Deciphering hidden code reveals brain activity

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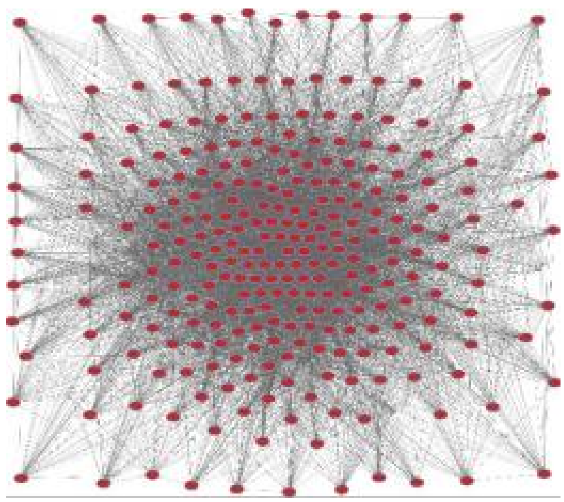

University of Pennsylvania scientists have shown that the mathematics used to find an efficient route through a complicated, connected network can be used to decode how the brain represents information.

(PhysOrg.com) -- By combining sophisticated mathematical techniques more commonly used by spies instead of scientists with the power and versatility of functional magnetic resonance imaging (fMRI), a Penn neurologist has developed a new approach for studying the inner workings of the brain. A hidden pattern is encoded in the seemingly random order of things presented to a human subject, which the brain reveals when observed with fMRI. The research is published in the journal *NeuroImage*.

Geoffrey K. Aguirre, MD, assistant professor of Neurology at the University of Pennsylvania School of Medicine, says "the same math that could break into your car can be used to crack the brain's codes." It's called a de Bruijn sequence, which is a set or "alphabet" of things (letters, pictures, sounds) in a cyclic order such that every possible "word" or combination of things occurs only once. De Bruijn sequences are what mathematicians call "pseudo-random" because they appear to be a confused jumble but actually contain an underlying structure. To break into a car protected by an electronic lock with a five-digit numerical keycode, for example, a thief could try every possible combination. However, such a brute-force technique is time-consuming because it involves a great deal of repetition. But a de Bruijn sequence uses "every possible combination squeezed together," explains Aguirre. The overlapping combinations encode a pattern scientists can observe in brain activity using fMRI, revealing how nerve cells work to represent the world.

Breaking Codes in Brain Studies

This approach measures how the order of things changes brain responses. Do you see a photo of your brother differently when it follows a picture of your sister? Aguirre says, "Many neuroscience experiments use the context and order of sights, sounds, words, and feelings to reveal how the nervous system is organized."

Previous experiments have presented information to study participants in more or less completely random order. This can be inefficient and inaccurate, making it difficult to discern important patterns and correlations between stimuli and neural responses. "We use the de Bruijn sequence to design the experiment," Aguirre says. "It tells us how to present things to the subject. By presenting a series of faces in different combinations and orders, as dictated by the de Bruijn sequence, it's possible to measure the brain response to each face individually."

Beating the Blood Flow Problem

Aguirre's new algorithm for creating de Bruijn sequences also helps correct an important limitation of fMRI, which works by measuring changes in brain blood flow. "It takes a little while for the blood flow changes to catch up with the brain response," Aguirre says. "By creating these sequences in a special way that accounts for the slower blood flow response, experiments are many times more powerful than before."

"The amazing thing is the person in the experiment just sees random pictures," Aguirre notes. "But in fact, we're hiding in this seemingly random sequence a signal that's invisible to the person but can be decoded by the MRI scanner. We can measure the nerve cells' response to that hidden pattern and then use that to understand how the brain is representing information."

Aguirre's unique marriage of advanced mathematics with the latest neuroimaging techniques promises to both open up new areas of research and improve current experimental designs in the study of the brain. The next step is to apply the new algorithm to actual fMRI studies in one of Aguirre's special research areas, visual perception and representation in the brain.

More information: Aguirre, G.K., et al., de Bruijn cycles for neural decoding, *NeuroImage* (2011), doi:10.1016/j.neuro-image.2011.02.005

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