Dr. Joseph Francis with Mulugeta Semework, doctoral student.

Within His Grasp: Enabling the Brain to Run a Robotic Arm

Joe Francis, PhD, lifts a cup of water to his lips.

In executing the motion, the assistant professor of physiology and pharmacology does not think about how far the cup is from his body, or how much it weighs. How he moves the various parts of his arm — his shoulder, his elbow, his wrist, each of his fingers — as he brings the object from his desk to his mouth is something to which he pays very little attention. At least most of the time.

That's because, like able-bodied people everywhere, Dr. Francis' motions are almost automatic; he doesn't break them down into their component parts.

Except in his lab at SUNY Downstate.

There, working with collaborator John Chapin, PhD, a professor of physiology and pharmacology, Dr. Francis explores how the brain, the nervous system, and the senses collaborate to make arms lift, carry, and move. What's different about Dr. Francis' studies is that the work these arms now do will eventually be performed by robotic limbs, not human ones.

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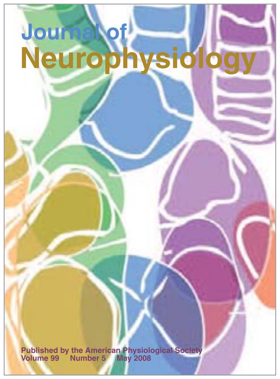
The goal of Dr. Francis' research is to create a brain-machine interface (BMI), a computer-enabled connection between a brain and a mechanical device that may allow individuals who are missing an arm to control a prosthesis simply by thinking. But the BMI Dr. Francis envisions will do much more than operate at a user's internal command. It will communicate vital information about objects, such as their weight and texture, back to the brain through what Dr. Francis calls a "closed-loop" system.

A significant amount of work remains to be done before BMIs are introduced to individuals who need them — people who lose the use of a limb, or the limb itself, through injury or illness. Most importantly, says Dr. Francis, scientists need to develop implantable electrodes that do not produce scar tissue, which may reduce the electrodes' ability to transmit the signals essential for BMI communication.



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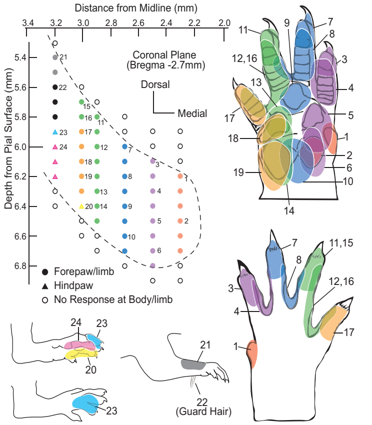

A comparison of the somatosensory thalamus in the rat and primate. An image of the rat forepaw with color-coded tactile receptive fields recorded from the middle Ventral Posterior Lateral (VPL) thalamic nucleus. The paw representation in the VPL of the rat is inverted with respect to most mammals studied; however, it shares the general trends seen in primates with subregions representing separate somatosensory modalities preferentially, such as proprioception in the rostral, light cutaneous in the middle, and perhaps pain in the caudal VPL.

The idea of connecting the brain to external sources of information has long appealed to Dr. Francis. "As a kid, I was more interested in sports than in school," he says. "I figured, if they could just download the lessons into my head, learning would be a lot nicer." That idea stuck, fueling his interest in the brain (and in school, which he turned out to like after all.) In 2001, Dr. Francis received his doctorate in neuroscience from George Washington University. While there, he was involved in early research into a BMI that may eventually enable people with epilepsy to control their seizures using an electromagnetic pacemaker.

At Downstate, Dr. Francis took on the challenge to develop a system of closed-loop feedback that can relay to the brain information that is vital to the tasks arms and hands perform. Without such a system, a BMI-enabled prosthetic arm cannot work like a real one. (Real limbs have closed-loop systems built in, through the sense of touch and through proprioception.) "When you pick up a coffee cup," explains Dr. Francis, "you sense how heavy it is, how slippery or rough its texture is, and you adjust your movements accordingly."

The process by which Dr. Francis is bringing this closed-loop BMI into being is, like most scientific endeavors, a complex one. In 2002 he started implanting electrodes into the brains of rats and recording the signals they transmitted as they used their forelimb to operate levers. "With these data, we began to formulate how their brains must be representing the information and how their brains must be working when their forelimbs move," Dr. Francis explains.

Joseph Francis, PhD

Drs. Francis and Chapin are using this information, and data collected from monkeys involved in similar but more complex tasks, to develop an algorithm that will convert brain-cell activity into robotic action. "Once we create models of how we think things are working, we can then translate the neural information so that it directs the motors in a robotic arm," Dr. Francis explains. "We can give the animal control over the position of the limb, over the joint torques (the force used in moving the joints), or over a combination of those variables."

Dr. Francis expects to begin work soon with the monkeys to explore how the nervous system relays information about touch to the brain and how such information might be used to operate a prosthetic arm. "Right now," says Dr. Francis, "we're attempting to use small electrical discharges in the thalamus to reproduce responses in the cortex like those that occur when an animal is touched on the hand."

Dr. Francis has his work cut out for him. Still, he has no question about whether he and scientists like him can develop a BMI that operates a fully functional prosthetic arm. "Once we overcome the hurdle of the electrodes," he says, "we're probably just a few years away. We're much closer to developing this than one might think." R