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Making Deaf Ears Hear with Light

A laser-based approach could make cochlear implants, which currently use electrical signals, more effective.

By Michael Chorost

About 100,000 profoundly deaf people now hear with cochlear implants, which work by stimulating the auditory nerve with a string of electrodes implanted in the inner ear. While the devices enable many users to converse easily and use telephones, they still fall short of restoring normal hearing. Now scientists at Northwestern University are exploring whether laser-based implants could one day outperform today's electrical version.

The mammalian ear uses neural firing rates as one way of encoding sound. As part of a project funded by the National Institute for Deafness and Other Communication Disorders (NIDCD), Claus-Peter Richter (http://www.communication.northwestern.edu/csd/faculty/Richter_Claus-Peter/) and his colleagues at Northwestern have demonstrated that they can control firing rates in the auditory nerve of animals using infrared laser radiation. They are now trying to establish that it's safe to use for long periods of time and that it can manipulate neural firing rates with enough precision to send useful information to the brain.

With conventional cochlear implants, electrical signals spread in the wet, salty environment of the body, muddying the signal. That makes it difficult to trigger specific populations of nerves inside the cochlea. Further complicating matters, simultaneous pulses in different locations merge with each other, stimulating the cochlea everywhere instead of in the desired locations.

Engineers work around the problem by triggering only one or two of the 16 or 24 electrodes in the inner ear at a time. It's done so rapidly that the user has the illusion that all of the electrodes are firing, but the result is still a relatively crude simulation of normal hearing. To many cochlear implant users, voices sound mechanical and music sounds washed out.

An infrared laser, on the other hand, can be beamed at nerve fibers with pinpoint accuracy. Furthermore, the directional nature of laser light means that optical pulses in different places won't interfere with each other. The increased precision of neural stimulation would make voices and music sound more natural, and users would be able to converse in noisy environments more easily.

While it's not yet clear why infrared radiation can trigger activity in the auditory nerves, Richter hypothesizes that it heats the cells slightly, opening ion channels in the cell walls and sending an electrical signal down the length of the neuron.

A major question is whether it's safe to stimulate nerves in this way for long periods of time. So far, Richter and his colleagues have shown that auditory nerves in anesthetized gerbils can be stimulated with infrared laser radiation for up to six hours without damage. At present it's not feasible to run the tests for longer, but Richter is planning long-term studies in animals with permanently implanted devices.

The researchers are also figuring out how to precisely control neuron activity with lasers. The ear encodes pitch and loudness not just by firing nerves in particular places, but also by modifying the *rate* at which they fire. So far, Richter has shown that laser radiation can reliably make neurons fire up to 250 times per second, which is comparable to the rate at which early-model conventional cochlear implants drive neurons.

Human trials are years away, but there are several ways in which infrared technology might be used to build a working cochlear implant. One is to use fiber optics instead of electrodes in an array inserted inside the cochlea, somewhat similarly to the way conventional cochlear implants now use electrodes. Early trials of such a system might involve replacing one or two electrodes of a conventional implant with fiber optics to test their effect. Another is to put an optical fiber bundle in front of the cochlea's round window to stimulate auditory neurons without opening the cochlea. (The round window is a thin membrane in the cochlea that absorbs fluid displacement as sound waves travel through it.)

An even more futuristic possibility is to use gene therapy to make auditory neurons responsive to particular wavelengths of light. At MIT, Ed Boyden (http://edboyden.org/) has been altering nerve cells' genes so that they fire when exposed to one wavelength of light and stop firing when exposed to another. According to Richter, this approach would require less power to activate cells, which might be safer in the long run. Of course, this approach carries all the caveats that typically accompany gene therapy and would require a way to precisely deliver gene therapy to the relevant auditory cells.

"If proven safe and efficacious, optical stimulation could open up ultra-high density stimulation interfaces for the peripheral nervous system," says Boyden. "The process of combining optics and neurons may also pave the way for many future innovations - moving beyond the ubiquitous electrode to new modalities of neural control."

Upcoming Events

Lab to Market Workshop (http://www.technologyreview.com/emtech/09/workshop.aspx)
Cambridge, MA
Tuesday, September 22, 2009
http://www.technologyreview.com/emtech/09/workshop.aspx (http://www.technologyreview.com/emtech/09/workshop.aspx)

EmTech 09 (http://www.technologyreview.com/emtech)
Cambridge, MA
Tuesday, September 22, 2009 - Thursday, September 24, 2009
http://www.technologyreview.com/emtech (http://www.technologyreview.com/emtech)

Nanotech Europe 2009 (http://www.nanotech.net)
Berlin, Germany
Monday, September 28, 2009 - Wednesday, September 30, 2009
http://www.nanotech.net (http://www.nanotech.net)

2009 Medical Innovation Summit (http://www.ClevelandClinic.org/innovations/summit)
Cleveland, OH
Monday, October 05, 2009 - Wednesday, October 07, 2009
http://www.ClevelandClinic.org/innovations/summit (http://www.ClevelandClinic.org/innovations/summit)

Optimizing Innovation 2009 (http://www.connecting-group.com/Web/EventOverview.aspx?Identificador=6)
New York, NY
Wednesday, October 21, 2009 - Thursday, October 22, 2009
http://www.connecting-group.com/Web/EventOverview.aspx?Identificador=6 (http://www.connecting-group.com/Web/EventOverview.aspx?Identificador=6)