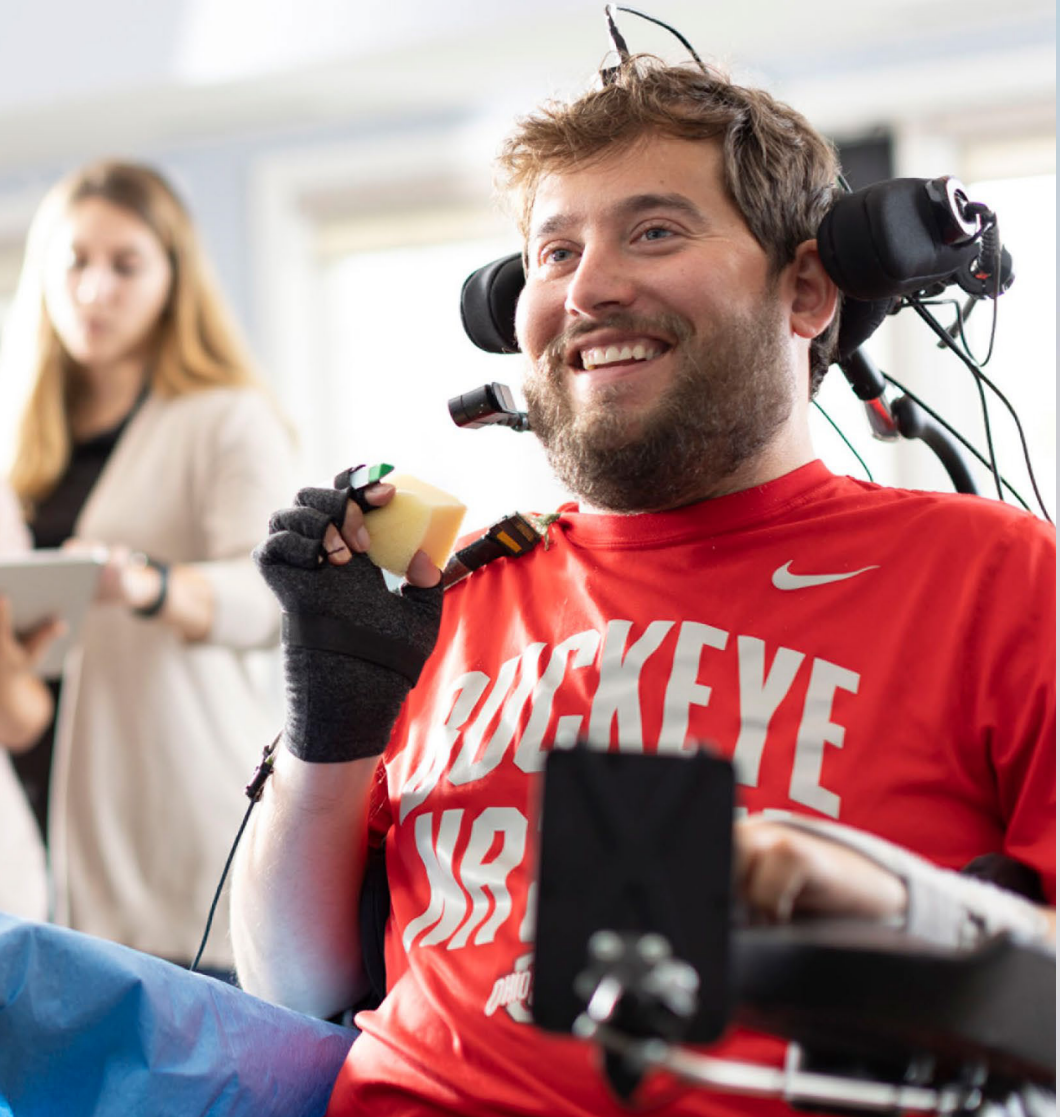
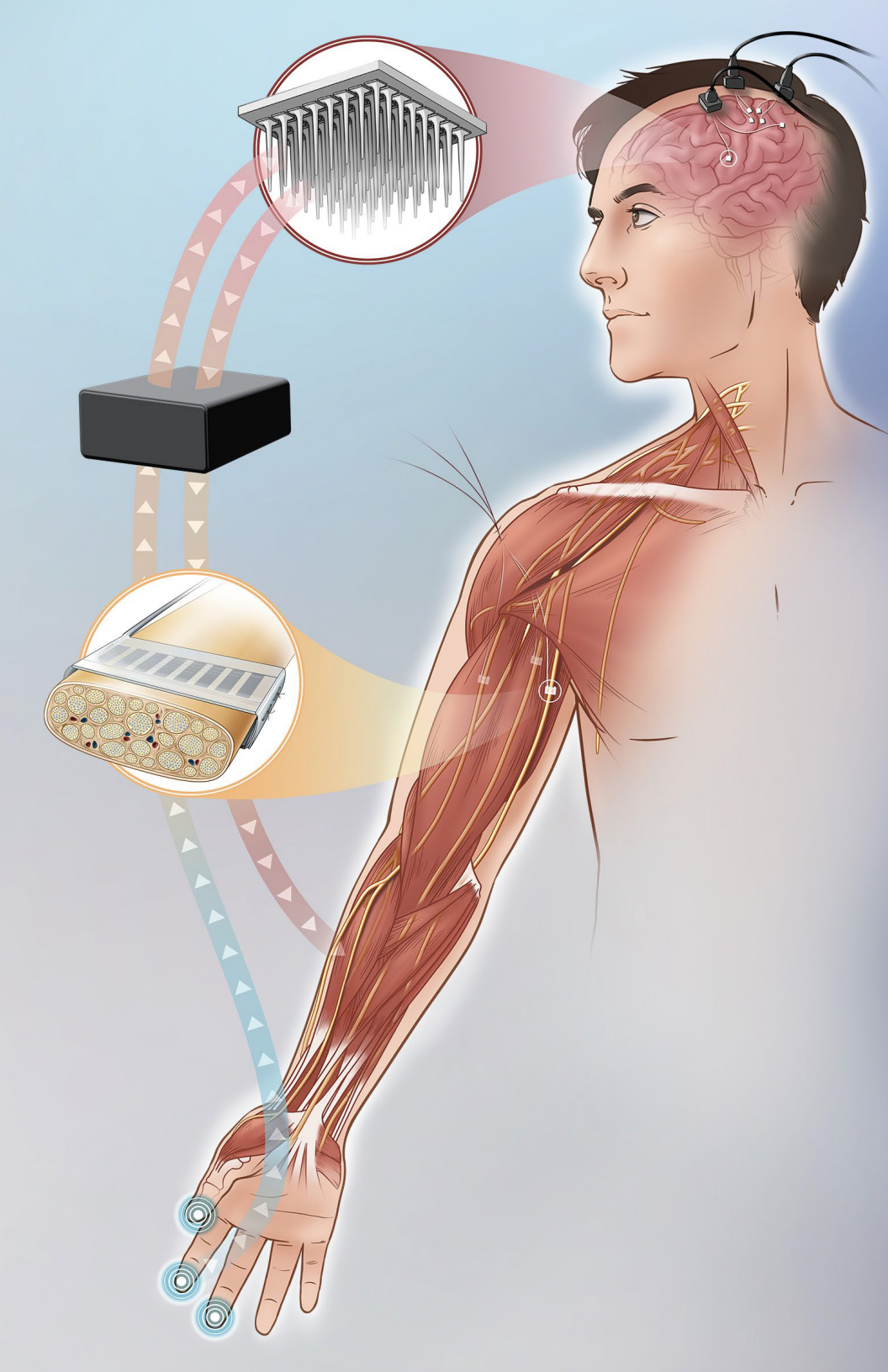
ReHAB

Reconnecting the Hand and Arm to the Brain





Using Electrical Stimulation to Restore Movement and Sensation After Spinal Cord Injury

Northwest Ohio native Austin Beggin learned about the Cleveland FES Center in the midst of his recovery. After a devastating 2015 spinal cord injury that paralyzed him from the shoulders down, Beggin began to explore potential research opportunities early on in his recovery journey.

In the first several months after his injury, Beggin received treatment at the Rehabilitation Institute of Chicago, now known as the Shirley Ryan AbilityLab, before transitioning to outpatient rehabilitation at Ohio State University's Center for Brain and Spinal Cord Research.

Treadmill and stationary bike sessions with an occupational therapist led to incremental increases in Beggin's movement capabilities, and the use of surface stimulation was also introduced. However, Beggin was not satisfied with his functional recovery.

"I felt like I was in great shape, but unfortunately, I never saw much recovery in the sense of anything coming back," says Beggin, whose spinal cord was injured in a diving accident on Florida's Gulf Coast. "I started to get much stronger in my lungs and other parts of my body, but the treadmill and surface stim didn't bring much movement back."

Beggin's occupational therapist pointed his patient to groundbreaking research taking place at the FES Center – namely, the use of brain implants and surgically implanted electrodes to revive movement and feeling for people with neurological impairments.

It's the work of the ReHAB project, which stands for Reconnecting the Hand and Arm to the Brain (ReHAB). The team comprises FES investigators A. Bolu Ajiboye, PhD; Emily Graczyk, PhD.; Robert F. Kirsch, PhD; Dawn Taylor, PhD; and Jennifer Sweet, MD.

Attention from the popular news program also helped the project secure a $4.5 million gift from an anonymous donor. Funding will expand the ReHAB team's research capabilities, ideally bringing the high-tech system to more people with spinal cord injury and/or paralysis.

An injury like Beggin's – specifically at the C3 or C4 level of the cervical spine – generally causes paralysis of all four limbs. Providing patient improvement is a daily motivator for Ajiboye, a professor in the Case Western Reserve University Department of Biomedical Engineering and a research investigator at the Louis Stokes Cleveland VA Medical Center.

"There is a scientific interest and there is a personal interest, because you have an opportunity to fundamentally change the lives of people living with these injuries," says Ajiboye. "It can give a new level of independence for the most severe cases – this population has very little or few options for volitional movements otherwise."

Ajiboye is joined in this effort by Graczyk, an assistant professor of biomedical engineering at Case and an investigator at the Louis Stokes Cleveland VA Medical Center.

Together, the team is unraveling the complex network of neural pathways between a patient's brain and arm using multiple methodologies. The system's electrodes stimulate neural pathways, enabling individuals with disabilities, including SCI and amputation, to experience varying levels of sensation required for grasping, touching, or even holding their child's hand.

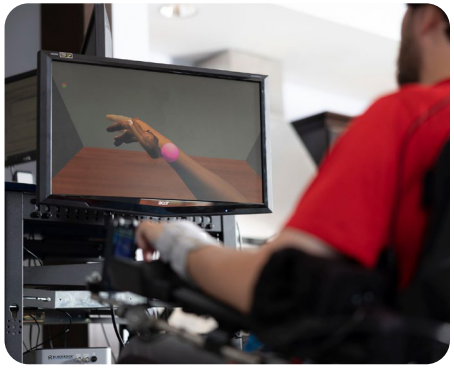
"We are able to restore function to people who, due to their injury, can't do simple things like feed themselves or drink a glass of water," Graczyk says. "That's something they rely on others to do, and that can be very challenging for them to deal with."

Showcasing the Center's Research

The FES Center, housed in the Louis Stokes Cleveland VA Medical Center, researches innovative solutions to improve quality of life for people with neurological or other musculoskeletal limitations. The Center is a collaboration among the Stokes facility, the Syracuse VA Medical Center, MetroHealth System, Case Western Reserve University, University Hospitals of Cleveland, and the Cleveland Clinic Neurological Institute.

The organization studies the use of electrical stimulation to help patients manage pain, regain hand and arm function, restore autonomic bodily functions, and treat nervous system disorders like Parkinson's Disease.

The ReHAB project focuses on tetraplegia, or paralysis of both upper and lower limbs, typically caused by



Since 2019, the ReHAB team has been developing an innovative implantable system that enables patients to directly control and move paralyzed limbs using their brain.

Beggin joined this work in late 2020, when he had cuff electrodes surgically placed around eight nerves in his arm, with 16 electrical contacts per cuff. Microelectrode arrays with a total of 384 contacts were also placed in Beggin's brain to record brain signals associated with movement and to stimulate the sensory areas of the brain for touch restoration.

Beggin acknowledged the significance of opting for brain surgery when making the decision to pursue the opportunities presented by the study.

"My body was almost this perfect vessel to be used for some type of research that could benefit me and others," Beggin says. "It's about giving people with spinal cord injuries some type of independence and a better quality of life."

Beggin dedicates two weeks monthly to the Center's ReHAB study, with research sessions averaging four hours each.

The months and years since Beggin had his brain mapped onto a computer have been marked by a series of small but significant milestones, he says.

"The first year, we didn't get much movement in the hand, but starting in year two, I got to the exciting part of finally getting to open and close my hand under brain control," says Beggin. "I'd get to do it for a couple minutes at a time. It wasn't drastic movements, but it was definitely a squeeze and the fingers and thumb opening up."

A Fundamental Life Change

The ReHAB Project harnesses a Brain Machine Interface (BMI) to measure the brain's electrical activity that occurs when Beggin attempts to make movements with his hand or arm. Electrodes are implanted in the motor cortex – the part of the brain responsible for sending movement information to the body's muscles, as well as other brain areas associated with movement planning. FES electrodes are implanted in a paralyzed upper limb as well, stimulating nerves which in turn send the signals to the paralyzed muscles, so the person can voluntarily move their own arm and fingers.

Sophisticated algorithms convert brain signals into commands that control arm movement. The ongoing clinical trial allows participants with spinal cord injury to govern limb movement directly with their thoughts, a breakthrough that garnered national interest during a segment on "60 Minutes" in spring 2023.

spinal cord injury at the neck level. Individuals with tetraplegia experience varying degrees of movement and sensory loss and may require assistance with everyday activities.

About 300,000 people in the U.S. have tetraplegia, with approximately 12,000 new cases treated each year. VA support is a cornerstone of the Center's work, and for this project in particular, because Military Veterans account for a disproportionately higher share of tetraplegia patients. Besides motor function impairments, those with partial injuries may suffer sensory deficits, including an inability to perceive touch.

Through electrical stimulation applied to his nerves and brain, Beggin is experiencing real-time sensory response akin to having his fingertip gently squeezed, Graczyk explains.

"We've used nerve stimulation to restore sensation to other participant groups in prior studies," Graczyk says. "But we've demonstrated (with Beggin) that we can get very repeatable, reliable sensation from stimulation of the brain that the participant perceives as existing on their finger."

The Most Freedom Possible

After three-plus years of at-times grueling work, Beggin can reach a hand to his face with the help of the FES provided by the ReHAB system. Enhanced sensation also lets him know how much force to apply when handling a hard or soft object.

"Right now, we're at the point where we can incorporate everything together, which I'm excited about," Beggin says. "We did a lot of sensory tests with the brain, but never incorporated it with moving. For example, grabbing objects while being stimulated at the exact same time to give you that enhanced sense of touch. So, we talked about different objects where you have to apply a certain amount of force without breaking it, like an egg."

Graczyk explains that the integration of sensory feedback and movement is the team's next immediate goal. "We have not yet integrated the full system together but are working towards it and should be ready to go with a fully integrated system demonstration in a few months," she says. "The full system would be BMI decoding plus FES for reanimation, plus stimulation for sensory feedback."

Similarly, Ajiboye notes that restoration of movement and sensory feedback remain the core objectives of the ReHAB project – not only the simple closing and opening of a hand, but more involved movements like reaching out to grab an object as well as performing basic personal hygiene activities.

"Our focus has been to restore the ability to move the shoulder and elbow, and, more recently, improve dexterous hand function," Ajiboye says. "Those complex hand patterns allow people to be more precise with activities of daily living."

Among the program's long-term goals is developing a take-home version of the brain recording and electrical stimulation system, a project funded via a $2 million U.S. Department of Veterans Affairs grant. Work on a home-based platform is in the lab phase, and researchers will be tasked with creating a portable system that people can use 24/7.

While many FES technologies are often employed for at-home therapeutic exercises as well as functional activities, existing systems fall short of the ReHAB project's larger mission, Ajiboye says.

"The brain-controlled FES system has not been developed for robust home use, so our goal with the grant is to integrate the systems and show feasibility in design criteria," Ajiboye says. "We haven't talked about commercialization yet – our immediate goal is to develop these systems further, show their efficacy, then talk about what it would take to make them more widespread and available for people."

Realizing these ambitious goals depends on a skilled team along with brave patients willing to pioneer new research, Graczyk says.

"That's why we do the work that we do – to see the impacts that it's having on people with spinal cord injuries," says Graczyk. "Austin has the best attitude and is a joy to be around. He's always excited to be doing sessions and to advance this technology. It's great to see him getting excited to do this science, and the students (at FES Center) being excited to work with him."

For Beggin's part, he says he feels blessed to contribute to an innovation with potential to transform lives.

"I've been honored to come across this technology," Beggin says. "I'm hoping the system can really take off from me to participant No. 2, to participant No. 3, to hopefully allow us the most independence and freedom possible."

Our Team

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DARPA

NIH National Institute of Neurological Disorders and Stroke

VA U.S. Department of Veterans Affairs Veterans Health Administration Office of Research & Development

For additional information about the ReHAB Study please visit **Rehabstudy.org** and check out **FESCenter.org** for information on additional studies and programs available at the Cleveland FES Center.

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