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## MEDICAL DISPATCH

### SILENT MINDS

*What scanning techniques are revealing about vegetative patients.*

BY JEROME GROOPMAN

Ten years ago, Adrian Owen, a young British neuroscientist, was working at a brain-imaging center at Addenbrooke's Hospital, at the University of Cambridge. He had recently returned from the Montreal Neurological Institute, where he used advanced scanning technology to map areas of the brain, including those involved in recognizing human faces, and he was eager to continue his research. The imaging center was next to the hospital's neurological intensive-care unit, and Owen heard about a patient there named Kate Bainbridge, a twenty-six-year-old school-teacher who had become comatose after a flu-like illness, and was eventually diagnosed as being in what neurologists call a vegetative state. Owen decided to scan Bainbridge's brain. "We were looking for interesting patients to study," he told me. "She was the first vegetative patient I came across."

For four months, Bainbridge had not spoken or responded to her family or her doctors, although her eyes were often open and roving. (A person in a coma appears to be asleep and is unaware of even painful stimulation; a person in a vegetative state has periods of wakefulness but shows no awareness of her environment and does not make purposeful movements.) Owen placed Bainbridge in a PET scanner, a machine that records changes in metabolism and blood flow in the brain, and, on a screen in front of her, projected photographs of faces belonging to members of her family, as well as digitally distorted images, in which the faces were unrecognizable. Whenever pictures of Bainbridge's family flashed on the screen, an area of her brain called the fusiform gyrus, which neuroscientists had identified as playing a central role in face recognition, lit up on the scan. "We were stunned," Owen told me. "The fusiform-gyrus activation in her brain was not simply similar to normal; it was exactly the same as normal volunteers."

Excited by this result, Owen resolved to try to conduct brain scans of other vegetative patients in the Cambridge area. Since 1997, he has studied several dozen people, though he decided to use speech sounds rather than photographs to stimulate their brains. (Owen was concerned that showing images of faces might not be a reliable way to test recognition, since the eyes of vegetative patients often wander. "We shifted to auditory responses because you can always put a pair of headphones on the person and know that you are transmitting sound," he said.) Three years ago, he began using a functional MRI (fMRI) scanner, which is faster than a PET scanner, capturing changes in blood flow in the brain almost as they occur. The patients' brains were scanned while they listened to a recording of simple sentences interspersed with meaningless "noise sounds." The scans of some of the patients showed the same response to the sentences as scans of healthy volunteers, but Owen wasn't sure that the patients had understood the words. "So we went the next step up the cognitive ladder, to look at comprehension," he said.

Psycholinguists have shown that when we hear a noun at the beginning of a sentence we tend to associate the word with its most common meaning. For example, Owen said, most people hearing a sentence that begins, "The shell was . . ." think of an object typically found at the beach. But if the sentence is completed by the phrase "fired at the tank," the listener quickly corrects himself, a process that is evident on a brain scan. "You can actually see it happening and image it on the scanner," Owen said. "The beautiful thing about the psychological task is that we just do it automatically. When you play ambiguous sentences, areas in the inferior frontal lobe and in the posterior temporal lobe become activated, and these areas

are very important for speech comprehension. They show that you understand the meaning of the word: it's not just about perceiving speech; it's about decoding. Your brain somehow appreciates that there are two meanings to a word like 'shell.'"

Owen eventually identified two vegetative patients whose brains showed the same activity in response to ambiguous sentences as the brains of healthy volunteers. He also took brain scans of healthy physicians, who were presented with the ambiguous sentences while under general anesthesia. Owen found that, as the effects of the anesthesia increased, the physicians showed less activity in the brain regions associated with comprehension. "That, of course, is in keeping with our personal experience of consciousness, which is that as you sort of drift into sleep you understand less and less of what is around you," he said. (An article about this experiment appears this week in *PNAS*, the journal of the National Academy of Sciences.)

Owen's final experiment was the most ambitious: a test to determine whether vegetative patients who seemed able to comprehend speech could also perform a complex mental task on command. He decided to ask them to imagine playing tennis. ("We chose sports, and tried to find one that involved a lot of upper-body movements and not too much running around," he said.) First, he took brain scans of thirty-four healthy volunteers who were instructed to picture themselves playing the game for at least thirty seconds. Their brains showed activity in a region of the cerebrum that would be stimulated in an actual match. "This was an extremely robust activation, and it wasn't difficult to tell whether somebody was imagining tennis or not," Owen said. He then repeated the experiment using one of the vegetative patients, a woman

who had been severely injured in a car accident. The woman had to be able to hear and understand Owen's instructions, retrieve a memory of tennis—including a conception of forehand and backhand and how the ball and the racket meet—and focus her attention for at least thirty seconds. To Owen's astonishment, she passed the test. "Lo and behold, she produced a beautiful activa-

tion, indistinguishable from those of the group of normal volunteers," he said. (Another vegetative patient, a man in his twenties, also passed the test, though Owen, having learned that the man was a soccer fan, asked him to imagine playing that sport instead of tennis.)

agreed-upon criteria, and there wasn't anything that she did that would lead anybody to say she wasn't vegetative," he told me. "Now, naturally, in hindsight she wasn't vegetative; she was actually conscious. It's a very interesting issue, because it means that she was in fact misdiagnosed, but not misdiagnosed in the sense that somebody made an error. Clearly, she is consciously aware

of things around her. So something is missing in the diagnostic criteria."

For decades, doctors assumed that patients who have been diagnosed as vegetative lack any capacity for conscious thought. Most are previously healthy people who suffered a traumatic brain injury, or oxygen deprivation after a heart attack or stroke, and have been regarded more or less as zombies: patients whose bodies continue to function—sometimes for decades—but whose minds are incapable of willed activity. (The term "vegetative" was proposed in 1972, by Bryan Jennett, a neurosurgeon, and Fred Plum, a neurologist, who chose it based on a definition in the O.E.D.: "an organic body capable of growth and development but devoid of sensation and thought.") In the occasional newspaper stories about someone



Brain scans showed one patient was able to imagine playing tennis.

who suddenly recovered consciousness after spending years in a vegetative state, the event was invariably described as a medically inexplicable "miracle." The Mohonk Report, a paper prepared by a group of experts in brain injury and presented to Congress last year, cited estimates suggesting that there are approximately thirty-five thousand Americans in a vegetative state and another two hundred and eighty thousand in a minimally conscious state—a less severe condition, in which patients show erratic evidence of deliberate behavior, such as responding to a simple command or focussing on a person or an object for a sustained period. Because insurers typically won't pay for rehabili-

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