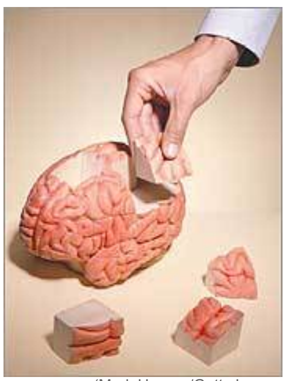
LIFE OF THE MIND

Picturing our thoughts

We're looking for too much in brain scans.

By Jonah Lehrer
August 17, 2008

In May 1991, Dr. Kenneth Kwong, a radiologist at Massachusetts General Hospital, became one of the first scientists to enjoy a new vision of the human brain. The experiment was simple: Kwong would show a subject some visual stimuli - such as a sequence of flashing red lights - and then monitor the brain to see how it reacted. To Kwong's surprise, even a brief light show triggered a telltale pattern of activity in the visual cortex, as the brain processed the sensory information.


(Mark Hooper/Getty Images)

"It took a few months before I believed what I was seeing," Kwong remembers. "I was actually watching the brain at work."

This ability to peer inside the mind was made possible by a new technology known as fMRI, or functional magnetic resonance imaging. The technology quickly became one of the most popular tools of neuroscience. Last year, an average of eight peer-reviewed papers using fMRI were published per day, and more than 19,000 fMRI papers have been published in the last 15 years. The past few months have brought articles on everything from the neural substrate of sarcasm to the patterns of brain activation triggered by pornography. The technique is invading other fields as well, as psychologists, psychiatrists, philosophers, and even economists increasingly rely on these powerful machines.

The brain scan image - a silhouette of the skull, highlighted with bright splotches of primary color - has also become a staple of popular culture, a symbol of how scientific advances are changing the way we think about ourselves. For the first time in human history, the black box of the mind has been flung wide open, allowing researchers to search for the cortical source for every flickering thought. The expensive scanners can even decode the hidden urges of the unconscious, revealing those secret feelings that we hide from ourselves. The machine, in other words, knows more about you than you do: It's like a high-tech window into the soul.

"These [fMRI] images get people excited in a way that other research just doesn't," says Kelly Joyce, a sociologist at the College of William & Mary. "The pictures have a tremendous authority, not only among scientists but among people who might just glance at a brain scan picture in a newspaper."

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In recent weeks, however, several high-profile papers have ignited a fierce debate over whether brain scanners are being widely misused and their results over-interpreted. Some eminent figures in the field have taken issue with the metaphors typically used to describe brain imaging, criticizing descriptions of scanners that rely on what Joyce refers to as the "myth of transparency."

The scanners, they say, excel at measuring certain types of brain activity, but are also effectively blind when it comes to the detection of more subtle aspects of cognition. As a result, the pictures that seem so precise are often deeply skewed snapshots of mental activity. Furthermore, one of the most common uses of brain scanners - taking a complex psychological phenomenon and pinning it to a particular bit of cortex - is now being criticized as a potentially serious oversimplification of how the brain works. These critics stress the interconnectivity of the brain, noting that virtually every thought and feeling emerges from the crosstalk of different areas spread across the cortex. If fMRI is a window into the soul, these scientists say, then the glass is very, very dirty.

"There are so many bad brain imaging studies, it's hard to believe," says Nikos K. Logothetis, director of the Max Planck Institute for Biological Cybernetics in Germany. "Too many of these experiments are being done by people who, unfortunately, don't really understand what the technology can and cannot do."

Logothetis and others believe that much of the misuse stems from the visual nature of the data. One study, by researchers at Colorado State University, showed that simply giving neuroscience students images from an fMRI machine, even if the images were redundant or irrelevant, made the students significantly more likely to find the data credible. According to Paul Bloom, a psychologist at Yale, this is because fMRI "has all the trappings of work with great lab-cred: big, expensive, and potentially dangerous machines, hospitals and medical centers, and a lot of people in white coats."

The data looks rigorous - it has the veneer of cutting-edge science - and people assume it's valid, even when the reasoning is shoddy.

"You can't just put people in a scanner and ask them whatever question you want," Logothetis says. "Many of these [fMRI] papers are such oversimplifications of what's happening in the brain as to be worthless."

A typical fMRI experiment goes like this: a subject is slipped into a tight space that's about the size of a coffin. The person is told to lie perfectly still, as even the slightest movement will muddy the results. At first, the subject does nothing. Then, he or she performs the experimental task, which might involve looking at a picture or making a decision.

While this is happening, noisy magnets whir overhead, as the machine detects the slightly different magnetic properties of blood with and without oxygen. The underlying assumption is that more active neurons require more oxygenated blood. Follow the oxygen, and you can construct precise maps of the brain at work.

Last year, the New York Times published an op-ed that used fMRI to investigate the brains of swing voters as they stared at photos and videos of presidential candidates. For instance, the scientists found that pictures of Mitt Romney led to activity in the amygdala, while pictures of Hillary Clinton activated the anterior cingulate. (Interestingly, the only two candidates who inspired "little activity in areas of the brain associated with thought or feeling" were Barack Obama and John McCain.)

Within days, 17 prominent cognitive neuroscientists signed a letter criticizing the study. "We are distressed," the scientists wrote, "by the publication of research . .

. that uses flawed reasoning to draw unfounded conclusions about topics as important as the presidential election." The critics pointed out that a specific brain area, such as the amygdala, can be involved in the production of a wide variety of emotions, from fear to pleasure. This makes it extremely difficult, if not impossible, to decipher the hidden feelings of people based on brain scans alone.

As Logothetis points out, the critical flaw of such studies is that they neglect the vast interconnectivity of the brain. How a voter feels about a politician is almost certainly the result of numerous interacting brain regions, and cannot be easily reduced to the activity of a single area. Because large swaths of the cortex are involved in almost every aspect of cognition - even a mind at rest exhibits widespread neural activity - the typical fMRI image, with its highly localized spots of color, can be deceptive. The technology makes sense of the mind by leaving lots of stuff out - it attempts to sort the "noise" from the "signal" - but sometimes what's left out is essential to understanding what's really going on.

"Unfortunately, these pretty pictures hide the sausage factory," says Geoffrey K. Aguirre, a professor of neurology at the University of Pennsylvania. When Aguirre looks at an fMRI image, he reminds himself that the picture is actually some "fancy statistics," and not an exact snapshot of brain activity. "It's important to ask what assumptions allowed the researchers to find these patterns of activity," he says.

The reason fMRI data requires so much statistical analysis is that the machines rely on indirect measurements of brain activity. Neurons communicate using bursts of electricity and squirts of neurotransmitter, but the scanners can only calculate changes in blood flow. In 2001, Logothetis published one of the first papers to directly test whether blood flow can be used as a proxy for what neurons are doing. Although he found that changes in blood flow often correlated with changes in neural activity, Logothetis also concluded that certain types of neural activity couldn't be reliably detected by fMRI. In these instances, increased blood flow could occur at the same time as a flat - or even decreasing - neural firing rate. As a result, scientists might see activation where there was only a subdued circuit of cells.

More recently, a paper from the lab of Mriganka Sur at MIT reported that the vast majority of the signal detected by fMRI machines was actually a byproduct of astrocytes, which are common cells in the brain that provide neurons with oxygen and energy. When the activity of astrocytes was blocked, but the activity of neurons remained unchanged, 80 to 90 percent of the fMRI signal disappeared. This suggests that fMRI machines are vulnerable to any disorder or drug that leads to changes in astrocyte function, since such changes will dramatically skew the imaging data. "Astrocytes remain so poorly understood," says Sur, "but researchers should keep in mind that astrocytes are largely what fMRI is measuring, and not neural activity directly."

Given the limitations of fMRI machines, many researchers have begun to wonder why the technology maintains such a grip on both mainstream neuroscience and popular culture. Some scientists argue that part of the problem is the relative ease of brain imaging research. "So much of the work is done by computers," Aguirre says. "It only takes about a week to learn how to do an fMRI experiment." This means that even researchers with a limited understanding of how the brain works can produce papers detailing aspects of brain function.

Other scientists are studying how the presence of fMRI images can lead people to overlook flaws in scientific reasoning. Deena Skolnick Weisberg, a researcher at Rutgers University, recently demonstrated how referencing brain scans can bias the evaluation of scientific papers. When she gave neuroscience students and ordinary adults a few examples of obviously flawed scientific explanations, people were consistently able to find the flaws. However, when the same explanations were prefaced with the phrase "Brain scans indicate" both the students and adults became much less critical.

While fMRI might not be a window into the soul, or even a particularly accurate reader of minds, it remains a useful technology when properly used. Some scientists, such as Logothetis, believe that brain scanners are best used in conjunction with other experimental tools, such as those that measure brain waves or the electrical activity of individual neurons. "The only way to really know what the brain is doing is to look at the brain in a variety of different ways," he says.

The problem, of course, is that these other research methods don't generate colorful graphics of the cortex, which can make them seem less accurate, meaningful, and exciting. The human brain, it turns out, loves to look at pictures of itself.

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