The brain communicates on several channels

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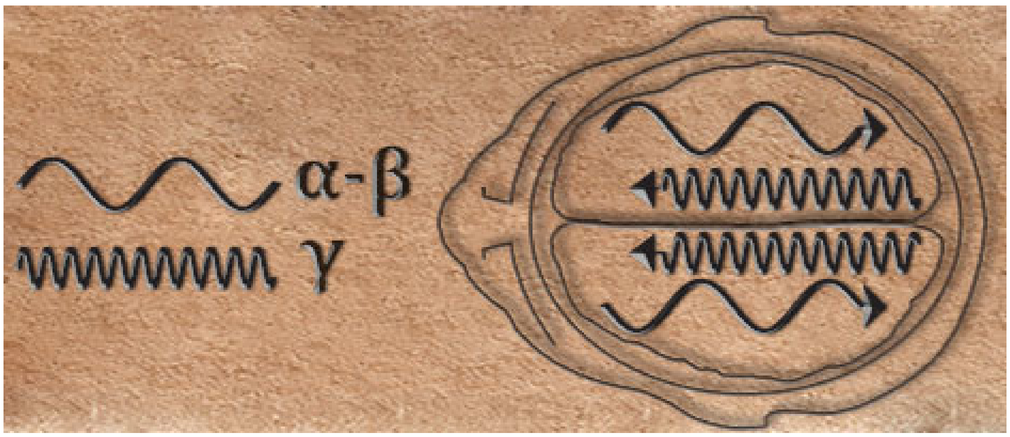

The human brain 'fires' on different channels: nerve cells are active in alpha, beta and gamma channels with different frequencies. This ensures that information can be exchanged between differing brain areas – also, in opposite directions, without the information streams getting mixed up. Credit: © ESI/ G. Michalareas

In the brain, the visual cortex processes visual information and passes it from lower to higher areas of the brain. However, information also flows in the opposite direction, e.g. to direct attention to particular stimuli. But how does the brain know which path the information should take? Researchers at the Ernst Strüngmann Institute (ESI) for Neuroscience in Frankfurt in Cooperation with Max Planck Society have now demonstrated that the visual cortex of human subjects uses different frequency channels depending on the direction in which information is being transported. Their findings were only possible thanks to previous research with macaque monkeys. They might help to understand the cause of psychiatric illnesses in which the two channels appear to be mixed up.

The terms "bottom-up" and "top-down" refer to processes by which the human brain processes information. "In the visual system, bottom-up communication occurs when information enters through the eyes and flows from lower to higher visual areas, i.e. from bottom to top," explains Pascal Fries from the Ernst Strüngmann Institute for Neuroscience.

As soon as a person observes the environment, sensory input is continuously processed using the bottom-up principle. But how do we know that one piece of information is more important than another? Fries: "The top-down principle helps us to do this. The brain uses previous experiences to organize information in the present context and to make predictions on this basis." The top-down flow therefore influences the bottom-up flow and steers our attention towards things that are important in the current situation. This can happen automatically, for example due to the sudden appearance of a threatening stimulus, as well as through attention, for example when we are looking for something or following instructions. "Many of our cognitive capabilities can only be explained by invoking this principle," says Fries.

For the top-down principle to work, the brain requires mechanisms that pass information from higher to lower areas of the brain. The anatomical connections in the top-down direction are known for a long time, but how the information is sent through these connections has remained elusive.

Macaque monkeys helped Fries and his colleagues to get on the right track. First, they examined the bottom-up flow in the brains of those animals and found that it uses a particular frequency band of rhythmic neuronal activity, known as the gamma band, around 60 Hertz. Information flows from bottom to top, when rhythmic oscillatory activity of lower brain areas entrains the rhythm of the next higher area.

Subsequently, the neuroscientists discovered the channel for top-down information flow, namely the so-called alpha and beta frequency rhythms, between 10 and 20 Hertz. Thus, in essence, the hierarchically arranged areas of visual cortex use a separate frequency channel to send information from higher to lower areas.

In their present work, the researchers show that a very similar principle is at work in the human brain. "We knew the rhythms and wanted to look for them in the human brain," explains Fries. To do this, they used a technique known as magnetoencephalography (MEG). MEG uses sensors outside the head to record the magnetic fields, which result from the electric currents of active nerve cells. The measurements allow conclusions to be drawn about the activity in certain areas of the brain. "In the raw MEG data, signals from several brain areas are mixed and have to be separated as well as possible using advanced mathematical methods," says Fries.

This is one of the reasons why the investigations into the macaque brain were so important. As macaques have a very similar brain to humans, scientific insights obtained on macaques can often be transferred to humans. It was thanks to the previous work on the animals that the researchers were able to interpret the MEG measurements correctly.

In their experiments, the researchers demonstrate that the human brain also uses different frequency ranges for bottom-up and top-down signalling. Furthermore, the neurophysiologists were able to describe the hierarchical positioning of additional areas, some of which only present in the human brain. A total of 26 areas were investigated in the human brain.

The new findings might help us to better understand the causes of some psychiatric illnesses to one day be able to treat them. In some mental illnesses, the top-down and bottom-up flow seem to get mixed up. There are indications that in individuals with schizophrenia, the top-down flow does not interact with the bottom-up flow in a normal way. "A healthy person can distinguish between sensory inputs and their interpretation produced in higher areas. For example, they can see facial features in a cloud without thinking that the cloud is a face. Schizophrenic patients may think the face is real, potentially taking the top-down interpretation for a bottom-up sensation," explains Fries.

More information: Georgios Michalareas, Julien Vezoli, Stan van Pelt, Jan-Mathijs Schoffelen, Henry Kennedy, and Pascal Fries, Alpha-beta and gamma rhythms subserve feedback and feedforward influences among human visual cortical areas. *Neuron*, 20 January 2016

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