Sensor-Fused Rattlesnakes:
How Coupled Neural Oscillators Integrate and Transform the Senses

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Wed. October 17, 2012
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Culler Hall, Room 46 at 4:15 PM

Coupled oscillators have had a place in physics ever since Huygens (1665) discovered them while modifying pendulum clocks for naval service. Their more recent use in understanding the brain could provide a common framework for understanding many different kinds of neural information combination problems. For example, sensory integration and sensory binding are similar problems separated by a vast methodological gulf. Binding theory concerns assembling a coherent percept out of the activity of legions of neurons responding to a sensory stimulus; sensory integration studies how different senses influence one another. The dominant paradigm of binding theory is neural synchronization, while sensory integration is built on observations of neurons that respond to more than one kind of stimulus. Such cells show large increases in firing rates if two senses are weakly stimulated, but little improvement for strong stimuli, a key finding known as the Principle of Inverse Enhancement. The rattlesnake provides a nice bridge between binding theory and sensory integration; the rattlesnake has two dissimilar visual systems: eyes for visible light and pinhole-camera-like thermal pits for infrared. Although this sounds a lot like a binding problem, the rattlesnake has been studied using the methods of sensory integration; many cells in rattlesnake optic tectum are sensitive only to visible light but their firing rates are strongly modulated by heat stimuli, or vice versa. I modeled these rattlesnake cells by assuming that they are members of synchronized pairs of excitatory-coupled neurons. I ignored the standard weak-coupling assumption of coupled neural oscillator theory and replaced it with 'Goldilocks-coupling': coupling is kept as strong as possible without distorting neural spike amplitudes. The same synchronized neuron model – without any parameter changes – accounts for a population of cells in cat visual cortex whose firing rates are enhanced by auditory stimuli. This model accounts for the Principle of Inverse Enhancement. It also produces neural firing rate enhancements that are similar to enhancements perceived by humans. It may be possible to explain some mysterious human color vision transformations using these neural synchronization models.