Discarded data may be gateway to new brain insights

May 12 2010

Scientists regularly discard up to 90 percent of the signals from monitoring of brain waves, one of the oldest techniques for observing changes in brain activity. They discard this data as noise because it produces a seemingly irregular pattern like those seen in river fluctuations, seismic waves, heart rates, stock market prices and a wide variety of other phenomena.

Now, though, researchers at Washington University School of Medicine in St. Louis have found evidence that these data may contain significant information about how the brain works. In a study published in the May 13 *Neuron,* a closer look reveals not only previously unrecognized patterns in the data but also shows that putting the brain to work on a simple task can change those patterns.

"We don't yet know how to decode the information contained in these signals, but the fact that they're such a large part of brain activity and that they can be modulated when you do a task suggests that they are going to be very important to understanding the brain," says lead author Biyu Jade He, PhD, a postdoctoral fellow.

Electroencephalography (EEG), a long-established technique for monitoring brain waves, involves attaching an array of electrodes to the head. The electrodes can detect minute changes in electrical fields caused by brain cells firing.

Routine EEG analysis, used both in basic research and in clinical contexts such as epilepsy and sleep disorders, focuses on periodic components of EEG activity that are caused by millions of brain cells firing in coordination. These components are known as brain waves, and they occur at varying frequencies. Slow waves during sleep, for example, occur about once per second.

The remaining, irregular signals in EEG recordings didn't seem to contain useful information. By using a mathematical technique called spectral analysis, neuroscientists have found that these "irregular" signals produce a regular pattern: a diagonal line on the results graph that goes from the upper left (high-power, low-frequency brain waves) to the lower right (low-power, high-frequency brain waves).

That didn't seem interesting because spectral analyses of many other phenomena produce the same pattern. In linguistics, for example, analysis of the most frequently used words in a language and the number of times they appear in a typical text produces a similar diagonal line. Analyzing changes in stock market prices versus how fast they change, or the power and frequency of waves of seismic energy also produces similar results.

"Why this pattern is so common is one of the great questions of modern physics, and it's spawned a relatively young field of research called complex dynamics," says Biyu He. "With the exception of a few labs, though, this hasn't been given much consideration in neuroscience."

She studied data gathered from five patients with drug-resistant epilepsy. To treat these patients, surgeons temporarily implant grids of electrodes on the surface of the brain, allowing them to gather detailed EEG readings and pinpoint the source of the seizures for surgical removal.

Using a technique called nested-frequency analysis, she showed that the temporal connections between low-frequency brain waves and high-frequency brain waves are more extensive than previously realized.

"These temporal connections reach outside of the domains of periodic brain waves that neuroscientists study and into the irregular, arrhythmic brain activity that we discard," she explains. "This suggests that there are patterns of temporal organization in those irregular signals. Those patterns may reflect important aspects of brain architecture and function."

Next, scientists asked six patients with electrode implants to press a button either in response to a cue or at random time intervals that they chose. During these experiments, Biyu He identified changes in the power spectrum of this irregular brain activity in brain regions involved in performing the tasks.

"Given that this statistical pattern of activity is so common in the world around us, it makes sense that evolution would mold our brains into a similar organization, and that our cultural activities, such as language or the stock market, would reflect that pattern," she speculates.

Biyu He completed her doctorate in neuroscience in the laboratory of Marcus Raichle, MD, professor of neurology, of radiology and of neurobiology. Raichle, a coauthor on the Neuron paper, pioneered approaches to the study of brain function at rest that have revealed significant insights into what researchers had previously regarded as noise.

"The noisy activity of the brain at rest and in the background when we perform tasks actually represents the majority of what the brain is really doing" Raichle says. "We know this to be the case when we measure the cost of running the brain and find that this background activity accounts for most of it. Biyu's pioneering research is a major step forward in helping us understand how this background activity is organized."

More information: He BJ, Zempel JM, Snyder AZ, Raichle ME. The temporal structures and functional significance of scale-free brain activity. Neuron, May 13, 2010.

Provided by Washington University School of Medicine