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Miller School Collaboration Achieves Next Step Transforming Thoughts to Movement Following Spinal Cord Injury

For German Aldana, being in the comfort of his home and able to grasp a spoon, turn a doorknob or grab his headphones to listen to music, is a life-altering step toward independence.

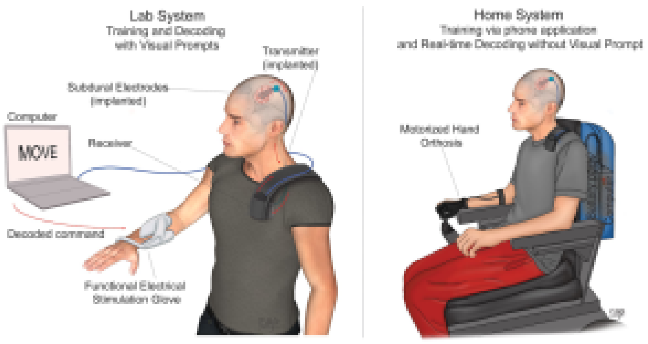

Figure showing the implantable interface for neuroprosthetic-enabled hand grasp restoration in spinal cord injury.

The Miami resident has been paralyzed from the neck down since a car accident months before his 17th birthday. Now 25, Aldana has for years participated in research at The Miami Project to Cure Paralysis with neurosurgeons and biomedical engineers from the University of Miami Miller School of Medicine to advance the use of an implantable brain-computer interface that turns Aldana’s thoughts about moving his hand into reality.

In a recent paper published in *Brain Communications*, “Implantable Brain-Computer Interface for Neuroprosthetic-Enabled Volitional Hand Grasp Restoration in Spinal Cord Injury,” Miller School authors described a method for restoring hand grasp control in Aldana, who has complete cervical quadriplegia, using a portable fully implanted brain-computer interface at home. Whereas, prior to surgery, German was only able flex his bicep, he can now open and close his hand with the assistance of the device.

Taking the Technology Home

This represents a crucial step – taking the technology outside the confines of the laboratory.

Jonathan R. Jagid, M.D.

In late 2018, neurosurgeon Jonathan R. Jagid, M.D., professor of clinical neurological surgery, and Abhishek Prasad, Ph.D., assistant professor of biomedical engineering at the Miller School, led the surgical procedure to implant the investigational system on Aldana’s brain as part of an ongoing FDA-approved clinical trial. Michael Ivan, M.D., M.B.S., assistant professor of neurological surgery at the Miller School and an authority and leader in brain mapping and skull base tumor surgery played a key role as part of the surgical team.

“Over the past decade, this unique piece of equipment and brain machine interface paradigm were developed with the idea of having a fully implanted device in an individual that can easily be transitioned out of the lab and into the normal everyday environment in order to improve quality of life,” Dr. Jagid said. “Prior to this leap forward, devices were bulky and tethered to large complex computer systems that could only provide benefit within the lab setting.”

During the initial portion of the study in 2019, German would come to the lab to get electrical stimulation to the hand as a response to his thoughts of wanting to move or not move his arm, according to lead author Iahn Cajigas, M.D., Ph.D., who at the time was a resident at the Miller School and now is an Epilepsy, Functional, and Stereotactic Neurosurgery Fellow at the University of California, San Francisco.

The thought of movement was translated to allow hand closure, whereas rest would allow the hand to open.

"We have since developed the technology to be used at home with minimal setup, which is novel in this field," Dr. Cajigas said. "Most research on brain-computer interfaces requires that patients use the technology in the lab, and often even requires that patients be connected to a computer and external power source for the device to function."

The technology, developed at the Miller School with the help of Massachusetts Institute of Technology (MIT) scientists, requires none of that, according to Dr. Cajigas, who graduated from MIT with a Ph.D. in electrical and medical engineering.

Patients like Aldana have the brain-computer interface implanted on the brain surface area charged with hand movement. The system connects to a transmitter implanted under the patient's skin below the clavicle, which allows for continuous readings of the patients' brain activity. This activity is then transmitted to a computer that can read and interpret these signals in real time.

"Instead of having to prompt German to think about moving or resting his hand, we came up with a way to in real time decode what he is thinking," Dr. Cajigas said. "Basically, we collected data while telling German to think about moving his hand or keeping at rest. We then looked at those signals and trained the computer to detect when the different brain signals were observed. Our team then developed a small portable computer that attaches to the patient's wheelchair that is able to do this decoding and can be configured from his phone. Whenever the system detects a move or rest thought, it opens or closes the hand."

Emery N. Brown, M.D., Ph.D., of the Institute for Medical Engineering and Science at MIT and director of the Neuroscience Statistics Research Lab at MIT, and his team assisted with the development and validation of the computer algorithm that decodes the patient's intent to move/rest in real time.

Connecting the Science

Well-known epilepsy surgeon Wilder Penfield noted characteristic changes in the electrical activity on the surface of the brain when patients thought about hand movement as early as the 1950s, according to Dr. Cajigas.

Iahn Cajigas, M.D., Ph.D.

"Dr. Prasad's lab at the Miller School also observed that these brain signal changes were also seen in patients with spinal cord injury, and in 2014 he and colleagues published a paper ["An adaptive brain actuated system for augmenting rehabilitation"] in *Frontiers in Neuroscience* showing that spinal cord injured subjects and normal controls both had these signals. So, even if the hand is not moving in patients with spinal cord injury, the brain activity corresponding to the desire to move is still present," Dr. Cajigas said.

Prior to performing the brain surgery required to implant the system, Miller School scientists leveraged this finding and performed a functional MRI of Aldana's brain while asking him to think about moving his hand. Lo and behold, specific areas of the brain that control the hand lit up.

"We then used that information to precisely target how to do our craniotomy and place electrodes exactly in that area where the MRI changes were being observed," Dr. Cajigas said.

It takes only minutes for Aldana's brother or nurse to help him set up the computer on his wheelchair at home. Today, Aldana is in college studying to become a computer programmer and is busy at home training with the technology, pushing it to its limits.

"Learning it is difficult and takes a lot of time. But when it works, it is awesome," Aldana said. "I think anyone in a wheelchair should be motivated to help scientists and doctors. They need our help in order to reach the ultimate goal of helping people to walk again."

The *Brain Communications* paper is a proof of concept that the technology can restore at least one degree of freedom, according to Dr. Cajigas.

"There are so many other functions that we could potentially aim to restore," he said. "We might also be able to decode wrist extension/flexion or use someone's decoded hand volition to trigger the initiation of stepping using an exoskeleton or other assistive device as we have demonstrated on our supplementary data with this paper."

Miller School coauthors on the *Brain Communications* paper include Drs. Jagid and Prasad; Noeline Prins, Ph.D.; Kevin C. Davis, M.D.; Jasim Ahmad Naeem, M.S.; Anne Palermo, D.P.T.; Audrey Wilson; Santiago Guerra, M.S.; Katie Gant, Ph.D.; Allan D. Levi, M.D., Ph.D.; Dalton Dietrich, M.D.; Letitia Fisher, B.A.; Steven Vanni, D.O.; and Michael Ivan, M.D., M.B.S.

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