Human brainwaves light up mouse genes

Implant uses the human brain's electrical activity to control gene expression in mice using flashes of light.

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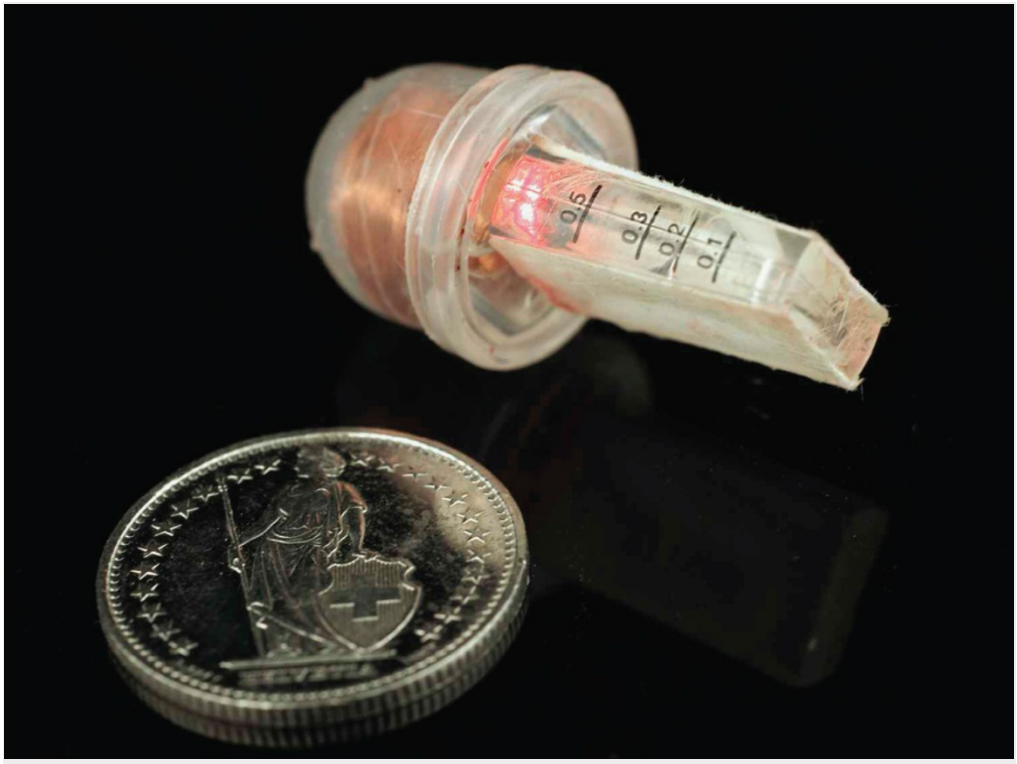

Ref. 1

Researchers tested an implant containing human stem cells that had been engineered to produce a protein called secreted alkaline phosphatase.

A system that uses brain activity to switch on genes with light could give new meaning to the phrase 'mind over matter'. The set-up, which was tested in mice, might one day allow human patients to pre-empt pain or seizures by recognizing brain activity that signals the onset of these phenomena and intervening to stop them.

The findings, reported on 11 November in *Nature Communications*[1], are another advance in the burgeoning field of optogenetics, which uses light to control the activity of genes. But whereas many experimental systems still require an outside power source, the team led by Martin Fussenegger, a bioengineer at ETH Zurich in Switzerland, used the brain's own electricity — picked up by means of electroencephalography (EEG) — to provide power through a daisy-chain of signals.

Light touch

Fussenegger and his colleagues first created a small, implantable cartridge containing human stem cells that had been engineered to produce a protein, called secreted alkaline phosphatase (SEAP), when the cells were exposed to a beam of near-infrared light. The researchers then put this cartridge under the skin of a mouse, along with a near-infrared light-emitting diode (LED).

Next, the team programmed a computer to receive and recognize brain-activity patterns from volunteers wearing an EEG headset. When the computer recognized a particular predetermined pattern, such as that caused by meditation, it switched on an electrical-field generator. The electrical current passed into the mouse, which was sitting on the generator, and powered up its implanted LED. The light caused the implanted cells to begin producing SEAP, which passed through the cartridge and into the mouse's bloodstream.

At the interface

Fussenegger says that human trials of this system are a very long way off. For instance, the researchers would first need to show that the stem cells do not harm the brain and find a way to control the amount of protein that the cells produce in response to the light. But

he has thought of numerous possible applications for a device that can respond so rapidly to brain signals. For instance, the device could be programmed to respond to the EEG patterns that predict a seizure and prevent it by delivering a drug to the brain.

“This is super innovative and very exciting,” says neuroscientist Michael Bruchas of Washington University in St. Louis, Missouri. “You can go from biology to electronics back to biology; I think that’s powerful.” He agrees that human trials are far off, but suggests that the device could also be implanted in many areas of the body, such as the gut, and be controlled by EEG patterns.

Others question how useful the system is, given the limitations of current technology and scientific knowledge. Medical ethicist Joseph Fins at Weill Cornell Medical College in New York City calls the experiment “a beautiful marriage of optogenetics and the conception of a brain–computer interface”. But he says that there is so much work left to be done, mapping the circuits of the brain and developing computer programs to interpret EEG signals, that talking about potential therapies is premature.

Still, Fins says, a device that can recognize and respond to certain brain signatures would be useful for patients with locked-in syndrome who rely on others for their care. EEG patterns that indicate pain, for instance, could be linked to the delivery of a painkiller. “If they had some measure of control, it would be a wonderful thing,” he says.

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References

1. Folcher, M. *et al*. *Nature Commun.* **5,** 5392; http://dx.doi.org/10.1038/ncomms6392 (2014).