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Differing structures underlie differing brain rhythms in healthy and ill

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Virtual brains modeling epilepsy and schizophrenia display less complexity among functional connections, and other differences compared to healthy brain models, researchers at Case Western Reserve University School of Medicine report.

The researchers worked backward from brain rhythms – the oscillating patterns of electrical activity in the brain recorded on electroencephalograms - from both healthy and ill individuals.

These oscillations relate to the state of awareness. But, instead of seeking answers to how the rhythms emerge, the investigators built models that, when they reproduced the different neural activity patterns seen in real brains, revealed underlying structural differences among the healthy and ill.

Their work is published in the online journal *PLoS Computational Biology.*

"Our hypothesis is that healthy brains share features with the virtual healthy brains and unhealthy brains share features with virtual unhealthy brains," said Roberto Fernández Galán, a professor of neurosciences at Case Western Reserve School of Medicine. Galán has a background in physics, electrophysiology and computational neuroscience.

Galán worked with G. Karl Steinke, a former graduate student in Biomedical Engineering at Case School of Engineering, and now a researcher at Boston Scientific Neroumodulation.

After breaking down the oscillating patterns of brain activity collected from real EEGs and MEGs into a usable form, the researchers applied inverse calculations and reverse engineering to develop brain models they refer to as virtual brains.

The most striking difference they found is in the hierarchical networks of brain connections among the models of healthy and unhealthy brains, Galán said. "The more complex the network, the more normal the EEG pattern."

"A healthy brain network is similar to the airport network," he explained. "There are a small number of hubs with many connections to other airports and a large number of smaller airports with only a few connections." In the brain model, the airports are called nodes and in the healthy model, about 10 percent of nodes are hubs.

In the real brain, the prefrontal cortex, which is a center for complex thought, social behavior and more, is a hub. "It is thus reasonable to think that the functional connectivity of the prefrontal cortex is altered in pathologies like schizophrenia", said Galán.

Indeed, the network in the epileptic brain model is less complex than the healthy model and the network in the schizophrenia model is even less so. The result is that the dominance of the hubs falls off, which may be indicative of a neuropathology or mental illness, the researchers say.

Their analysis reveals that oscillating brain activity in the virtual models appear to emerge from interactions among neurons and not from so-called pacemakers, which some researchers hypothesize are specialized neurons generating different rhythms of activity in the brain.

This information, combined with finding that healthy brain rhythms are not homogeneously distributed across all virtual brain nodes, supports the idea that oscillations may be a mechanism linking perceptual information across sensory and associative areas of the brain, the researchers say.

Galán and Steinke also discovered that nodes receiving the greatest input produced the smallest fluctuations in activity in the healthy and epileptic brain models. But the inverse relationship was not seen in the schizophrenic model.

The researchers have made the computer programs that run their algorithms and simulations available free to clinicians and other investigators who want to test the predictions made by the models or to expand their own studies. They are included in the supplemental materials, along with technical instructions supplied with the paper or at http://www.case.edu/med/galanlab/software.html.

Provided by Case Western Reserve University

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