Hacking the Soul

10 COMMENTS

It was an expedition seeking something never caught before: a single human neuron lighting up to create an urge, albeit for the minor task of moving an index finger, before the subject was even aware of feeling anything. Four years ago, Itzhak Fried, a neurosurgeon at the University of California, Los Angeles, slipped several probes, each with eight hairlike electrodes able to record from single neurons, into the brains of epilepsy patients. (The patients were undergoing surgery to diagnose the source of severe seizures and had agreed to participate in experiments during the process.) Probes in place, the patients – who were conscious – were given instructions to press a button at any time of their choosing, but also to report when they'd first felt the urge to do so.

Later, Gabriel Kreiman, a neuroscientist at Harvard Medical School and Children's Hospital in Boston, captured the quarry. Poring over data after surgeries in 12 patients, he found telltale flashes of individual neurons in the pre-supplementary motor area (associated with movement) and the anterior cingulate (associated with motivation and attention), preceding the reported urges by anywhere from hundreds of milliseconds to several seconds. It was a direct neural measurement of the unconscious brain at work – caught in the act of formulating a volitional, or freely willed, decision. Now Kreiman and his colleagues are planning to repeat the feat, but this time they aim to detect pre-urge signatures in real time and stop the subject from performing the action – or see if that's even possible.

A variety of imaging studies in humans have revealed that brain activity related to decision-making tends to precede conscious action. Implants in macaques and other animals have examined brain circuits involved in perception and action. But Kreiman broke ground by directly measuring a preconscious decision in humans at the level of single neurons. To be sure, the readouts came from an average of just 20 neurons in each patient. (The human brain has about 86 billion of them, each with thousands of connections.) And ultimately, those neurons fired only in response to a chain of even earlier events. But as more such experiments peer deeper into the labyrinth of neural activity behind decisions – whether they involve moving a finger or opting to buy, eat, or kill something – science could eventually tease out the full circuitry of decision-making and perhaps point to behavioral therapies or treatments. "We need to understand the neuronal basis of voluntary decision-making – or 'freely willed' decision-making – and its pathological counterparts if we want to help people such as drug, sex, food, and gambling addicts, or patients with obsessive-compulsive disorder," says Christof Koch, chief scientist at the Allen Institute of Brain Science in Seattle (see "Cracking the Brain's Codes"). "Many of these people perfectly well know that what they are doing is dysfunctional but feel powerless to prevent themselves from engaging in these behaviors."

There is no "god in the machine"—only neurons that are firing, Kreiman says.

Kreiman, 42, believes his work challenges important Western philosophical ideas about free will. The Argentine-born neuroscientist, an associate professor at Harvard Medical School, specializes in visual object recognition and memory formation, which draw partly on unconscious processes. He has a thick mop of black hair and a tendency to pause and think a long moment before reframing a question and replying to it expansively. At the wheel of his Jeep as we drove down Broadway in Cambridge, Massachusetts, Kreiman leaned over to adjust the MP3 player – toggling between Vivaldi, Lady Gaga, and Bach. As he did so, his left hand, the one on the steering wheel, slipped to let the Jeep drift a bit over the double yellow lines. Kreiman's view is that his neurons made him do it, and they also made him correct his small error an instant later; in short, all actions are the result of neural computations and nothing more. "I am interested in a basic age-old question," he says. "Are decisions really free? I have a somewhat extreme view of this – that there is nothing really free about free will. Ultimately, there are neurons that obey the laws of physics and mathematics. It's fine if you say 'I decided' – that's the language we use. But there is no god in the machine – only neurons that are firing."

Our philosophical ideas about free will date back to Aristotle and were systematized by René Descartes, who argued that humans possess a God-given "mind," separate from our material bodies, that endows us with the capacity to freely choose one thing rather than another. Kreiman takes this as his departure point. But he's not arguing that we lack any control over ourselves. He doesn't say that our decisions aren't influenced by evolution, experiences, societal norms, sensations, and perceived consequences. "All of these external influences are fundamental to the way we decide what we do," he says. "We do have experiences, we do learn, we can change our behavior."

But the firing of a neuron that guides us one way or another is ultimately like the toss of a coin, Kreiman insists. "The rules that govern our decisions are similar to the rules that govern whether a coin will land one way or the other. Ultimately there is physics; it is chaotic in both cases, but at the end of the day, nobody will argue the coin 'wanted' to land heads or tails. There is no real volition to the coin."

Testing Free Will

It's only in the past three to four decades that imaging tools and probes have been able to measure what actually happens in the brain. A key research milestone was reached in the early 1980s when Benjamin Libet, a researcher in the physiology department at the University of California, San Francisco, made a remarkable study that tested the idea of conscious free will with actual data.

Libet fitted subjects with EEGs – gadgets that measure aggregate electrical brain activity through the scalp – and had them look at a clock dial that spun around every 2.8 seconds. The subjects were asked to press a button whenever they chose to do so – but told they should also take note of where the time hand was when they first felt the "wish or urge." It turns out that the actual brain activity involved in the action began 300 milliseconds, on average, before the subject was conscious of wanting to press the button. While some scientists criticized the methods – questioning, among other things, the accuracy of the subjects' self-reporting – the study set others thinking about how to investigate the same questions. Since then, functional magnetic resonance imaging (fMRI) has been used to map brain activity by measuring blood flow, and other studies have also measured brain activity processes that take place before decisions are made. But while fMRI transformed brain science, it was still only an indirect tool, providing very low spatial resolution and averaging data from millions of neurons. Kreiman's own study design was the same as Libet's, with the important addition of the direct single-neuron measurement.

When Libet was in his prime, Kreiman was a boy. As a student of physical chemistry at the University of Buenos Aires, he was interested in neurons and brains. When he went for his PhD at Caltech, his passion solidified under his advisor, Koch. Koch was deep in collaboration with Francis Crick, co-discoverer of DNA's structure, to look for evidence of how consciousness was represented by neurons. For the star-struck kid from Argentina, "it was really life-changing," he recalls. "Several decades ago, people said this was not a question serious scientists should be thinking about; they either had to be smoking something or have a Nobel Prize" – and Crick, of course, was a Nobelist. Crick hypothesized that studying how the brain processed visual information was one way to study consciousness (we tap unconscious processes to quickly decipher scenes and objects), and he collaborated with Koch on a number of important studies. Kreiman was inspired by the work. "I was very excited about the possibility of asking what seems to be the most fundamental aspect of cognition, consciousness, and free will in a reductionist way – in terms of neurons and circuits of neurons," he says.

One thing was in short supply: humans willing to have scientists cut open their skulls and poke at their brains. One day in the late 1990s, Kreiman attended a journal club – a kind of book club for scientists reviewing the latest literature – and came across a paper by Fried on how to do brain science in people getting electrodes implanted in their brains to identify the source of severe epileptic seizures. Before he'd heard of Fried, "I thought examining the activity of neurons was the domain of monkeys and rats and cats, not humans," Kreiman says. Crick introduced Koch to Fried, and soon Koch, Fried, and Kreiman were collaborating on studies that investigated human neural activity, including the experiment that made the direct neural measurement of the urge to move a finger. "This was the opening shot in a new phase of the investigation of questions of voluntary action and free will," Koch says.

Better Decisions

A perennial debate in philosophy is whether, if our choices are caused by something (anything), we can still be said to possess free will. Hilary Bok, a philosopher at Johns Hopkins University, says many modern philosophers – perhaps most – believe freedom of decision is possible, but that of course neural processes lead to urges and actions. "The idea that your choice might be caused – including by something happening in the brain – occurred to us a long time before the neuroscientists started filling in the details of how it happened," she says. Freedom doesn't require a ghost in the machine; we might still have some sort of free will if it can be shown that our neural circuits give us the capacity to weigh options and choose the right ones. "I love these experiments and think they are really interesting," she says, "but I'm less convinced whether they have shown anything crucial about free will."

What's really important about the experiments, she adds, is that they start to provide insights into human behavior. This could someday lead to therapies, but until then, insight alone can help. Consider the case of James Fallon, a neuroscientist at the University of California, Irvine, who discovered that his own fMRI scan bore similarities to those of known psychopaths (it indicated low activity in brain regions associated with self-control and empathy). Fallon has described how he now makes a conscious effort to modify his everyday decisions and behaviors – such as his tendency to want to defeat his young grandchildren at games. "When I think about freedom of the will, a part of what is required is that we have some ability to control our own actions," Bok says. "It would be important to me to discover whether a psychopath who decides to use his or her narcissism to defeat that narcissism can actually succeed."

Though it's still at an early stage, Kreiman's work adds to this kind of understanding, says Patricia Churchland, a philosopher at the University of California, San Diego, who avers that neuroscience can illuminate old philosophical questions. Churchland believes that the experiments could be important in shedding light on whether decisions can be altered or urges held in check, and might help explain why some people have difficulty controlling their impulses after brain damage. "The explanations are far from complete, but a pattern of results is fitting together in illuminating ways," she says. "Self-control is an entirely real brain phenomenon. Insofar as self-control is a key component of free choice, we do in fact have free choice. From a range of data it is becoming quite clear that there are significant neural differences between people who have the capacity to cancel actions or defer gratification and those whose capacity is diminished."

Kreiman, too, sees practical potential in teasing apart the circuitry of decision-making but deflects my questions about how his work could lead to new drugs or therapies. "The main question at the scientific level is to understand the mechanism by which volitional decisions are made: where, when, and how they are orchestrated," he says.

In his quest for a better picture of how that orchestration works, Kreiman now has a new collaborator in Ed Boyden, a neuroscientist at MIT who has developed novel tools for analyzing brain circuits. Among other efforts, Boyden is testing far denser neural probes in mice; these have the potential to record from as many as 100 times more neurons simultaneously (see "Neuroscience's New Toolbox" and "Eavesdropping on Neurons"). This technology could allow scientists to identify many of the neurons involved in making an "urge" neuron fire. "If we can get that, it would be transformative for this project as well as many others," Kreiman says. Projects around the world that are currently working to map the brain's circuitry would especially stand to benefit.

With such tools, rather than just seeing a single neuron light up, you might see a network of electrical signals that made it happen. Then you could, perhaps, see what lit the neuron that makes you wiggle the finger, and the neuron that makes you reach for the bottle. "If you can map the neural activity and see how neurons are dynamically generating the outcomes – it's like seeing how the brain is computing a decision," Boyden says. "You'd like to be able to see how the emotions, sensations, and memories work together."

While Kreiman sees no free will, he does believe mechanisms of self-control are built into the circuits that guide him down Broadway and through life. He wants to discover them, but he concedes that even if he were to do so today, "tonight, everything will be the same." It may be that the illusion of free will is part of the wiring – and impossible to shake off.

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