NEUROSCIENCE

Jacking into the Brain

How far can science advance brain-machine interface technology? Will we one day pipe the latest blog entry or NASCAR highlights directly into the human brain as if the organ were an outsize flash drive?

By Gary Stix

▼ **NEURAL IMPLANTS—iconic props in science-fiction and futurist literature—have now made their way into the lab. But the more far-reaching uses of the technology (text input into the brain, for one) are still a literary figment.**

Ghost in the Shell

Johnny Mnemonic

transfer of self—a machine-based facsimile of the perception of the ruddy hues of a sunrise, the constantly shifting internal emotional palette and the rest of the mix that combines to evoke the uniquely subjective sense of the world that constitutes the essence of conscious life—is still nothing more than a prop for fiction writers.

Hoopla over thought-controlled prostheses, moreover, obscures the lack of knowledge of the underlying mechanisms of neural functioning needed to feed information into the brain to recreate a real-life cyberpunk experience. "We know very little about brain circuits for higher cognition," says Richard A. Andersen, a neuroscientist at Caltech.

What, then, might realistically be achieved by interactions between brains and machines? Do the advances from the first EEG experiment to brain-controlled arms and cursors suggest an inevitable, deterministic progression, if not toward a Kurzweilian singularity, then perhaps toward the possibility of inputting at least some high-level cognitive information into the brain? Could we perhaps download *War and Peace* or, with a nod to *The Matrix,* a manual of how to fly a helicopter? How about inscribing the sentence "See Spot run" into the memory of someone who is unconscious of the transfer? How about just the word "see"?

These questions are not entirely academic, although some wags might muse that it would be easier just to buy a pair of reading glasses and do things the old-fashioned way. Even if a pipeline to the cortex remains forever a figment of science fiction, an understanding of how photons, sound waves, scent molecules and pressure on the skin get translated into lasting memories will be more than mere cyberpunk entertainment. A neural prosthesis built from knowledge of these underlying processes could help stroke victims or Alzheimer's patients form new memories.

Primitive means of jacking in already reside inside the skulls of thousands of people. Deaf or profoundly hearing-impaired individuals carry cochlear implants that stimulate the auditory nerve with sounds picked up by a microphone—a device that neuroscientist Michael S. Gazzaniga of the University of California, Santa Barbara, has characterized as the first successful neuroprosthesis in humans. Arrays of electrodes that serve as artificial retinas are in the laboratory. If they work, they might be tweaked to give humans night vision.

The more ambitious goal of linking Amazon.com directly to the hippocampus, a neural structure involved with forming memories, requires technology that has yet to be invented. The bill of particulars would include ways of establishing reliable connections between neurons and the extracranial world—and a means to translate a digital version of *War and Peace* into the language that neurons use to communicate with one another. An inkling of how this might be done can be sought by examining leading work on brain-machine interfaces.

Your Brain on Text

Jacking text into the brain requires consideration of whether to insert electrodes directly into tissue, an impediment that might make neural implants impractical for anyone but the disabled. As has been known for nearly a century, the brain's electrical activity can be detected without cracking bone. What looks like a swimming cap studded with electrodes can transmit signals from a paralyzed patient, thereby enabling typing of letters on a screen or actual surfing of the Web. Niels Birbaumer of the University of Tübingen in Germany, a leading developer of the technology, asserts that trial-and-error stimulation of the cortex using a magnetic signal from outside the skull, along with the electrode cap to record which neurons are activated, might be able to locate the words "see" or "run." Once mapped, these areas could be fired up again to evoke those memories—at least in theory.

Some neurotechnologists think that if particular words reside in specific spots in the brain (which is debatable), finding those spots would probably require greater precision than is afforded by a wired swim cap. One of the ongoing experiments with invasive implants could possibly lead to the needed fine-level targeting. Philip R. Kennedy of Neural Signals and his colleagues designed a device that records the output of neurons. The hookup lets a stroke victim send a signal, through thought alone, to a computer that interprets it as, say, a vowel, which can then be vocalized by a speech synthesizer, a step toward forming whole words. This type of brain-machine interface might also eventually be used for activating individual neurons.

Still more precise hookups might be furnished by nanoscale fibers, measuring 100 nanometers or less in diameter, which could easily tap into single neurons because of their dimensions and their electrical and mechanical properties. Jun Li of Kansas State University and his colleagues