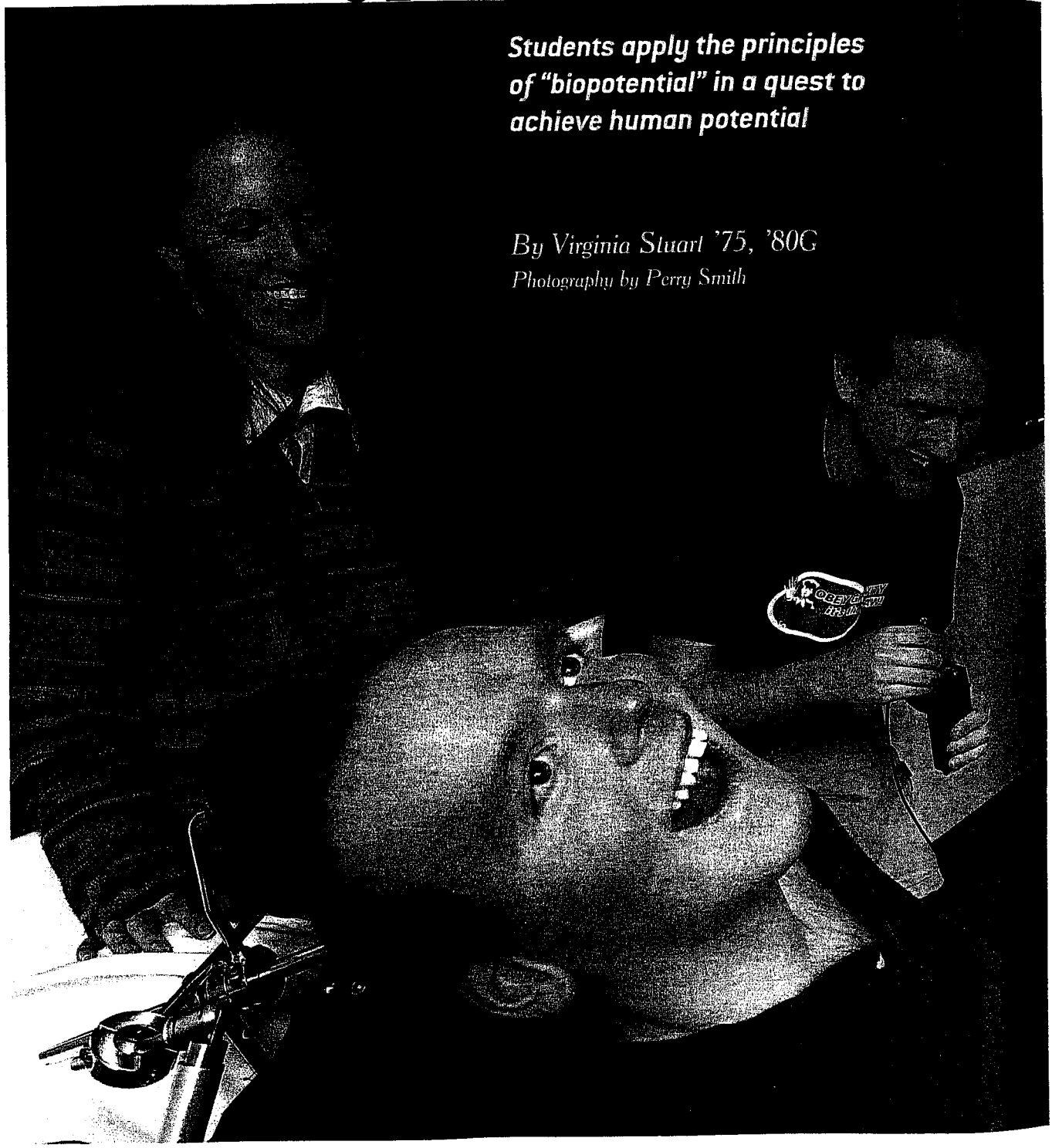
MINDS OVER MATTER

TECHNICAL CHALLENGE: UNH students, from left, Tibbany Black, Matthew Minuti and Christopher Rappa work with Luke Samuelson on the technology that could help him communicate through a computer.

Students apply the principles of "biopotential" in a quest to achieve human potential

By Virginia Stuart '75, '80G

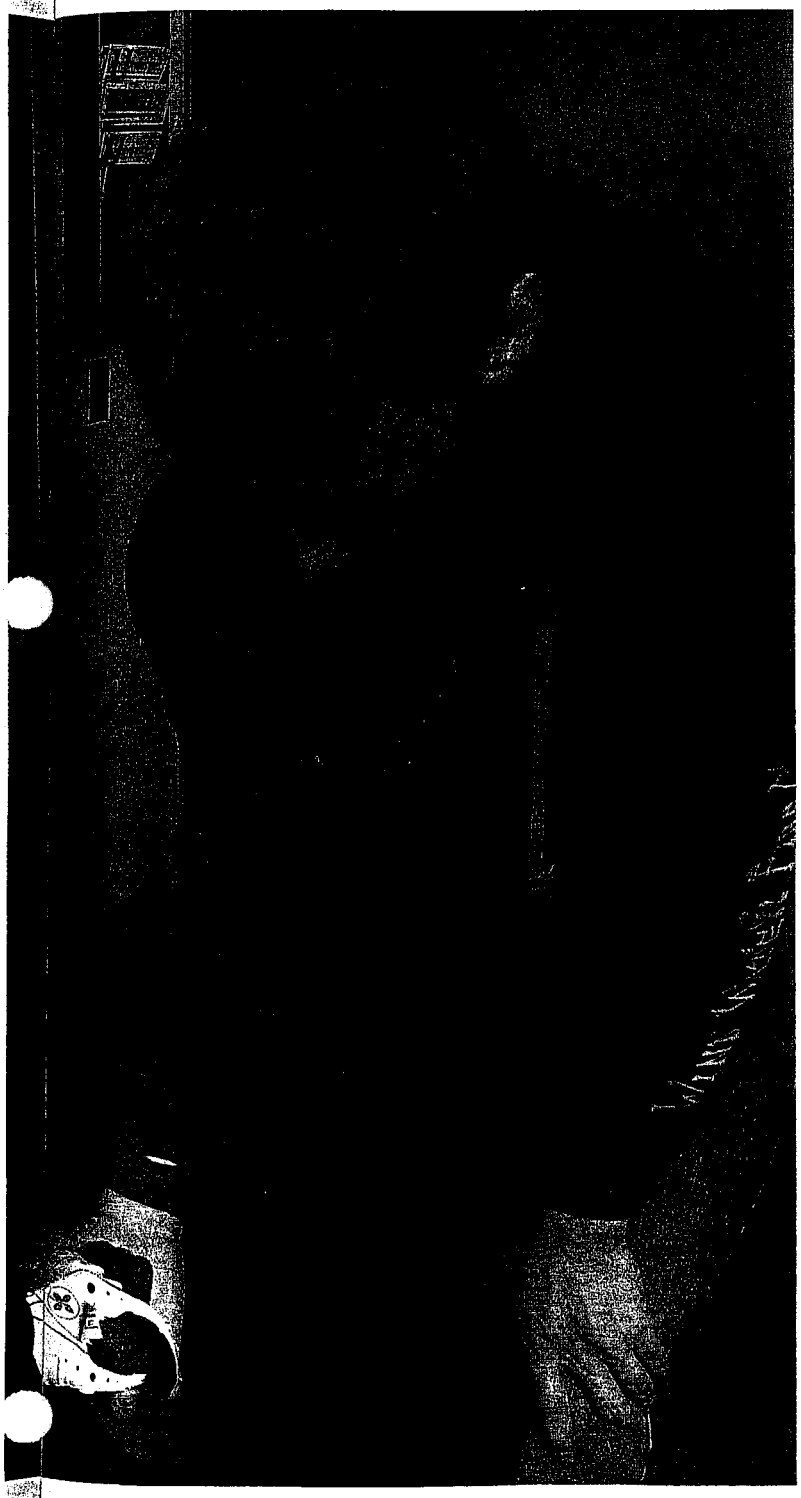
Photography by Perry Smith



When it comes to communicating, Luke Samuelson

uses all he's got. He says yes by nodding and blinking, with a smile lighting up his round blue eyes. He says no by puckering up his face as if he just ate something sour. If he's really upset, he sticks out his tongue. But everyone who works with him knows there are so many things this 21-year-old young man with cerebral palsy would say, if only he could get his own muscles to do his bidding.

He might talk about the stories he hears on the news every day, the NASCAR races he loves to watch, the college course on human development he's been taking. Surely, he'd crack a few jokes. He might gripe about the excruciatingly slow "pick and choose" computer program he formerly used to communicate, pressing his head against a switch to select a row of letters on a computer screen, passing over each letter in the row until he came to the right one, and returning to the top to select another row. The process was so exhausting that he could produce only a handful of letters, which his caregivers would use as clues to what was bothering him or what he wanted to say in an e-mail to a friend, perhaps a certain young lady. Lately, difficulties with moving his neck have prevented him from using the computer at all.



Ever since he watched a man in Maine use a finger switch to control a computer with Morse code, it has been Samuelson's dream to do the same—a dream that brought him to UNH in search of technical assistance last fall and then brought a team of three students and a professor together to help him. Morse code could provide a communication lifeline for Samuelson, a way to manipulate a computer and "speak" with more ease. Ultimately, it could also allow him to control lights and doors and other things in his environment. The goal, in the words of computer engineering senior Chris Rappa '08, is no less than this: "to provide Lucas Samuelson with an interface to the world."

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Rappa and Matthew Minuti '09, a junior in electrical engineering, volunteered last fall to work with Samuelson in a year-long independent study project under the direction of John LaCourse, chair of the electrical and computer engineering department and an experienced biomedical engineering researcher. During the year, the two students developed a great deal of empathy for Samuelson. They tried the pick-and-choose computer system and found it nearly impossible to use—even with full control of their hands. They came to recognize Samuelson's intelligence and his longing to further his education, first evidenced when he spelled out C-O-L-L-E-G-E at the age of 14. He's already made it through high school and two community college courses by using his gaze to choose the correct answer in multiple choice tests. His auditory comprehension is excellent. He is obviously engaged in team meetings or in the classroom, and when someone makes a humorous remark, his laughter often reveals that he's the first to get the joke.

For many people with cerebral palsy, physical disabilities stem from problems with the motor cortex, the part of the brain that controls voluntary movement. The effect is one of being trapped in one's own body, and over time the inability to move—or release—certain muscles can lead to further weakening.

At the start, the technological steps required to achieve Samuelson's goal had seemed relatively straightforward to Rappa and Minuti. But as is so often the case in biomedical engineering, "the human aspect is critical," notes LaCourse. The team considered 10 different switching systems and several places where Samuelson seemed to have the strength to manipulate a switch—his elbows, his index finger, his head, and perhaps easiest of all, his eyes. He had a strong preference for the finger switch, however, and everyone understood why he ruled out his eyes. "He wants

to go off to college and meet young ladies," says LaCourse. "He doesn't want electrodes stuck on his face."

On a rainy Tuesday in May, Samuelson sits in his wheelchair surrounded by the electrical and computer engineering team—plus Tibbany Black '05, '08G, a graduate student in communication sciences and disorders who has volunteered to help. "Whenever you're ready, give us a good squeeze. Give us a dot," says Rappa. Samuelson clenches his left hand, which is encased in a white batting glove, with a thin, flexible piece of metal in one finger. The new glove seems to be serving better than an earlier golfing-glove prototype. A tiny electrical current, undetectable to Samuelson, flows through the metal strip, producing measurable changes in resistance as his finger bends. A wire connects the glove to an audio trainer, an electrical circuit inside a small black box held by Minuti, whose T-shirt proclaims, *Obey gravity, it's the law!*

When the box beeps, the squeeze has been strong enough to produce a digital on/off signal that could be converted into a Morse code dash or dot. "We're trying to get the threshold," Rappa explains to Samuelson. Once the threshold is set for differentiating an intentional squeeze from an involuntary spasm, he will be given the trainer to practice with at home.

Over the past few months, Minuti has been working on two circuits—one to run the trainer and the other to send signals to an interface device, which Rappa has programmed to run a computer with Morse code. Meanwhile, Samuelson has spent time at his Hampton, N.H., home studying Morse code in his least uncomfortable position, flat on his back, looking at a chart his father has tacked to his bedroom ceiling.

By the end of the hour, everyone agrees that the trainer box is ready to go home with Samuelson. Now his homework assignment is to practice squeezing his hand in the glove, creating a long, loud beep whenever he succeeds.

"You can put it on and annoy people all day long," teases Rappa.

"And annoy your old man all night long," adds LaCourse.

"And all the way to Laconia tomorrow," says Samuelson's personal assistant as she wheels him out of the room to "go check out the girls" before heading home.

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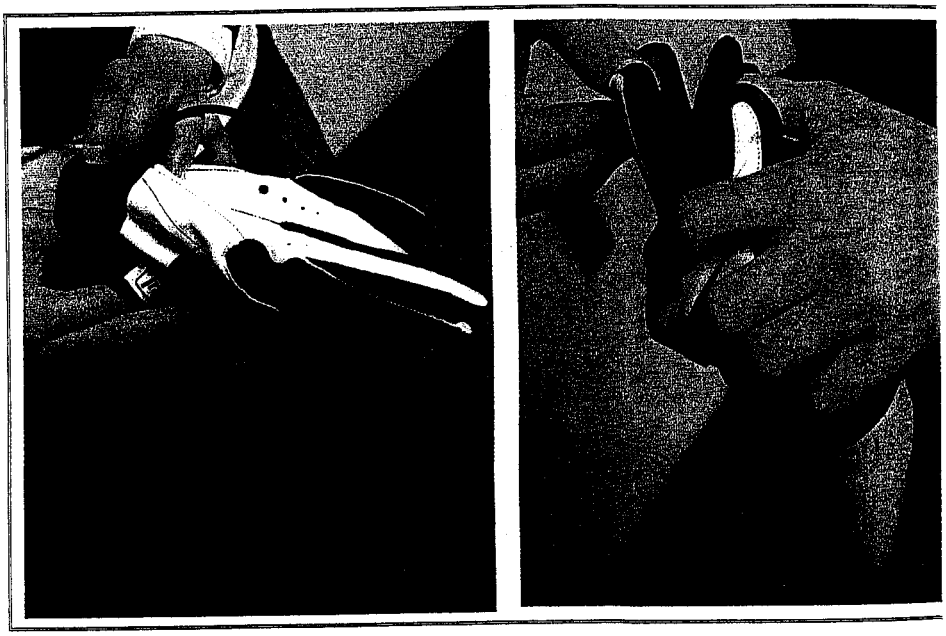
In 1771, Luigi Galvani observed that a spark could cause a muscle twitch in a dead frog's leg, a discovery that sparked humankind's awareness of the electrical basis of life. Rappa came to his own understanding of electricity and movement in high school after an automobile accident nearly paralyzed him. Recovering from a broken neck, he spent a lot of time at home in a cervical collar, and one day he watched a "Ripley's Believe It or Not" program about researchers in France who had helped a man walk for the first time in 10 years. Paralyzed in a car accident, his legs had been miraculously summoned back to life by a computer chip, which sent signals to electrodes implanted in his legs. "Engineers were able to do something medical doctors couldn't do," says Rappa. He knew then that he would go into biomedical engineering.

"Muscles are essentially electrically controlled motors," Rappa explains, "and the computer was able to send signals to them the same way the brain does." For many engineering students, these connections become clear during senior year in a course on biomedical instrumentation. "Your entire body is engineered perfectly. It's really cool," says Robert Sandler '07, who earned his degree in electrical engineering in May. Before taking the course, Sandler says he knew nothing about biopotential signals—electrical currents created by chemical reactions in the body. "Your eyes are like a battery—who knew that?"

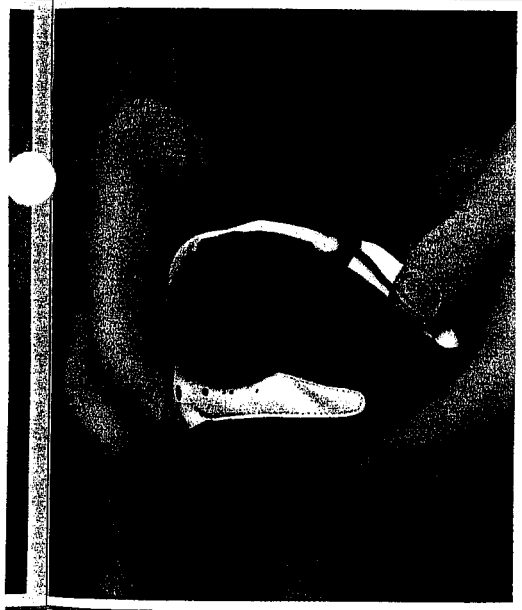
With this knowledge comes another realization: Biopotential can be harnessed. While Luke Samuelson's glove uses electricity from a battery, other rehabilitative engineering projects can make use of the body's own electrical signals, once they have been isolated and amplified. LaCourse finds that these projects are of particular interest to many students. Some, like Rappa, have a personal connection to the field. Minuti, on the other hand, says, "I'm not the typical biomed guy. I'm just fascinated with the brain's higher functions."



Sandler was one of six electrical and computer engineering majors who devoted many hours over the past year to a very challenging senior project: the development of a "universal wheelchair" that could be controlled by voice waves, eye movements and brain waves. LaCourse, adviser to this team as well, says that as far as he knows, a wheelchair has never been controlled by all three.

At UNH, every engineering student must complete a year-long senior project, and the universal wheelchair was one of 14 projects in the senior projects course taught jointly by Gerry Sedor of mechanical engineering and Alan Drake of electrical and computer engineering. Throughout the year, students attend weekly classes, meet biweekly with their project adviser, and report to their course instructors as they might to a manager if they were working on a team in an industrial setting. In fact, the experience of working on a team is considered one of the most challenging—and valuable—aspects of the senior project.

Some of the projects continue for years, with a new team building on the work of previous students. Sandler and his five teammates were the first to try to devise a universal wheelchair, but presumably not the last. "I've always wanted to start something that could be carried on," he said in April, looking ahead even as the team was putting in long hours to accomplish as much as possible before presenting their results at the university's Undergraduate Research Conference, an annual weeklong symposium featuring the scholarly and creative work of UNH students from all academic disciplines. "This is a really interesting project, definitely cutting edge, and regardless of what we get for an outcome, there will be something great for next year's team to pick up."



IF THE GLOVE FITS: Samuelson tries the second finger-switch prototype in a modified batting glove. As his finger bends, a tiny current running through a strip of metal produces measurable changes in resistance, which can be converted into Morse code. The final version, a single glove finger, was easier to manipulate.

By the end of the semester, the universal wheelchair team had made considerable progress. The students added a number of safety features to the wheelchair, such as tilt control, edge control, proximity control and an electrical ground to protect the occupant from any stray biopotential electrical currents. Katie Schwarzenberg '07 and Matthew Jamrog '07 succeeded at getting the chair to move in different directions by voice command through the use of a voice-recognition computer chip.

Sandler and partner Lucas Liimatainen '07 worked on the eye-movement control system. The front of the eye acts as a positive pole, explains Sandler, and the back is negative. Electrodes attached to the face near the eyes can detect changes in voltage as the eyes rotate. The students used an electro-oculograph to measure the changes and built a circuit to translate them into the on/off signals needed to move the wheelchair with a joystick. They succeeded in getting the chair to turn left by this method.

Christopher Bancroft '07 and Christopher Sabato '07 worked on the most elegant and challenging goal: thought control. The brain waves known as μ (mu) waves "are almost like idle waves—they're generated in the motor cortex when you're relaxed," says Bancroft. "When the left side of the body is relaxed, they're generated in the right hemisphere, and vice versa." Moving a muscle—or even intending to move a muscle—stops the μ waves. So theoretically this method could be used by someone like Luke Samuelson, who can intend to move his arm, even if he can't actually move it. These waves, too, can be captured and converted to on/off signals—UNH engineers have already demonstrated how μ waves can be harnessed in place of a mouse to move the cursor on a computer screen.

The brain waves proved difficult to capture, especially since none of the students offered to shave his or her head for the sake of science. Lacking the perfect hairless scalp for attaching electrodes, the team made do with a bathing cap coated with gel. LaCourse believes that more advanced equipment, including touchless electrodes and a dynamic filter, could help this year's team separate the extremely weak μ waves—at a mere 10^{-6} volts, they must be amplified 100,000 times—from background noise.

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For Samuelson, who now knows Morse code but can't yet "send" a message, difficulties with technology are far from academic. Tibbany Black witnessed his determination last spring when she helped him use Rappa and Minuti's finger-switch and black-box trainer: "I've seen him keep practicing until sweat is pouring down his face, and then he'll continue to practice." Still, the balance between frustration and motivation can easily tip the wrong way, and over the summer, she and his caregivers had to think outside the little black box, at least temporarily, moving away from the dot-dash approach in an effort get any muscle to fire consistently. So he practiced with a wrist-activated laser beam switch and something that motivates millions: a computer game, albeit a simple bowling game designed to record his timing.

This fall, Black expects to work more intensively with Samuelson at the UNH Speech-Language-Hearing Center as part of her required clinical practicum. It didn't take long to discover that "everything is communication" for someone like Samuelson, and she could easily interpret his expressions. Still, a conversation with him often resembles a game of 20 Questions, and she envisions a time when he might finally be able to use language to reveal his jokester personality and perhaps even approach young women with some clever pickup lines.

Deb Hiney, a speech language pathologist who has worked with Samuelson since he was 3, believes he will persevere. As to what he has gained so far, she says, "I believe he has learned what he has always known: that he is unique, and it will take a whole team of folks to figure out the best way for the outside world to get to know him." ~