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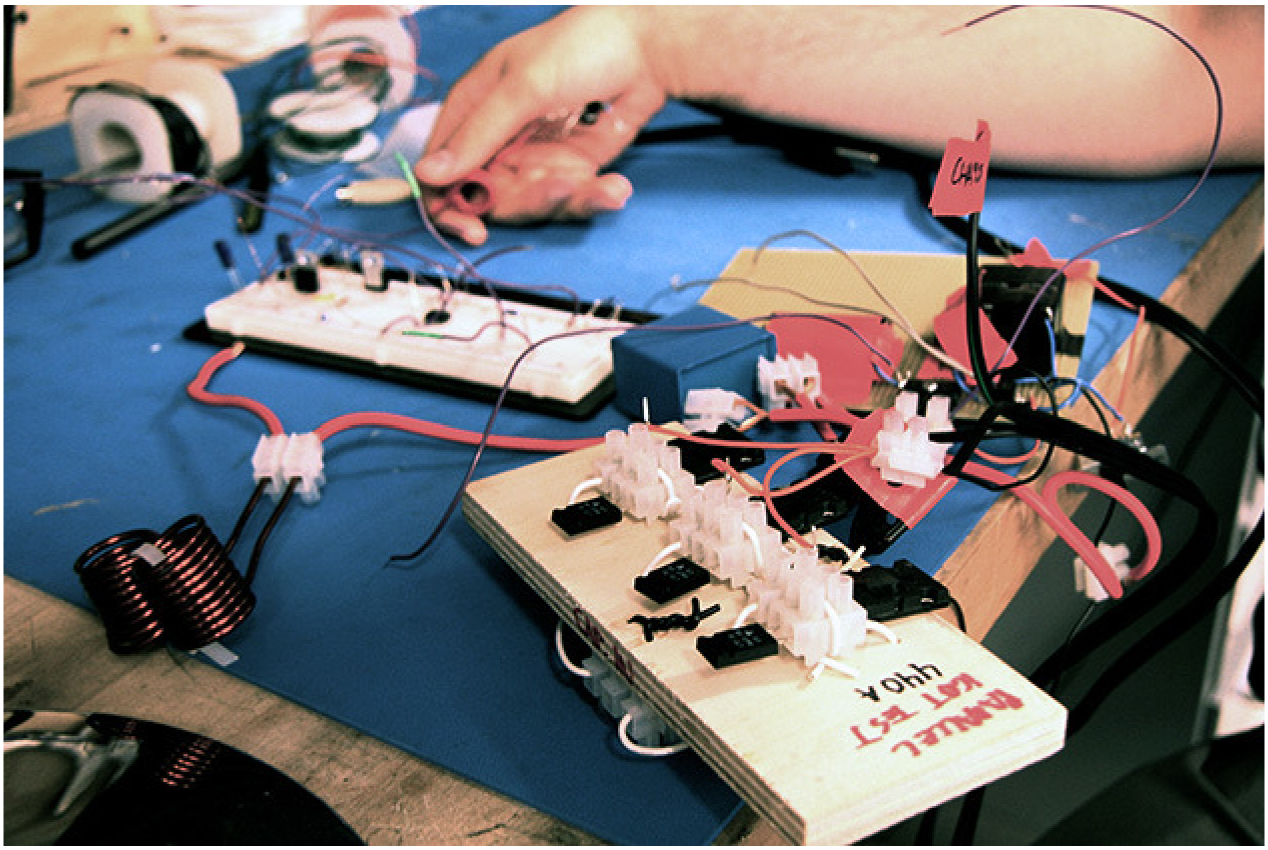
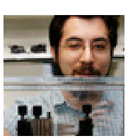
Dial H for Happiness: How Neuroengineering May Change Your Brain

By Quinn Norton 03.03.09



Dr. Ed Boyden displays the small prototype Transcranial Magnetic Stimulation machine built by his students at the Neuroengineering and Neuromedia Lab at MIT. The copper coils generate magnetic fields that creates a current in adjacent brain tissue.
Photo: Quinn Norton

PART ONE:



Rewiring the Brain: Inside the New Science of Neuroengineering

This is the second of two parts on the convergence of engineering and neuroscience. Part One, "Rewiring the Brain," examined attempts to control the brain using surgically implanted optical switches.

Sci-Fi author Philip K. Dick may have best anticipated neuroengineering in his most famous work, *Do Androids Dream of Electric Sheep?*, the basis of the movie *Blade Runner*. The main character and his wife get up in the morning and select their moods on what Dick called a Penfield mood organ.

We're a long way from building a Penfield mood organ, but we already have ways of prodding our brains. Sometimes we achieve miracle cures, sometimes just trim the edge off the pain, but even the little tweaks can mean the difference between the livable and unlivable life.

Next to the microscopes and viruses at Dr. Ed Boyden's MIT lab is an electronics bench littered with half-finished breadboards, bits of wire and solder. From a drawer, Boyden lifts a twisted mess of connectors and wires hooked to a copper coil the size of a golf ball. This is a transcranial magnetic stimulation, or TMS, machine. When held to the head it's capable of electrically affecting areas of the brain within a few centimeters of the surface.

Luigi Galvani, a physician and natural philosopher of the 18th century, was the first to figure out that nerves were electrical in nature. His assistant tapped a dissected frog's leg with a scalpel he'd picked up from a statically charged table. The static electricity arced to the nerve of the dead frog's leg, making it twitch like living material.

From then on it was understood that the brain and its attendant peripheral nerves ran on electricity. Inspired by the twitching dead nervous system, Mary Shelley had Frankenstein's monster raised from the dead by a lightning bolt. But her approach, while a nice literary touch, was overkill: All you need is a very weak current to activate brain cells in a given region.

In fact, TMS gets electricity into the brain peacefully, without either cutting it open or shocking it with millions of volts.

The target area of the brain is treated like the coil in a generator, subjected to rapidly changing magnetic fields until electricity begins to dance across its neurons. Unlike the optical switch developed by Boyden and Stanford's Dr. Karl Deisseroth, TMS doesn't reach the deeper regions of the brain, but there are a lot of important and interesting areas in the cortex where TMS delivers its current. It's also far less precise than the optical switch, although TMS seems positively surgical when compared to the imprecisions of the pharmaceuticals we pump into our bodies.

"The magnetic field has an effective area of stimulation that is — at the smallest — the size of a thumb," says Dr. Bret Schneider, a neurological researcher at Stanford Medical School. TMS produces an impressionistic sweep of neural activation in the brain that researchers have used to do everything from inducing savant-like skills to causing people to take greater risks. Clinicians use it to treat migraines and depression, among other things.

Schneider has agreed to give me TMS. Specifically, he will use it on a part of my brain that controls movement: the motor cortex. He ushers me into an overly large black leather chair. Except for the large, two-lobed paddle hanging from the back, which is connected to an impressive power supply, the chair resembles something a therapist might use. "There are a number of nerves that pass through the scalp, and consequently, most patients do feel the magnetic pulses," he says by way of warning.

A few inches over my ear is the part of my brain that controls my hand and arm. Schneider holds the coil there and activates it. The muscles in my scalp contract automatically, and it stings. My hand is jumping with each loud snap from the TMS machine.

"What you're feeling is nerves actually depolarizing," he says. "[It's] sending a current through them, they're releasing their neurotransmitters with each pulse."

TMS feels like a determined and annoying older sibling repeatedly flicking you in the head. It's easy to imagine the subtleties of subjective experience being lost in the snapping, cracking, and the arm-twitching, that, while involuntary, is easy to misinterpret as sheer exasperation. Ow, quit it! Ow, quit it!

At first I imagine that my arm jerking is just me responding to the annoyance of being thumped on the head. I am, in short, confabulating wildly. Then I lift my arm on my own power, and watch as it continues jump in midair. I am definitely not doing that.

Schneider hands me the coil and shows me how to hold it over my left motor cortex, which controls the right side of my body. I use it on myself, holding the unit over my left brain, making my own right hand jump involuntarily.

"TMS seems to be relatively benign, and a fairly short list of adverse effects have been identified," says Schneider.

Transcranial magnetic stimulation is quite safe for use as a neurological therapy or research tool. Its effects are temporary, and while TMS can induce a seizure, that usually won't occur without a deliberate effort or gross negligence on the part of the operator. Focused on a bipolar patient, TMS can also induce massive mania and psychosis. The effect there is also also temporary, although the damage to the person's credit rating, car or goodwill of his neighbor may not be.

In short, TMS, which has been around for barely 20 years, shows enormous potential for certain types of neural conditions.

Boyden's lab has several plans for this technology. Smaller, cheaper and more hackable versions of TMS machines are being built. They've put together an open source TMS project that might allow anyone to start an at-home DIY brain hacking lab. Boyden tells me that his own TMS machine is a working prototype for an affordable, wearable unit that could go into much wider use in regular therapy offices, or even at home.

"One nice thing about medications is that they are compact — you can use them when you're at home, when you're traveling," he says. "It would be nice to achieve that in other fields of neurotechnology."

Back in his office, he goes beyond the medical applications. "As technologies are proven safe and effective, they will become more widespread, helping more people — not always those with the most severe needs. It's the same story that any health-related technology has ever taken."

Boyden theorizes that TMS could someday be a "prosthetic for creativity," based on its ability to increase concentration and risk-taking. That is, if people can get past how strange the whole thing seems.

"We know so little about the brain that it's easy to find projects that [are] both ... philosophically important problems, and also can assist [with] new treatments of neurological and psychiatric disorders," he says.

It's a shotgun approach to trying to work out what can be done with the most complicated system we've yet found in the universe — ourselves — using the output of that system, technology.

"The field as a whole is wrestling with what to make of such technology," says Boyden.

Neuroengineering raises a number of ethical issues, not the least of which centers on the question of when and how to treat certain conditions using the new technology. As an example, Dr. Debra Matthews, a bioethicist at The Berman Institute of Bioethics, points out that many in the deaf community feel that treatment of deafness is an assault on their culture. For them it's a question of identity, not necessarily a handicap.

"Who is defining better?" says Matthews. "Who decides what is a disability? Who decides what is normal?"

But she also says that these questions are not a sufficient reason to prevent neuroengineers from pressing ahead, no matter what kind of strange wonders they might produce.

"A course of research shouldn't be stopped by the mere presence of moral disagreement," she says. "[But] it's absolutely a reason to think about it and have a public conversation about it."

The MIT Media Lab, which houses Boyden's neuroengineering lab, is a kind of utopia of clutter, a fluorescent lit cave of saliva-worthy geek toys. Everyone there is sure that innovations to change the world are just around the corner, and that Boyden's lab, like Deisseroth's out at Stanford, is on the brink of changing the way we control our brains.

Walking a few blocks away from MIT late that night I find the other side of the universe, still in Cambridge. There's a gig going strong at 1 a.m., deep in the back of a dive bar on Massachusetts Avenue. On the street outside, old black men stand around, some with instrument cases, some with cigarettes dangling from their lips. It gets me to thinking.

All of us — them, me, the cops gliding past in their cruisers — are really just brains floating around on the ends of spine sticks. Involuntarily, I see everyone with a wire fed into their cortexes, some part of themselves commanded by their choice at a given moment. A little primitive Penfield mood organ above every ear, if you will.

So I wonder: What bit of themselves would each of us wish to control? Where would we direct our own TMS, if we could?

It's a terrible responsibility to consciously shoulder. What is the mind that's choosing the shape of its own brain?

"I think if you ask most neuroscientists, they don't find that particular question puzzling," says Deisseroth. "Thoughts, feelings and drives derive from patterns of electrical activity ... [but] there are other ways to think about it.

"The mind could be that little spark of consciousness that is floating around, guiding your direction and attention and desires and thoughts. Something that recruits different parts of the brain.... What is that little floating entity that uses the brain? The part that uses the visual cortex, that uses sensory input, what is that?"

If that part isn't what puzzles neuroscientists at the moment, it's important to remember that it's the crucial part for the old men on Mass. Ave. A description of reward pathways and their functions will never really explain what it means to *need* a clearly unneeded cigarette, much less the define a lifetime of desire that turned a second-hand guitar into the organ of an old blues player's soul. But without a doubt, changing those pathways can change everything.

When I ask Boyden what this work means for the far-off future, he puts his hands in his pockets and scrunches back in his seat.

"I think society is going to change," he says. "People are going to understand more about themselves than they've ever understood before."