Six paths to the nonsurgical future of brain-machine interfaces

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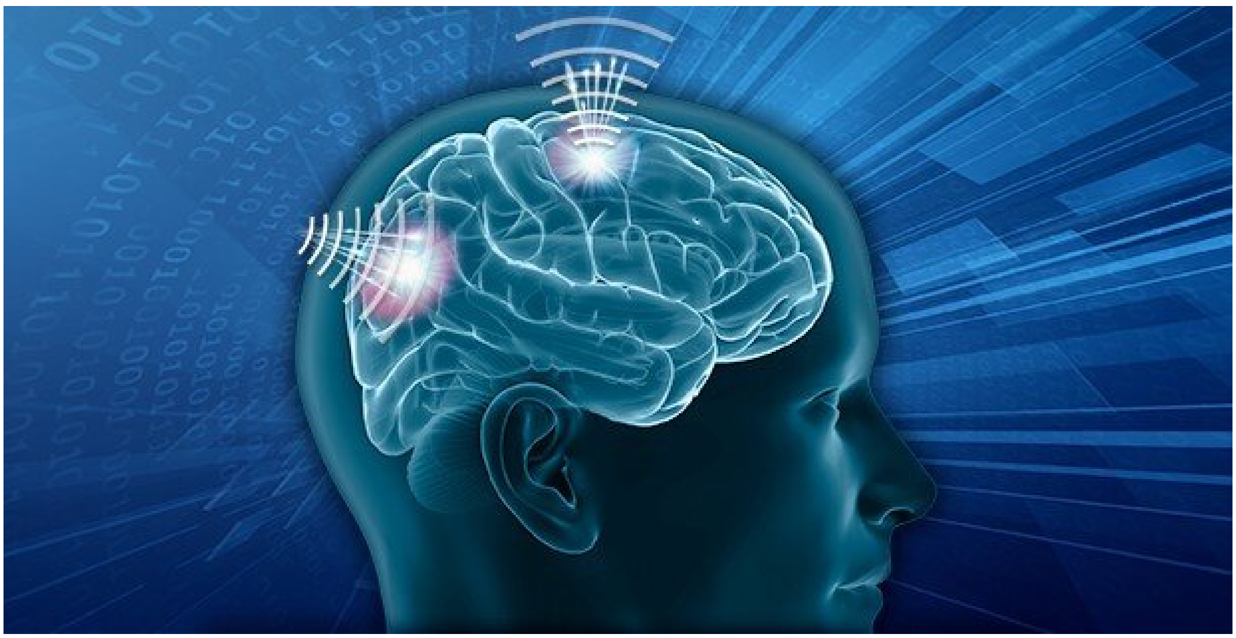

Credit: DARPA

DARPA has awarded funding to six organizations to support the Next-Generation Nonsurgical Neurotechnology (N^3) program, first announced in March 2018. Battelle Memorial Institute, Carnegie Mellon University, Johns Hopkins University Applied Physics Laboratory, Palo Alto Research Center (PARC), Rice University, and Teledyne Scientific are leading multidisciplinary teams to develop high-resolution, bidirectional brain-machine interfaces for use by able-bodied service members. These wearable interfaces could ultimately enable diverse national security applications such as control of active cyber defense systems and swarms of unmanned aerial vehicles, or teaming with computer systems to multitask during complex missions.

"DARPA is preparing for a future in which a combination of unmanned systems, artificial intelligence, and cyber operations may cause conflicts to play out on timelines that are too short for humans to effectively manage with current technology alone," said Al Emondi, the N^3 program manager. "By creating a more accessible brain-machine interface that doesn't require surgery to use, DARPA could deliver tools that allow mission commanders to remain meaningfully involved in dynamic operations that unfold at rapid speed."

Over the past 18 years, DARPA has demonstrated increasingly sophisticated neurotechnologies that rely on surgically implanted electrodes to interface with the central or peripheral nervous systems. The agency has demonstrated achievements such as neural control of prosthetic limbs and restoration of the sense of touch to the users of those limbs, relief of otherwise intractable neuropsychiatric illnesses such as depression, and improvement of memory formation and recall. Due to the inherent risks of surgery, these technologies have so far been limited to use by volunteers with clinical need.

For the military's primarily able-bodied population to benefit from neurotechnology, nonsurgical interfaces are required. Yet, in fact, similar technology could greatly benefit clinical populations as well. By removing the need for surgery, N^3 systems seek to expand the pool of patients who can access treatments such as deep brain stimulation to manage neurological illnesses.

The N^3 teams are pursuing a range of approaches that use optics, acoustics, and electromagnetics to record neural activity and/or send signals back to the brain at high speed and resolution. The research is split between two tracks. Teams are pursuing either completely noninvasive interfaces that are entirely external to the body or minutely invasive interface systems that include nanotransducers that can be temporarily and nonsurgically delivered to the brain to improve signal resolution.

- The Battelle team, under principal investigator Dr. Gaurav Sharma, aims to develop a minutely invasive interface system that pairs an external transceiver with electromagnetic nanotransducers that are nonsurgically delivered to neurons of interest. The nanotransducers would convert electrical signals from the neurons into magnetic signals that can be recorded and processed by the external transceiver, and vice versa, to enable bidirectional communication.
- The Carnegie Mellon University team, under principal investigator Dr. Pulkit Grover, aims to develop a completely noninvasive device that uses an acousto-optical approach to record from the brain and interfering electrical fields to write to specific neurons. The team will use ultrasound waves to guide light into and out of the brain to detect neural activity. The team's write approach exploits the non-linear response of neurons to electric fields to enable localized stimulation of specific cell types.
- The Johns Hopkins University Applied Physics Laboratory team, under principal investigator Dr. David Blodgett, aims to develop a completely noninvasive, coherent optical system for recording from the brain. The system will directly measure optical path-length changes in neural tissue that correlate with neural activity.
- The PARC team, under principal investigator Dr. Krishnan Thyagarajan, aims to develop a completely noninvasive acousto-magnetic device for writing to the brain. Their approach pairs ultrasound waves with magnetic fields to generate localized

electric currents for neuromodulation. The hybrid approach offers the potential for localized neuromodulation deeper in the brain.

- The Rice University team, under principal investigator Dr. Jacob Robinson, aims to develop a minutely invasive, bidirectional system for recording from and writing to the brain. For the recording function, the interface will use diffuse optical tomography to infer neural activity by measuring light scattering in neural tissue. To enable the write function, the team will use a magneto-genetic approach to make neurons sensitive to magnetic fields.
- The Teledyne team, under principal investigator Dr. Patrick Connolly, aims to develop a completely noninvasive, integrated device that uses micro optically pumped magnetometers to detect small, localized magnetic fields that correlate with neural activity . The team will use focused ultrasound for writing to neurons.

Throughout the program, the research will benefit from insights provided by independent legal and ethical experts who have agreed to provide insights on N^3 progress and consider potential future military and civilian applications and implications of the technology. Additionally, federal regulators are cooperating with DARPA to help the teams better understand human-use clearance as research gets underway. As the work progresses, these regulators will help guide strategies for submitting applications for Investigational Device Exemptions and Investigational New Drugs to enable human trials of N^3 systems during the last phase of the four-year program.

"If N^3 is successful, we'll end up with wearable neural interface systems that can communicate with the brain from a range of just a few millimeters, moving neurotechnology beyond the clinic and into practical use for national security," Emondi said. "Just as service members put on protective and tactical gear in preparation for a mission, in the future they might put on a headset containing a neural interface, use the technology however it's needed, then put the tool aside when the mission is complete."

More information: Additional details of the program schedule and metrics are available in the 2018 broad agency announcement: go.usa.gov/xmK4s.

Provided by DARPA