Tutorial 10: Temporal and Spatial Summation
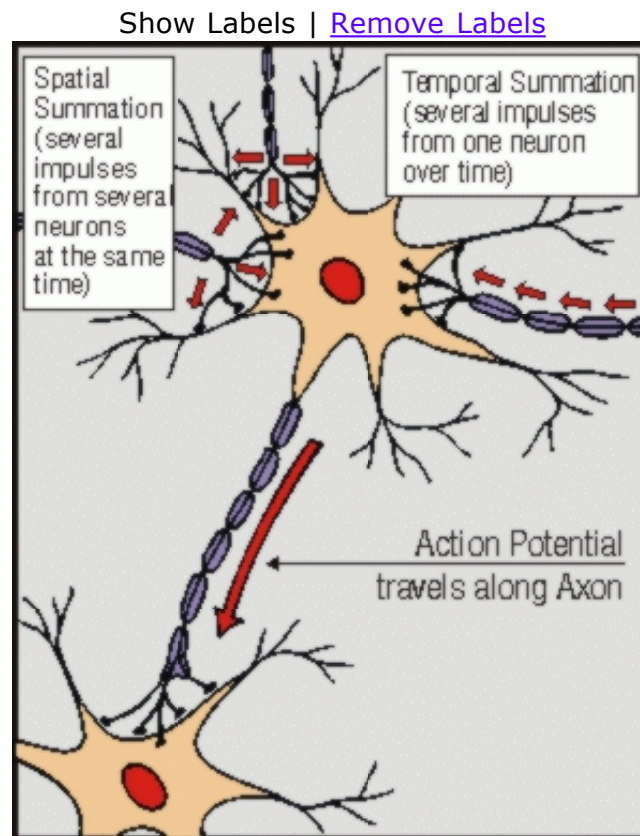
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Figure 10: Temporal and Spatial Summation

Intro | Spatial Summation | Temporal Summation

Part 1: Image-Mapped Tutorial
Part 2: Matching Self-Test
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Tutorial 10 discusses the integration of postsynaptic potentials across both time and space. As described in Tutorial 9, whether or not a neuron will trigger an action potential at any given instant is dependent on the summation of PSPs at the axon hillock. Four primary factors control whether an impulse will be generated on a neuron. At any given moment, a neuron may be under the influence of input from thousands of other neurons. Any combination of synapses on a given neuron may be active at any given time, and the rate of this activity at the synaptic level may vary. Whether or not threshold is reached, and an action potential generated, is dependent upon the spatial (i.e., multiple impulses from several neurons at the same time) and temporal (i.e., several impulses from one neuron over time) summation of all inputs at a given moment. In addition, the summation of excitatory and inhibitory influences will modulate the outcome. Synapses that are located closer to the axon hillock, where all input on a neuron is summated, have a greater influence on the outcome.

Neurons encode information and make decisions based on a number of different integration schemes. The simplest, of course, involves the onset and rate of action potential transmission. It is

important to note that many neurons, however, spontaneously trigger action potentials. For these neurons, EPSPs and IPSPs act to modify this spontaneous rate of transmission by adjusting rate up or down, respectively. Information is therefore carried via the *change* in action potential rate. In other instances, information is conveyed and decisions made based on the combination of double negatives or the effect of inhibitory postsynaptic potentials on a neuron with an inhibitory function. This integration results in the indirect excitation of a process via disinhibition.

Temporal and spatial summation of synaptic input on a neuron underlies the integration of information from diverse sources. The convergence of input and comparison of this input at the neuronal level is the foundation of decision-making. The "decisions" of many neurons forming a network and acting in concert underlie the types of decisions that guide our behaviors.

 Advanced

Much of what we know today about neurophysiology and synaptic communication was presaged by observations made by Charles Scott Sherrington at the end of the nineteenth century (Gregory, 1987; Simmons, 1996). The nervous system was basically uncharted territory when Sherrignton began his career as a physician. It was known that nerves had electrical properties, and preliminary studies of the spinal cord had been conducted. In his study of the knee jerk or reflex, Sherrington noted the difference between the motor neurons and sensory neurons, which he called proprioceptors. With this distinction, the role of the nervous system in the **integration of information** emerged. The knee jerk reflex, he noted, was the result of interaction between two reciprocal forces, excitatory and inhibitory. Sherrington also proposed a nervous system of pathways, composed of sites where cells transmitted information to other cells. He called these sites synapses. In addition, Sherrington introduced the possible role of evolution in the development of the nervous system, with his suggestion that higher centers of the brain inhibit the excitatory functions of the lower centers.

Although very much a man of science, Sherrington had a philosophical side which supported a mind/body dualism. In his 1935, *Man on His Nature*, he wrote, "We have to regard the relation of mind to brain as not merely unresolved but still devoid of a basis for its very beginning. When Sherrington published *The Integrative Action of the Nervous System* in 1906, he gained the highest stature as a scientist. This book was and remains a classic text in neurophysiology. He was awarded the Nobel Prize for medicine and physiology in 1932, along with Edgar D. Adrian.

Jumping from the seeds of our understanding of neuronal integration to the present involves a shift in technology. New recording techniques that allow for simultaneous recording from multiple sites of the dendritic tree have shed light on mechanisms underlying spatial summation. One recent study has described the attenuation of action potentials during the coincident stimulation of EPSPs at two separate points of the dendritic tree (Kogo & Ariel, 1999). Two distinct responses are distinguished based on the interval between the time of stimulation at each of the two sites of postsynaptic membrane. Surprisingly, a facilitation of response was never observed. This could be a unique characteristic of the retinal neurons stimulated. Response attenuation, however, was measured. Approximately one half of the attenuated responses had a duration that was similar to the duration of the decaying phases of the first EPSP generated by each pair. This temporal relationship suggests that this attenuation was dependent entirely on a change in the activity of voltage-dependent channels. The other half of attenuated responses lasted for a shorter period of time compared to the duration of the decaying phase of the first EPSP. These attenuated responses were more likely mediated via a shunting mechanism due to the opening of synaptic receptor channels. More research of this nature is needed to clarify the mechanisms underlying the process of spatial summation.

Suggestions for further study

SUGGESTED READINGS:

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RELATED LINKS:

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(Protein Studies Reveal Sophisticated Control Of Nerve Communication)
Science Daily Research News

http://www.csuchico.edu/psy/BioPsych/neurotransmission.html
(Neurotransmission)
Maintained by Biopsychology at University of California at Chico

http://www.sfn.org/briefings/nmda.html
(NMDA Receptors)
from Society for Neuroscience - *Brain Briefings*, 1994.
NMDA receptor blockers and the prevention of neuronal damage due to stroke, epilepsy,
Huntington's Disease, and AIDS.

http://psych.hanover.edu/Krantz/neural/actionpotential.html
(Physical Factors Underlying the Action Potential)
Krantz - Psychology Tutorials