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Tiny magnetic coils modulate neural activity, may be safer for deep-brain implants

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Magnetic fields generated by microscopic devices implanted into the brain may be able to modulate brain-cell activity and reduce symptoms of several neurological disorders. Micromagnetic stimulation appears to generate the kind of neural activity currently elicited with electrical impulses for deep brain stimulation (DBS) – a therapy that can reduce symptoms of Parkinson's disease, other movement disorders, multiple sclerosis and chronic pain – and should avoid several common problems associated with DBS, report Massachusetts General Hospital investigators.

"We have shown that fields generated by magnetic coils small enough to be implanted into the central nervous system can be used to modulate the activity of neurons, potentially leading to a new generation of neural prosthetics that are safer and possibly more effective than conventional electrical stimulation devices," says Giorgio Bonmassar, PhD, of the Martinos Center for Biomedical Imaging at MGH, co-lead author of the report in the online journal *Nature Communications*.

DBS involves implantation of small electrodes called leads into structures deep within the brain. The leads, connected to a battery-operated power source implanted into the abdomen, generate electrical signals that modulate neural activity at sites that vary depending on the condition being treated. DBS has successfully alleviated symptoms in patients not helped by other therapies, but it does have limitations. Magnetic resonance imaging (MRI) can cause metallic DBS implants to heat up and damage adjacent brain tissue, which limits the use of MRI in these patients. In addition, the presence of DBS implants typically elicits an immune system response, leading to scarring around the implant that can block the electrical signal.

Magnetic stimulation has been used to diagnose and treat neurological disorders for two decades, but until now it has required the use of large hand-held coils that generate fields from outside the skull, limiting the brain structures that can be stimulated and the accuracy with which a signal can be delivered. The current study was designed to investigate the potential of much smaller magnetic coils to generate the kind of neural activity produced by DBS, exploring a concept first developed by Bonmassar. The investigators first developed a computational simulation that verified that magnetic coils 1 millimeter long and .5 mm in diameter would generate magnetic and electrical fields that should stimulate neuronal activity.

The research team then tested whether a commercially available coil of that size, coated with a plastic material, would activate neurons in retinal tissue. Positioned right above retinal tissue and either parallel or perpendicular to the tissue surface, the coil generated fields that successfully elicited neuronal signals in retinal cells. How the coil was positioned relative to the retinal surface produced significant differences in the physiologic responses. When the coil was oriented parallel to the retina, the induced field appeared to activate retinal bipolar cells, which transmit signals from the light-sensing photoreceptors to retinal ganglion cells. A coil oriented perpendicular to the retina produced responses indicative of ganglion cell activation.

"These differences suggest that, by modifying the geometry of the coil, we may be able to selectively target populations of neurons and minimize the effects on non-targeted cells," says Shelley Fried, PhD, of the MGH Department of Neurosurgery, corresponding author of *Nature Communications* report. "By sizing and orienting the coil appropriately to any given population of central nervous system neurons, we should be able to either activate or avoid activation of that population.

"This study provides a proof of concept that small coils can activate neurons, and much work still needs to be done," he adds. "We need to explore how to optimize coil properties and then evaluate the devices in animal models. We also hope to explore the use of these coils in non-DBS applications, including cardiovascular procedures such as heart muscle pacing." Fried is an instructor in Surgery and Bonmassar an assistant professor of Radiology at Harvard Medical School.

Provided by Massachusetts General Hospital

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