Medical Xpress

Direct recording shows brain signal persists even in dreamless sleep

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Neuroscientists at Washington University School of Medicine in St. Louis have taken one of the first direct looks at one of the human brain's most fundamental "foundations": a brain signal that never switches off and may support many cognitive functions.

The results, appearing online this week in the *Proceedings of the National Academy of Sciences*, are an important step forward for efforts to outline what neuroscientists call the functional architecture of the brain. Better understanding of this architecture will aid efforts to treat brain injury and mental disorders.

Although the brain's different specialized regions can be considered as a collection of physical structures, functional architecture instead focuses on metaphorical structures formed by brain processes and interactions among different brain regions. The "foundation" highlighted in the new study is a low-frequency signal created by neuronal activity throughout the brain. This signal doesn't switch off even in dreamless sleep, possibly to help maintain basic structure and facilitate offline housekeeping activities.

"A different, more labile and higher-frequency signal known as the gamma frequency activity has been the focus of much brain research in recent years," says first author Biyu He, a graduate student. "But we found that signal loses its large-scale structure in deep sleep, while the low-frequency signal does not, suggesting that the low-frequency signal may be more fundamental."

"What we've been finding is reorienting the way we think about how the brain works," says senior author Marcus Raichle, M.D., professor of radiology, of neurology and of neurobiology. "We're starting to see the brain as being in the prediction business, with ongoing, organized carrier frequencies within the systems of the brain that keep them prepared for the work they need to do to perform mental tasks."

Neurologists have already spent many years exploring the upper levels of the brain's functional architecture. In these studies, researchers typically ask volunteers to perform specific mental tasks as their brains are scanned using functional magnetic resonance imaging (fMRI). Such "goal-oriented" tasks might include looking for or studying a visual stimulus, moving an arm or leg, reading a word or listening for a sound. As the subjects perform these tasks, the scans reveal increases in blood flow to different parts of the brain, which researchers take as indications that the brain areas are contributing to the mental task.

In the past decade, though, scientists have realized that deeper structures underlie goal-oriented mental processes. These underlying brain processes continue to occur even when subjects aren't consciously using their brain to do anything, and the energies that the brain puts into them seem to be much greater than those used for goal-oriented tasks.

"The brain consumes a tremendous amount of the body's energy resources—it's only 2 percent of body weight, but it uses about 20 percent of the energy we take in," says Raichle. "When we started to ask where all those resources were being spent, we found that the goal-oriented tasks we had studied previously only accounted for a tiny portion of that energy budget. The rest appears to go into activities and processes that maintain a state of readiness in the brain."

To explore this deeper level of the brain's functional architecture, Raichle and others have been using fMRI to conduct detailed analyses of brain activity in subjects asked to do nothing. However, a nagging question has dogged those and other fMRI studies: Scientists assumed that increased blood flow to a part of the brain indicates that part has contributed to a mental task, but they wanted more direct evidence linking increased blood flow to stepped-up activity in brain cells.

In the new study, He and her colleagues took fMRI scans of five patients with intractable epilepsy at St. Louis Children's Hospital. The scans, during which the subjects did nothing, were taken prior to the temporary installation of grids of electrodes on the surfaces of the patients' brains. The level of detail provided by the grids is essential clinically for pinpointing the source of the seizures for possible surgical removal, a last resort employed only when other treatments failed.

Patients and their guardians gave permission to use the clinical data gathered from these electrodes for scientific research purposes. He's results confirmed that the fMRI data she had gathered earlier reflected changes in brain cell activity exhibited in the gamma frequency signal. But she also noticed the persistent low-frequency signal, which also corresponded to the fMRI data.

"When we looked back in the literature, we found that a similar signal had been the subject of a great deal of animal research using implanted electrodes in the 1960s through the 1980s," she says. "There were suggestions, for example, that when this low-frequency signal, which fluctuates persistently, is in a low trough, the brain may handle mental tasks more effectively."

"What we've shown provides a bridge between the fMRI work many scientists are doing now and the earlier work involving electrical recordings from the brain that emphasized slow activity," says He. "Bringing those two fields together may give us some very interesting insights into the brain's organization and function."