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BRAIN-MACHINE INTERFACES OFFER IMPROVED OPTIONS FOR PROSTHETICS AND TREATMENTS AFTER INJURY

Artificial retinas, thought-controlled devices, and brain stimulation therapy show promise

SAN DIEGO — Two experimental brain-machine technologies — deep brain stimulation coupled with physical therapy and a thought-controlled computer system — may offer new therapies for people with stroke and brain injuries, new human research shows. In addition, an animal study shows a new artificial retina may restore vision better than existing prosthetics. The findings were announced today at Neuroscience 2010, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news on brain science and health.

Brain-machine interface is an emerging field of neuroscience that aims to translate basic neuroscience research on how the brain packages and processes information to develop devices that help people regain functions lost to disease or injury.

Today's new findings show that:

- Researchers have developed a faster, more accurate way to control cursors with thoughts alone. This scientific advance gives "real-time" feedback of brain activity and may provide more therapeutic options to people with brain injuries or syndromes that limit communication abilities (Anna Rose Childress, PhD, abstract 887.27, see attached summary).
- Brain stimulation and physical therapy restores the use of paralyzed limbs — at least temporarily — in people recovering from a stroke. Few people recover completely after a stroke, and the new method may help in developing therapies to increase range of motion in affected limbs (Satoko Koganemaru, MD, PhD, abstract 898.5, see attached summary).
- Scientists have constructed an artificial retina that incorporates the signals the eye normally sends to the brain. The new prosthetic may be capable of reproducing normal vision more effectively than existing technologies (Sheila Nirenberg, PhD, abstract 20.1, see attached summary).

"Harnessing the brain's ability to process, decode, and utilize information has untold therapeutic possibilities," said press conference moderator Miguel A. Nicolelis, MD, PhD, of Duke University and an expert in neurotechnology and brain-computer interfaces. "Today's research advances clearly demonstrate neuroscience's ability to expand our understanding of how the brain works, and translate that knowledge into better treatments, therapies, and technologies."

This research was supported by national funding agencies, such as the National Institutes of Health, as well as private and philanthropic organizations.

– more –

Related Presentation:

Symposium Session 213: **Removing Brakes on Adult Brain Plasticity: Molecular, Cellular, and Behavioral Interventions**
Sunday, Nov. 14, 2010, 1:30–4 p.m. PST, Room 6B
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Abstract 887.27 Summary

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Controlling Cursors with Thoughts: Faster, Simpler, and More Accurately

Advance helps people regulate their own brain response, with therapeutic implications

Using a new brain-computer training approach, 14 volunteers learned in only six minutes how to move a screen cursor with their thoughts. Near-instant feedback helped the people quickly master some of their own brain responses. The findings were presented at Neuroscience 2010, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Researchers have developed a speedier system that allows people to control a cursor with thought alone. Studies show that when people and animals are given feedback about their brain signals, they can gain some control over those signals. It's now possible to acquire that feedback faster than ever before — in "real time" — using functional magnetic resonance imaging (fMRI), which registers blood flow in active brain regions.

"For most of us, most of the time, the ongoing activity of the brain is hidden and not under voluntary control," said lead author Anna Rose Childress, PhD, of the University of Pennsylvania School of Medicine. "Brain feedback studies are changing this long-standing, one-way relationship."

Thought-only cursor control may provide more options for people with "locked-in" syndromes — in which a person is aware but unable to communicate — and individuals with brain injuries. Previous trials have also shown that people can learn to control pain using real-time fMRI, and researchers believe this same technique may be applied to other conditions. They theorize that if the structures that underlie these diseases can be controlled, the disease itself can be altered.

The study consisted of two parts: the computer training and the actual cursor control, both inside the MRI scanner. During training, computers learned to recognize two distinct brain patterns in the volunteers. In one, participants were asked to think about hitting a tennis ball. In the second, they imagined moving from one room to another. Each set of thoughts corresponded with activity in specific parts of their brains, which the computer analyzed. The volunteers were then instructed to repeat those same thought patterns and move a screen cursor linked to their brain activity. All the participants were able to move the cursor by alternating their thoughts, creating brain patterns that were quickly recognized by the computer.

Research was supported by the National Institute on Drug Abuse, the National Institute of Biomedical Imagine and Bioengineering, and the U.S. Department of Veterans Affairs' Mental Illness Research, Education and Clinical Center.

Scientific Presentation: Wednesday, Nov. 17, 3–4 p.m., Halls B–H

887.27, Rapid control of a screen cursor by thought: A whole-brain classifier for real-time fMRI feedback training of cognitive control

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TECHNICAL ABSTRACT: Real-time feedback of brain activity offers intriguing new possibilities for enhanced volitional control of brain states. Potential clinical applications range from enhanced cognitive control of pain (deCharms, et al. 2005) or other problematic states (e.g., drug craving), to thought-directed screen communication during "locked-in" syndromes and even cognitive rehabilitation following brain injury. For real-time technology to be successful, both the speed and accuracy of the feedback approach are important. We thus tested whether a "whole brain" classifier based on a Partial Least Squares (PLS) algorithm could 1) rapidly distinguish alternating brain states in a cognitive control task, and 2) provide accurate rtfMRI feedback, enabling control of a screen cursor by the subjects' thoughts. BOLD fMRI at 3T (Siemens; TR=two sec) with a Partial Least Squares (PLS) linear classifier was used to characterize the whole- brain response for 14 subjects (11 normal controls; three abstinent cocaine patients) during on-magnet instructions to alternate between two (30 sec each) sets of distinct thoughts: 1) *repetitive motor (arm) activity* - "Think about hitting a tennis ball (or similar activity)" vs. 2) *spatial navigation* - "Think about moving from room-to-room in a familiar space." Following classifier training (approx. six minutes), subjects attempted to control a classifier-driven screen cursor (horizontal bars) solely with their thoughts. Whole-brain classifier training was extremely rapid (~five minutes) and robust: frame-by-frame classification accuracies during feedback ranged from .67-.93; $6<t<30$, $p<10^{-6}$). Impressively, classifier-driven real-time fMRI feedback enabled each of the 14

participants to control the screen cursor solely with their thoughts. The speed, accuracy and ease of the approach – for both controls and cocaine patients – opens the way for wide-ranging real-time studies in controls, and in clinical disorders characterized by compromised cognitive control, e.g., the addictions.

Abstract 898.5 Summary

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New Method Helps Stroke Patients Recover Short Term Hand Control

Brain stimulation and practice ease paralysis of wrist and fingers

People paralyzed by stroke temporarily regained the use of their hands after weeks of brain stimulation and physical therapy, according to new research. Stroke patients — who often struggle to unfurl their hand rather than to crook it— increased their range of motion for at least two weeks after completing the therapy. Details of the new approach were presented at Neuroscience 2010, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Stroke is the leading cause of disability in adults worldwide. Only a few people ever recover completely, and many have limited abilities for years. One of the results of stroke is often abnormally increased muscle tension in addition to weakness or paralysis in one side of the body. This study could offer disabled individuals a new hybrid form of rehab.

"Our results show a novel rehabilitative approach that takes advantage of the brain's ability to change and acquire new motor skills by practicing to overcome abnormal muscle tension," said lead author Satoko Koganemaru, MD, PhD, of Kyoto University in Japan.

Nine individuals with moderate-to-severe paralysis underwent the dual treatment for six weeks. Koganemaru and her colleagues applied high-frequency transcranial magnetic stimulation — a noninvasive method sometimes used to treat depression — over the damaged side of the brain, specifically in the area associated with motor control. Over the same period of time, the participants practiced contracting the muscles for extension of their fingers and wrists. At the end of the trial, the volunteers could grip and pinch objects.

"The improvements suggest that the brain adapts through practice and brain stimulation, making for better control of muscles," Koganemaru said. "This method could be a powerful approach for people with stroke and might be applied to other movement disorders."

Research was supported by the Strategic Research Program for Brain Sciences of the Ministry of Education, Culture, Sports, Science and Technology of Japan, the Japan Society for the Promotion of Science, and by a grant for Longevity Sciences from the Ministry of Health, Labour and Welfare.

Scientific Presentation: Wednesday, Nov. 17, 1–2 p.m., Halls B–H

898.5, Long-lasting improvements of spastic hemiparesis using rTMS combined with motor training

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TECHNICAL ABSTRACT: Chronic stroke patients with moderate-to-severe hemiparesis often suffer from motor deficits associated with flexor hypertonia, as well as motor weakness in their paretic upper-limbs. The enhancement of the extensor function, to counteract the flexor hypertonia, might be useful for those patients. However, the beneficial effects of training in chronic-phase patients are relatively limited. Additional extensor training of the affected hand did not change the clinical outcome (Trombly, 1986). As presented before, we found that combining extensor training with repetitive transcranial magnetic stimulation (rTMS; EEx-TMS) could facilitate use-dependent plasticity (UDP) both in stroke and healthy people, and can achieve functional recovery that cannot be attained by either intervention alone in stroke patients. In previous reports, therapeutic TMS protocols for stroke patients could induce long-lasting effects by repeating the stimulation for ~1 month (Khedr et al., 2005; Fregni et al., 2006). Therefore, we examined whether 12 times (once a day, on two days a week for six weeks) of repeating the EEx-TMS session (EEx: voluntary upper-limb extensors contraction of wrist and fingers in paretic side supported by neuromuscular stimulation, TMS: 5 Hz high frequency stimulation) could induce the long-term effects, resulting in sustained functional improvements of paretic upper limbs in nine chronic stroke patients. As a result, we found that repeating the EEx-TMS sessions over 6 weeks (12 times in total) could produce sustained improvements of the paretic upper limb function not only for extensors but also for flexors, and reduction of flexors hypertonia for >two weeks in chronic stroke patients. The improvements of whole upper-limb function seemed to be due to the amelioration of a non-use condition by the long-term intervention. This combined EEx-TMS method could be a powerful rehabilitative approach for hemispastic stroke patients.

Abstract 20.1 Summary

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Artificial Retina More Capable of Restoring Normal Vision

Animal study shows including retina's neural "code" improved prosthetic

Researchers have developed an artificial retina that has the capacity to reproduce normal vision in mice. While other prosthetic strategies mainly increase the number of electrodes in an eye to capture more information, this study concentrated on incorporating the eye's neural "code" that converts pictures into signals the brain can understand. The research was presented at Neuroscience 2010, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Degenerative diseases of the retina — nerve cells in the eye that send visual information to the brain — have caused more than 25 million people worldwide to become partially or totally blind. Although medicine may slow degeneration, there is no known cure. Existing retinal prosthetic devices restore partial vision; however, the sight is limited. Efforts to improve the devices have so far largely focused on increasing the number of cells that are re-activated in the damaged retina.

"But our research shows that another factor is just as critical," said Sheila Nirenberg, PhD, of Weill Cornell Medical College, lead author of the study. "Not only is it necessary to stimulate large numbers of cells, but they also have to be stimulated with the right code — the code the retina sends to the brain."

Using mice as subjects, the authors built two prosthetic systems: one with the code, one without. The researchers found the device with the code reconstructed more details. "Incorporating the code jumped the system's performance up to normal levels — that is, there was enough information to reconstruct faces, newsprint, landscapes, essentially anything," Nirenberg said.

Next, the authors plan to coordinate with other researchers who are already working with prosthetics on human participants.

Research was supported by the National Eye Institute.

Scientific Presentation: Saturday, Nov. 13, 1–1:15 p.m., Halls B–H

20.1, A retinal prosthetic strategy with the capacity to restore normal vision
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TECHNICAL ABSTRACT: Retinal prosthetics offer hope for patients with retinal degenerative diseases. There are currently 25 million people worldwide, who are blind or facing blindness due to these diseases, and there are few treatment options. Alternate therapies, such as drug and gene transfer approaches, are able to help some subpopulations - they can slow the degeneration down - but for the large majority of patients, their best hope is through prosthetic devices (reviewed in Chader et al., 2009). Current prosthetics, though, aren't yet able to restore normal vision: for example, they allow for perception of spots and edges, but not yet natural scenes. Efforts to improve prosthetic capabilities have been focusing largely on increasing the resolution of the device's stimulators (either electrodes or optogenetic transducers). Here, we show that a second factor is also critical: driving the stimulators with the retina's neural code. Using the mouse as a model system, we generated a prosthetic system that incorporates the code - this dramatically increased the system's capabilities, well beyond what could be achieved just by increasing resolution. Further, the results show, using 6000 optogenetically stimulated mouse ganglion cell responses, that the combined effect of using the code and a high-resolution stimulator is able to bring prosthetic capabilities out of the realm of simple image detection into the realm of natural sight.