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Rising above the din: Attention makes sensory signals stand out amidst the background noise in the brain

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The brain never sits idle. Whether we are awake or asleep, watch TV or close our eyes, waves of spontaneous nerve signals wash through our brains. Researchers at the Salk Institute for Biological Studies studying visual attention have discovered a novel mechanism that explains how incoming sensory signals make themselves heard amidst the constant background rumblings so they can be reliably processed and passed on.

"We live with the illusion that our visual system processes all the information that is available in the visual scene in a single glimpse," says John H. Reynolds, Ph.D., an associate professor in the Systems Neurobiology Laboratory at the Salk Institute and senior author of the current study. "In reality, there is far too much detail in a typical scene for the visual system to take it in all at once. So our perception of the world around us is in a sense pieced together from what we pay attention to."

Researchers had known for some time that paying attention to visual details increases the firing rate of neurons tuned for attended stimulus. Until now, it was assumed that these attention-dependent increases in neural activity were the primary cause of the improvement in perceptual discrimination that we experience when we focus a sensory stimulus.

The findings of the Salk researchers, published in the September 24, 2009 issue of the journal *Neuron*, reveal that the uptick in the firing rate

is only a small part of the story. "What we found is that attention also reduces background activity," says postdoctoral researcher and first author Jude Mitchell, Ph.D. "We estimate that this noise reduction increases the fidelity of the neural signal by a factor that is as much as four times as large as the improvement caused by attention-dependent increases in firing rate. This reduction in noise may account for as much as 80% of the attention story."

When light hits the retina, visual information is translated into a cascade of nerve impulses sending signals deep into the brain. It is here, in the brain's visual cortex, which resides in the occipital lobe at the back of the skull, that these signals are interpreted and give rise to perception. But the visual system has limited capacity and cannot process everything that falls onto the retina. Instead, the brain relies on attention to bring details of interest into focus so it can select them out from background clutter.

In their study, Reynolds, Mitchell, and former graduate student Kristy Sundberg asked whether attention, which so efficiently tunes out external distractions, does the same for the internal racket. Attention generally increases the firing rate of responsive neurons: The stronger the stimulus, the more impulses are sent per second, which improves the quality of the signal somewhat. "It's a little bit like turning up the volume from very low to high on a stereo," says Reynolds. "You are not hearing it very clearly at low volume not only because the signal is weak but because ambient noise is masking the stimulus. As you increase the volume, the signal becomes clearer."

But even under the most controlled laboratory conditions, the responses evoked by identically repeated stimuli vary from trial to trial. "Neurons are very noisy computing devices," says Mitchell. "Each neuron receives input from thousands of neurons and needs to distinguish the incoming information from the background noise."

If each neuron produced random noise that is independent from what its neighbor neuron is doing, the brain cell on the receiving end could simply pool all incoming signals and average out the noise. Reynolds compares it to diversifying risk in a stock portfolio: "If you have a portfolio of stocks whose prices vary independently, you can reduce fluctuations by dividing your investment among a large pool of stocks."

Unfortunately, for neurons this option is off the table since most of the brain's background noise originates in waves of spontaneous nerve signals that undulate across a large population of brain cells. Says Mitchell, "These fluctuations can't be simply averaged out since they are shared across the neural population." To extend the investment analogy, say you put your money into a pool of real estate investments. Your portfolio is subject to fluctuations in the real estate market - the correlated fluctuations in the values of individual investments - no matter how big the pool.

But an interesting thing happened when the researchers measured the activity of a large population of visual neurons in animals trained to play a simple video game that required rapt attention to a visual stimulus on the screen. The internal fluctuations or shared noise quieted down, increasing the visibility of the incoming sensory information.

"Attention is an essential part of perception," says Reynolds. "Brain disorders in which attention fails therefore have devastating effects. Gaining insight into the neural mechanisms of attention is essential if we are to understand the causes of these perceptual deficits and find ways to treat them. By revealing a major new attentional mechanism, Jude has taken a major step toward understanding the neural mechanisms of conscious awareness."

Source: Salk Institute (news : web)