Research yielding insights into brain's signaling network

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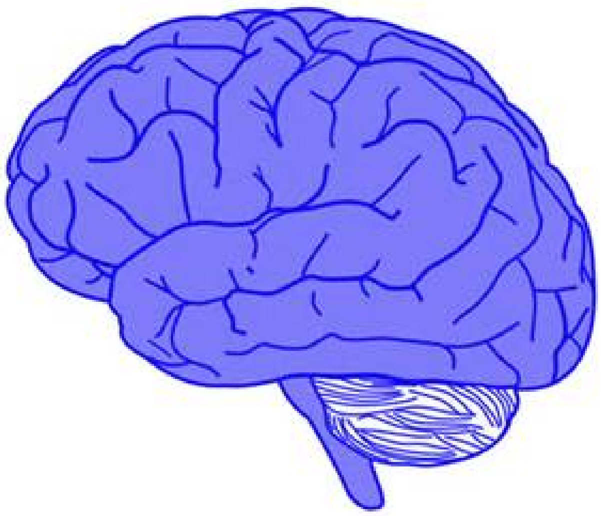

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Researchers have taken an important step toward deciphering the brain's complex neuroelectric communication system that could underlie sleep disorders and conditions such as Alzheimer's, epilepsy and schizophrenia.

The complex communication network connects groups of neurons that can be identified and studied by imaging the brain while a person rests using functional magnetic resonance imaging. Because the brain's resting state is not biased by any particular task, the approach provides a way to study its "intrinsic functional organization," said Zhongming Liu, an assistant professor of biomedical engineering and electrical and computer engineering at Purdue University.

"The rationale behind this is that when the brain is not doing anything it is not literally quiet but remains very active, providing many kinds of signals," he said.

Purdue researchers are working to interpret data from functional magnetic resonance imaging, which monitors blood flow changes in the brain.

"Data related to blood flow are different from the language used by the neurons themselves," said Liu, whose research is also affiliated with the Purdue Institute for Integrative Neuroscience. "The neurons use electrical signals to talk to each other, and these electrical signals happen much faster than blood flow. So we are translating those slow blood-flow signals into the fast signals the neurons use."

New research findings are detailed in a research paper appeared on June 1 in the Journal of Neuroscience, the flagship journal of the Society for Neuroscience. The paper was authored by doctoral student Haiguang Wen and Liu.

The work ties in with the Human Connectome Project, a nationwide effort funded by the National Institutes of Health to map the brain's neural pathways.

To translate the fMRI blood-flow data into the neuroelectric signals used by neurons, the Purdue researchers used brain data from three methods: electrocorticography, which uses sensors on the cortex to record electrical signals; magnetoencephalography, which measures magnetic fields generated by the brain; and electroencephalography, which measures electrical signals on the scalp while a person is also scanned with fMRI.

It is thought that neurons talk to each other by using "oscillations" at the same frequency. While regions communicate with each other in well-defined rhythmic oscillations, researchers are also probing a "scale-free" form of communication that lacks well-defined rhythmic features.

"These featureless signals are often discarded by neuroscientists because they are considered noise or something unimportant," Liu said. "We took these signals out of the trash can and found that they are actually very important because they are synchronized among nearly all groups of neurons in the brain."

At the same time, the fMRI blood-flow data show that the brain networks also function using a "global" form of communication transcending these groups and involving the entire brain.

"We are finding that the seemingly featureless scale-free activity tends to be globally fluctuating and globally synchronized," he said.

Understanding the workings of the brain's complex and global communication network could allow researchers to study the mechanisms behind sleep disorders and various conditions such as schizophrenia, autism, Alzheimer's disease and epilepsy.

Changes or disruptions in the brain's fluctuation of "arousal," or alertness, may play a central role in many disease conditions.

"This scale-free activity is fluctuating due to arousal fluctuation," Liu said. "These signals are globally synchronized across all networks. Importantly, we now know this global communication is using a unique language entirely different from oscillations at specific frequencies used within each individual network. And that is important because it helps in translating the blood flow signal and fluctuation patterns into the different languages the neurons use for different purposes. This brings us one step closer to translating the blood flow signal into the neuronal signal. We haven't completely solved this translation problem, but we think we have solved a major part of it."

Future research will include work to investigate sleep disorders and neurological disorders and also will involve researchers at the Indiana University School of Medicine.

More information: Broadband Electrophysiological Dynamics Contribute to Global Resting-State fMRI Signal. The *Journal of Neuroscience*, 1 June 2016, 36(22): 6030-6040; DOI: 10.1523/JNEUROSCI.0187-16.2016

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