Making memories: Researchers explore the anatomy of recollection

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With the help of data collected from intracranial electrodes implanted on epilepsy patients, researchers in Drexel's School of Biomedical Engineering, Science and Health Systems are getting a rare look inside the brain in hopes of discovering the exact pattern of activity that produces a memory.

What was your high school mascot? Where did you put your keys last night? Who was the first president of the United States?

Groups of neurons in your brain are currently sending electromagnetic rhythms through established pathways in order for you to recall the answers to each of these questions. Researchers in Drexel's School of Biomedical Engineering, Science and Health Systems are now getting a rare look inside the brain to discover the exact pattern of activity that produces a memory.

Dr. Joshua Jacobs, a professor in Drexel's School of Biomedical Engineering, Science and Health Systems, is analyzing data accumulated from 60 epilepsy patients who have had electrodes implanted on their brains in order to determine the causes of their epileptic episodes.

"When performing seizure mapping, surgeons implant electrodes in many brain areas, while searching for seizure activity," Jacobs said. "Thus, there many electrodes end up being in normal brain tissue, and they measure neuronal activity that reflects normal brain function – this is the function that we're studying to learn about the nature of working memory."

A Hi-Res Look at the Brain

This type of study is unique because researchers are essentially looking at a more detailed picture of the brain than those generated from the more common electroencephalogram (EEG) and magnetic resonance imaging (MRI).

"Because the electrodes are implanted directly on the brain surface, inside of the skull, they measure brain activity more precisely than noninvasive technique, such as EEG or MRI," Jacobs said. "This reveals more detailed brain patterns than can be observed with external recording technology."

Jacobs equates his research technique to using a set of microphones to record an orchestra. If each microphone is positioned right next to an individual instrument, it gives a better recording than if the microphones are outside of the building.

The Mental Time Machine

Jacobs and his research assistants are monitoring patients' memory-related brain activity in two ways.

First, for some subjects, they record brain activity near the electrodes while asking the patients a series of questions designed to make them use their active memory. The prompts include exercises such as reciting a sequence of letters or numbers or remembering information about sets that are presented to them. The process of coming up with these answers activates the parts of the brain responsible for working, or short-term, memory.

For other subjects, the researchers add electric stimulus to various sets of electrodes while questioning the patient and recording the effects of the administered stimuli on the patients' responses.

In a recent study, a rare opportunity presented itself to combine the two types of brain monitoring and data collection. This testing that has yielded one of Jacobs' most interesting discoveries thus far.

"We explored the rare but fascinating phenomenon of how applying electrical current to a patient's brain surface causes them to remember old memories," Jacobs said.

During a series of testing sessions with a single patient, the researchers stimulated an area of the patient's brain that triggered his high school memories.

In a follow-up a week later, Jacobs asked the patient a series of questions, including some about high school experiences and people from high school, while monitoring the brain activity. What he found was that the areas of the brain that he stimulated to cause the patient to have memories about high school, were the same areas that responded when the patient was asked to recall information about high school on his own.

"By conducting this unique experiment that combined brain stimulation and normal recordings without stimulation, our findings suggest that stimulation causes memory retrieval when it puts the brain back in the old brain state that corresponds to a memory," Jacobs said. "Thus, stimulation causes a sort of neural time travel."

Moving Forward on Thinking Back

Jacobs is in his third year of research in conjunction with The University of Pennsylvania, Jefferson Hospital and UCLA's medical center. Thus far he's examined 60 subjects, but the research has already yielded some intriguing results, including the high school memory discovery, which Jacobs recently published in the *Journal of Cognitive Neuroscience* and presented at the Society for Neuroscience.

One of the ways that Jacobs' work could prove valuable in mental health studies is by helping to answer questions about the nature of schizophrenia. A recent grant from the Brain & Behavior Research Foundation Scientific Council has charged Jacobs to examine the link between disruptions in working-memory pathways and schizophrenia.

"Going forward, I am interested in characterizing how the human brain represents a range of different memories and, in particular, distinguishing the extent to which separate memories are stored in individual, specialized brain regions or whether memories are represented throughout the entire brain," Jacobs said.

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