News

Can the brain be engineered and controlled like a machine?

Engineering genomes is routine in biology, but MIT's Ed Boyden wants to engineer the brain, opening the door to precise brain repair and even cognitive augmentation.

15 Nov 2007 Peter Dizikes 0 comments

The human brain functions like a powerful, sophisticated computer. While we can easily build, rebuild, and program a computer, we can't do the same for the brain, even though scientists have long dreamed of eradicating mental illness and restoring functions to damaged parts.

Brain engineering is the goal of MIT's Ed Boyden , an assistant professor in the university's Media Lab and Department of Biological Engineering. He is helping to create a subdiscipline he calls "synthetic neurobiology," intended to isolate and manipulate elements of the brain's circuitry and to repair or eventually improve the brain. "Synthetic neurobiology is a way of actually engineering the brain itself, through things like brain stimulation, to control the computations being performed by neurons," says Boyden, who received an award for innovative research from the Society for Neuroscience earlier this month.

Boyden believes synthetic neurobiology will offer precise medical remedies. The drawback with many current drugs for mental illness is that they affect many circuits in the brain, not just the ones going awry, leading to side effects. But by teasing apart the role of individual neurons and circuits in the brain, scientists hope to more precisely stimulate or dampen specific circuits with drugs or devices, reducing side effects.

"Having trained as an engineer, I think you understand a system most when you can engineer its functions," he says.

Circuit on, circuit off

Boyden and colleagues took their first steps in neuroengineering when they developed and refined a method, described in papers published in 2005 and 2007 , to trigger and halt the firing of neurons in rats through the use of light. They did this by introducing into neurons the genes for a pair of proteins–ChR2 and halorhodopsin–that respond to different types of light. Researchers could already record neuronal activity; now they can direct it, too.

This finding suggests that scientists can develop controlled experiments to reprogram brain activity in more detail than ever before. "Many people are trying to jump on this advance and use it for specific research projects," says Jennifer Raymond, a Stanford neuroscientist who codirected Boyden's doctoral work. Boyden says his lab has already distributed the materials and protocols for this technique to more than 60 other labs.

The Boyden group is now applying the technique to the study of neurological diseases such as Parkinson's in mice. Since the onset of Parkinson's disease is associated with changes in one part of the brain, the striatum, the Boyden lab hopes to pinpoint the trouble spots in that region by selectively turning on and off particular circuits in Parkinson's mouse models to determine what roles those circuits play in the disease. They also want to study the patterns of neural activity in the area associated with Parkinson's. That could show doctors where to more precisely implant electrodes in the brain as part of a Parkinson's treatment known as deep brain stimulation.

Defining the parts list

Neuroengineers face abundant challenges. "The problem with just turning neurons on and off is that's not the way the brain normally does things," Boyden acknowledges. Controlling activity in one brain region can have effects on neighboring areas, so neuroengineers will have to analyze complex patterns of neuronal activity to more fully understand the brain.

Another problem is figuring out what the basic building blocks are for neuroengineering. In genetic engineering and synthetic biology, the basic unit is the gene. But with a variety of possible "engineering parts"—neurons, synapses, circuits–synthetic neurobiology does not have a conceptual common currency describing brain function.

Repairing or enhancing?

The idea of tinkering with the brain's circuitry also raises fundamental ethical questions. Should the goal of neuroengineering be to provide medical treatments or to enhance the cognitive abilities of already-healthy people? "The neuroethics of neuroengineering are wide open," says Judy Illes, a professor of neurology and neuroethics at the

University of British Columbia.

While Boyden's current work aims to develop medical treatments, he has written on his blog that "it's arguably time for a discipline to emerge around the idea of human augmentation," and that it may be possible to "enhance memory, creativity and happiness in humans."

Ethicists say it may be difficult to draw a line between therapy and augmentation. Illes, for one, views these concepts as existing on one continuum of biomedical interventions. People suffering from serious anxiety problems or attention-deficit disorders, for instance, may need therapeutic remedies, while others considered "normal" may want the same treatments to enhance their calmness or attentiveness. Like synthetic neurobiology itself, this discussion of ethics will only grow in significance–especially if Boyden and his cohorts continue making progress.

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