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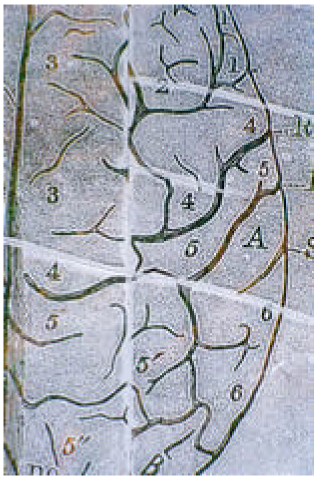
Physics in biology: Noisy thoughts

Physical Review Letters **88,** 218101 (10 May 2002)

Stochastic resonance, in which addition of noise actually enhances the detection of weak signals by a nonlinear system, has been seen in the sensory processes of many living organisms. Now, it has been found within the human brain.



Noise usually gets in the way of signal detection, but in certain situations it can actually have the opposite effect, boosting a signal to the necessary detection threshold. This effect, called stochastic resonance, helps to increase sensory sensitivity to physical stimuli in many living organisms including rats, fish and humans. In Physical Review Letters, Toshio Mori and Shoichi Kai now reveal that stochastic resonance also plays a role in the propagation of electrical signals in the human brain.

If a signal's amplitude is below a system's detection threshold, adding noise can increase the total amplitude of the signal and so allow it to be detected. The level of noise added is important — too little and the signal will remain obscure, too much and it will be swamped. Such stochastic resonance can boost signal response to sensory input in many animals, increasing human's touch sensitivity, for example. But might it also have a role in higher cognitive functions?

The huge range of random processes that take place in the human brain - such as the chaotic firing of neural networks — makes for a particularly noisy environment. Mori and Kai reasoned that the brain might have evolved not only to take account of this noise, but also to harness it to aid signal transmission and detection. To test this idea, the authors looked for stochastic resonance in human 'brain waves'.

There are several types of brain wave, all of which are detected as low frequency, spatially averaged oscillations in the brain's electrical field potential. Mori and Kai focused on alpha waves, which have a frequency of about 8-13 Hertz. These waves are useful because their production can be synchronized — entrained — in a subject by shining bright oscillating lights onto the person's closed eyelids.

The authors first determined the minimum light intensity at which alpha-wave synchronization occurred in their subjects. They then applied a periodic light signal with constant intensity below this threshold to one eyelid and a noisy light signal of varying intensity to the other. In all cases, the amplitude of the resulting alpha waves increased with noise intensity until the noise reached an optimal threshold, after which the waves' amplitude decreased — the hallmark of stochastic resonance.

Although stochastic resonance has been seen in human sensory processing before, this is the first time that the effects have been found within the neural networks of the brain, beyond the sensory organs — in this case the eyes — used for the signal's input.

Noise-Induced Entrainment and Stochastic Resonance in Human Brain Waves
TOSHIO MORI & SHOICHI KAI
We present the first observation of stochastic resonance (SR) in the human brain's visual processing area. The novel experimental protocol is to stimulate the right eye with a subthreshold periodic optical signal and the left eye with a noisy one. The stimuli bypass sensory organs and are mixed in the visual cortex. With many noise sources present in the brain, higher brain functions, e.g., perception and cognition, may exploit SR.
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