Brain waves in harmony

The human brain continuously processes sensory impulses that compete for our attention. Our ability to select enables us to process specific information and ignore irrelevant stimuli. In this way, we can recognize a familiar face in a large crowd of people. But how is this made possible? Max Planck researcher Pascal Fries explains this through electrophysiological mechanisms between nerve cells at different processing layers in the brain, which synchronize through a characteristic key signal.

The brain consists of millions and millions of closely networked nerve cells that exchange electrical signals within a few milliseconds. Fries was able to show that neurons in different brain areas form a unit for processing visual information by synchronizing and firing rhythmically in a characteristic frequency band. This explains why elements such as the shape of a human face and hair color result in specific frequency patterns and signal characteristics that enable the brain to recognize a person.

In time with the brain waves

Fries presented this hypothesis in 2005 in the journal Trends in Cognitive Sciences as a process of communication between nerve cells in different areas of the brain by producing synchronized excitation waves (Communication-Through-Coherence Theory). This explains how our brain is able to direct and maintain attention to very specific elements of our environment despite the various visual stimuli we are constantly confronted with.

Fries used laboratory experiments to show that among the numerous signals that reach the next higher processing level of vision in the brain from our retina in the eye, certain impulses prevail over others. For example, he found synchronous electrical excitation of the gamma frequency band between nerve cells at different levels of visual processing when a visual stimulus was paid attention to. At the same time, he found that neuronal beta rhythms also mediated between neurons.

Fries concluded from subsequent experiments that there must be two opposing information processes during the processing of visual sensory stimuli between nerve cells of the lower and higher hierarchical levels of the brain: According to this, fast gamma waves lead to feedforward impulses between neurons and mediate from lower to higher processing levels of the brain when our eye perceives something new or unexpected. At the same time, feedback connections in the beta frequency band bring predictions about already known information from higher brain regions to the lower processing levels. Fries suggests that feedback communication helps to maintain a state of information.

Disturbances in communication

In the event of pathological changes in the brain, this rhythmic synchronization between neurons can get out of sync. The scientist assumes that his theory is not only applicable to vision and visual information processing in the brain, but also to disorders of the motor cortex in people with Parkinson's disease.

This area of the brain works together with the spinal cord and muscles. Gamma waves mediate when a movement is to be initiated. Beta waves take over the task of maintaining a state. The ratio of signal strengths between gamma and beta waves in turn regulates the speed of movement.

In Parkinson's patients, cell degeneration in the brain stem leads to a lack of dopamine and often to an amplification of the beta waves. As a result, a resting signal remains predominant, which makes it difficult for those affected to start a movement from a standstill – a typical symptom of the disease.

From basic research to application

At the Max Planck Institute for Biological Cybernetics, Fries is now investigating how the findings of his previous research can be applied to human cognitive and emotional processes. In particular, he is focusing on the decision between approach and avoidance behavior, a mechanism that is crucial for the search for reward in the context of both positive and negative experiences.

Together with his research group, he proposes the idea that these processes are also controlled by synchronization in different frequency ranges of the brain. If this is confirmed, it could open up new possibilities for therapeutic applications, especially for people with anxiety disorders and depression, where malfunctions in approach and avoidance behavior play a central role.

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Further information

Dr. Pascal Fries
Max Planck Research Group Leader
Phone: +49 (0)7071 601 606
Email: pascal.fries(at)tuebingen.mpg.de
Max Planck Institute for Biological Cybernetics, Tübingen

Media contact
Dr. Daniel Fleiter
Phone: +49 (0)7071 601 777
Email: daniel.fleiter(at)tuebingen.mpg.de
Max Planck Institute for Biological Cybernetics, Tübingen

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