MAKING THE SPINAL CORD TALK

A BIOMEDICAL ENGINEER DECODES THOUGHTS ALONG THE BRAIN'S OPEN ROAD

Think of the brain as Manhattan at rush hour, with cars and buses aggressively shifting lanes on clogged avenues, horns blaring. At any given moment, a hundred billion neurons are talking to each other along thousands of separate pathways. The spinal cord, which transports neural commands to the extremities, is a more leisurely ride on the interstate with fewer lights and exits.

MESUT SAHIN, A BIOMEDICAL ENGINEER DEVELOPING WAYS TO HARNESS BRAIN SIGNALS TO CONTROL PROSTHETIC DEVICES, HAS SPENT MUCH OF HIS CAREER EXPLORING THE NERVOUS SYSTEM'S QUIETER ROADWAYS. A PIONEER IN THE FIELD OF NEURAL ENGINEERING, WHICH COMBINES ELECTRONICS, HIGH-POWERED COMPUTING AND NEUROSCIENCE, HE IS DEVELOPING DEVICES TO CAPTURE "INTENTION" FROM THE SPINAL CORD.

"In the brain, there are so many cells spread over the cerebral cortex that it's difficult to trace a particular intention as it jumps from neuron to neuron. With so much happening simultaneously, it takes a massive computer to decode these messages," Sahin says. "But it's possible to record the same signals from the spinal cord where it's less noisy."

In 2011, Sahin, an associate professor of biomedical engineering, was awarded a $1 million grant from the National Institutes of Health to investigate the possibility of developing an electronic interface between the spinal cord and a computer that will allow quadriplegics, many of them young people paralyzed in sports or traffic accidents, live a more independent life.

"This is a unique project no one else is pursuing," notes Sahin, who describes his research as an alternative to the brain-computer interface, a link between the brain and a computer. The command signals he is decoding from the spinal cord would control wheelchairs, computers and other electronic devices. In recent animal studies, he and his colleagues have been able to not only capture brain signals from the cervical spinal cord, but to show their correlation to limb movements.

"There are a lot of signals and our job is to figure out which ones control particular motions. So far, we have identified the descending signals in the spinal cord that control a rat's forelimb as it pushes a lever. The next step is to identify the signals for more complicated movements," he says.

In popular culture, these capabilities took on monstrous form in the character of Dr. Octopus, the villainous scientist in *Spider-Man* who attaches powerful tentacles to his spinal cord in order to wreak destruction on the world. "We were working on essentially the same idea before the movie came out!" Sahin laughs. "But the reality is micron-size electrodes attached to the cervical spinal cord."

The force behind these emerging capabilities is the new and powerful relationship between engineering and neuroscience.

"The term neural engineering did not exist until the mid-1990s. Until then, most engineers typically didn't learn much about the life sciences," Sahin notes. "But an understanding of biology is now integral to what we do. The field is highly interdisciplinary, with lots of room for contributions by engineers with respect to neuro-prosthetic devices, neural tissue engineering, among other innovations."

NJIT's graduate program in biomedical engineering is run jointly by NJIT and Rutgers Graduate School of Biomedical Sciences, which gives engineering students access to medical laboratories and other medical school resources at Rutgers.

The field is also driven by significant recent advances in electronics and computing, including ever-faster microprocessing speeds and a vast expansion in computer memory. "In order to work, neuroprosthetic devices need computing power to extract brain signals and process them in real time," Sahin says.

It is these connections that drew Sinan Gok, a Turkish Ph.D. student, to Sahin's lab.

"I'm an electrical and computer engineer who came to NJIT to work with devices and circuits, to apply my knowledge of electronics to biomedical engineering," recounts Gok, who described his introduction to biology as "like watching a gripping documentary and realizing that I could actually have an impact on human life."

Gok looks closely at the relationship between spinal cord signals and the electrical activity of skeletal muscles.

"The body has its own electrical currents in the form of charged ions and we can both record these biological currents and stimulate them with electrical devices. I'm trying to understand on a physiological level how the brain controls motion – how it sends commands and how the muscles react," he says. "One of the interesting questions is how the brain plots movement. Is it directional – a signal that tells the arm to move from point A to point B – or does the brain order limbs to move in one direction at a certain speed for a certain amount of time?"

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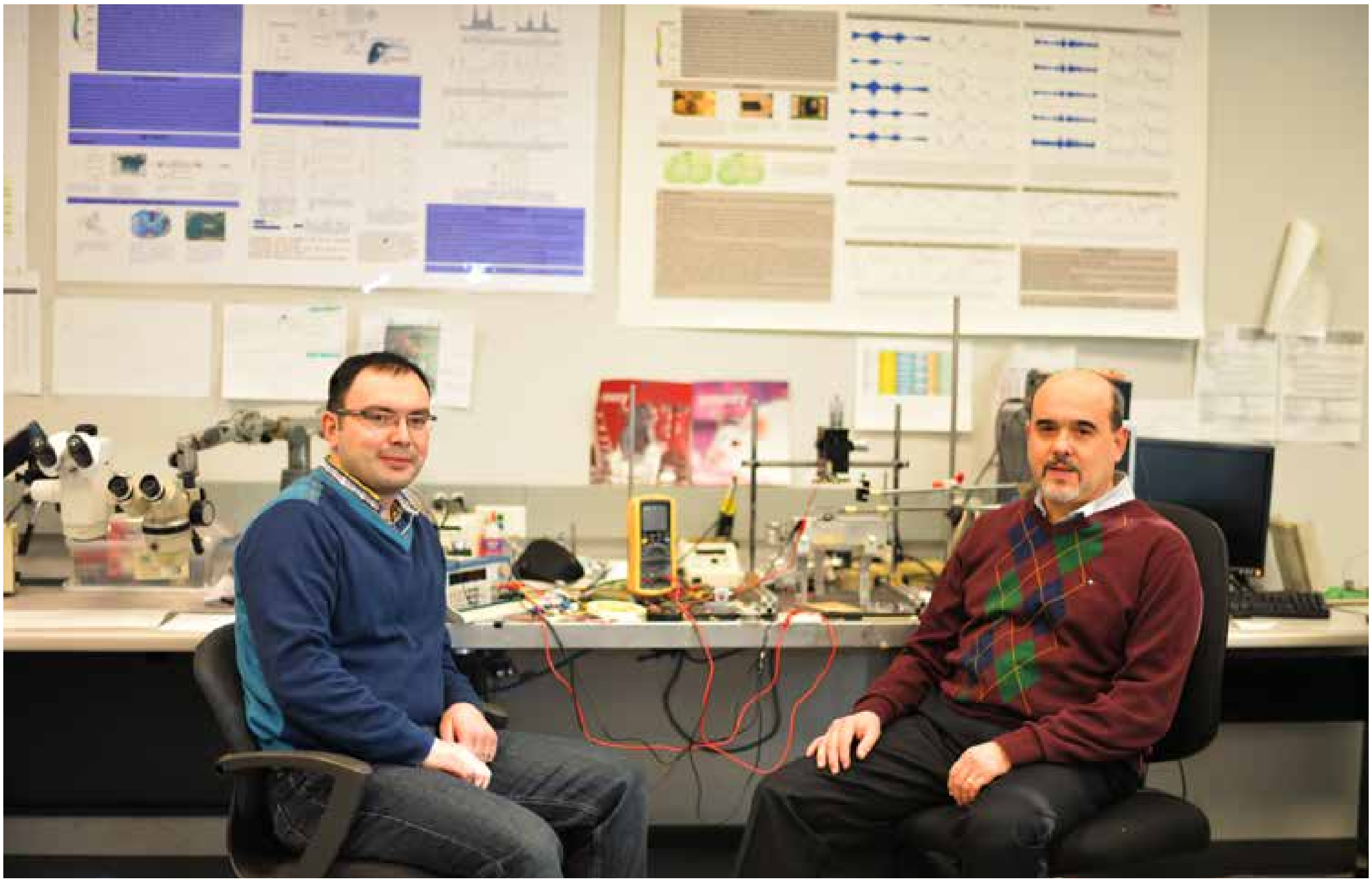
— Associate Professor Mesut Sahin



He adds, "It's exciting to feel I'm at the beginning of a new era in neural engineering."

Sahin's lab, in collaboration with Sergei Adamovich and Richard Foulds, associate professors of biomedical engineering, is also interested in the way the spinal cord "thinks" in reorganizing brain signals to adapt to the body's position.

"What sort of calculations does the spinal cord make depending on where the arm is, for example, and the amount of force it would take to move it? This context-dependent relationship between the brain and the muscles and the role of the spinal cord in this equation is one of the long-sought answers in neuroscience," he says.

Sahin got his start in biomedical engineering by studying sleep apnea, a condition caused when the muscles of the windpipe lose tone and collapse, obstructing breathing and, as a result, preventing deep sleep. He initially thought to develop methods to stimulate the airway muscles with electrodes and remove the obstructions by stiffening the muscles, but doubted peoples' willingness to have electrodes implanted.

While he has switched to research on the central nervous system, he continues to explore alternative methods to treat obstructive sleep apnea, a severe disorder that affects up to six percent of the population worldwide.

"The many different neuroprosthetic devices now being developed offer a real chance of restoring critical life functions, from the ability to comb your hair unaided and sip from a coffee cup, to the opportunity to type your own novel and surf the Internet," Sahin says. "The computational tools to translate brain signals exist already. Our next step is to create electrodes that can survive in the harsh biological environment of the central nervous system." ■

Ph.D. candidate Sinan Gok (left) and Associate Professor Mesut Sahin are asking critical spinal-cord questions.

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