The Desire to Be Wired

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Will we live to see our brains wired to gadgets ? How about today ?

Just mention "neural interfacing" (being wired directly to a machine) on a computer bulletin board and you will quickly receive comments like the following :
I am interested in becoming a guinea pig (if you will) for any cyberpunkish experiment from a true medicine/military/cyber/neuro place. New limbs, sight/hearing improvements, bio-monitors, etc. Or even things as simple as under the skin time pieces.

Online conversants will pour forth such cybernetic dreams as computers driven by thoughts, implanted memory chips, bionic limbs and, of course, the full-blown desire to have one's brain patched directly into "cyberspace", the globally-connected computer networks. The romantic allure of the "cyborg" seems to captivate the fringes of digital culture, especially on the nets.

Neural interfacing fantasies have mainly grown out of science fiction, where "add-on" technologies turn people into powerful hybrids of flesh and steel. Since so much of our contemporary mythology comes from SF, an inherent confusion between fantasy and reality is to be expected. This already has happened in the field of virtual reality. Today's crude systems in no way reflect the media hype and "Cyberspace NOW " mentality of the impatient computerized masses. Neuroscientists and engineers in the area of implant technologies offer a similar tale of woe. Science fiction has fed us so many images of technologically souped-up humans that the current work in neural prosthesis (devices that supplement or replace neurological function) and mind-driven computers seems almost retro by comparison.

Images of human-machine courtship are omnipresent in pop culture. Recent albums by digital artists Brian Eno, *Clock DVA*, and Frontline Assembly sport names like *Nerve Net*, *Man Amplified* and *Tactical Neural Implant*. A recent *Time Magazine* article on the cyberpunk movement made a number of dubious references to the near-future tech of brain implants, offering "instant fluency in a foreign language or arcane subject". Roleplaying games based on bionic, post-apocalyptic SF are gobbling up market share once reserved for *Dungeons & Dragons*.

Computer network and hacker slang is filled with references to "being wired" or "jacking in" (to a computer network), "wetware" (the brain), and "meat" (the body). Science fiction films, from *Robocop* to the recent Japanese cult film *Tetsuo: The Iron Man*, imprint our imaginations with images of the new, increasingly adaptable human-cum-cyborg who can exfoliate one body and instantly construct another. One might even speculate a link between the surprising popularity of modern primitivism (piercing, tattooing, body modification) and the emerging techno-mythology of "morphing" the human body to the demands and opportunities of a post-human age. The human body is becoming a hack site, the mythology goes, a nexus where humanity and technology are forging a new and powerful relationship.

Academic discourse also is rife with talk of cyborg bodies and the need to re-think the postmodern relationship between humans and machines. "There's a rapt, mindless fascination with these disembodying or abilityaugmenting technologies", says Allucquere Rosanne Stone, director of the Advanced Communications Technology Lab at the University of Texas. "I think of it as a kind of cyborg envy... The desire to be wired is part of the larger fantasy of disembodiment, the deep childlike desire to go beyond one's body. This is not necessarily a bad thing. Certainly for the handicapped, it can be very liberating. For others, who have the desire without the need, there can be problems. Political power still exists inside the body and being out of one's body or extending one's body through technology doesn't change that".

"People want the power without paying the attendant costs", says Don Ihde, professor of the Philosophy of Technology at SUNY, Stonybrook. "It's a Faustian bargain".

Is the desire to be wired a fantasy born of our relationship with increasingly personalized and miniaturized technology ? Will neural interfacing be commonplace in a future we will live to see ? If so, what biomedical and bioengineering feats will be necessary ? Most important, what function-restoring neural prostheses are being researched that show promise for the disabled, and may eventually lead to function-amplifying implants ?

Bionic Hardware

In her influential essay "A Cyborg Manifesto", science historian Donna Haraway suggests that the severely disabled are often the first to appreciate the fruitful couplings of humans and machines. A brief conversation with anyone who has a pacemaker, a new hip, a (good) hearing aid, an artificial heart, or any one of a host of bionic devices will bear this out.

The neural prosthetic and interface technologies of today can be broken down into three major areas : auditory and visual prosthesis, functional neuromuscular stimulation (FNS), and prosthetic limb control via implanted neural interfaces. So far, the most successful implants have been in the realm of hearing. Larry Orloff, a scientist who had suffered hearing loss since childhood, edits Contact, a newsletter for people with hearing implants. He reports that there are more than 7,000 people worldwide outfitted with cochlear implants. These devices work through tiny electrodes placed in the cochlea region of the inner ear to compensate for the lack of cochlear hair cells, which transduce sound waves into bioelectrical impulses in ears that function normally. Although current versions of these devices may not match the fidelity of normal ears, they have proven very useful. Dr. Terry Hambrecht, a chief researcher in neural prosthetics, reports in the *Annual Review of Biophysics and Bioengineering* (1979) that implanted patients had "significantly higher scores on tests of lipreading and recognition of environmental sounds, as well as increased intelligibility of some of the subjects' speech".

The hearing-implant patients and family members I interviewed spoke of their desperation during their deaf years and emphasized how much they appreciated the technology that had changed their lives. John Anderson, a 43-year-old implant recipient from Massachusetts offered his views via electronic mail (he still has trouble communicating by phone) : "the silence of those three years when I was totally deaf is still deafening to me these many years later. My life was in the hearing world and it was critical for me to be able to hear like 'everyone else'". Orloff spoke movingly of hearing things like crickets, birds, and church bells for the first time. He also points out that computer networking was instrumental in his getting the implant : he first learned of the technology on CompuServe.

An even more radical type of auditory prosthesis now under development snakes hair-thin wires deep into the brain stem, linking it with an external speech processor. But don't expect to see it soon.

Visual prosthetics is still a long way from offering any major breakthroughs, though several promising directions are being explored. The goal of most of these schemes is to implant electrodes into the visual cortex of the brain to stimulate discernible patterns of phosphenes which can then be interpreted by the user. Phosphenes are those tiny dots (the proverbial stars) that can be seen after rubbing one's eyes or after getting beaned on the head. These phospenes originate in the brain and are responsive to electrocortical stimulation. Recently, Dr. Hambrecht and fellow researchers at the National Institutes of Health (NIH) implanted a 38-electrode array into the visual cortex of a blind woman's brain. She was able to see simple light patterns and to make out crude letters when the electrodes were stimulated.

Richard Alan Normann, professor of bioengineering at the University of Utah, has been developing similar "artificial eyes" that would use denser phosphene arrays (100 electrodes). The long-range goal of his research is the development of vision hardware that "will consist of a miniature video camera mounted on a pair of sunglasses, signal processing electronics, a transdermal connector to pass across the skin, and an array of... microelectrodes permanently implanted in the visual cortex". The development timetable for these systems is still long-term; advances have been slow. Often years pass between experiments as researchers painstakingly assemble the required miniature electronics.

Beyond sight and sound, functional neuromuscular stimulation systems are in experimental use in cases where spinal cord damage or a stroke has severed the link between the brain and the peripheral nervous system. These systems usually combine implanted electrodes and an external battery-powered microprocessor. The system is controlled by switches, either triggered manually or through movement of some body part (an elbow or shoulder) that is still operational. These types of systems are likely to be used clinically one day to restore movement in legs, arms, and hands. Similar electrical stimulation schemes to restore bladder control and respiratory functions are also in experimental and even clinical use.

Some of the most compelling research in the area of neural interfacing is being done at Stanford University. A recent article in the *IEEE Transactions on Biomedical Engineering* (V39, N9) reports that "a microelectrode array capable of recording from and stimulating peripheral nerves at prolonged intervals after surgical implantation has been demonstrated". These tiny silicon-based arrays were implanted into the peroneal nerves of rats and remained operative for up to 13 months. The ingeniously designed chip is placed in the pathway of the surgically severed nerve. The regenerating nerve grows through a matrix of holes in the chip, while the regenerating tissue surrounding it anchors the device in place. Although this research is very preliminary and there are still many intimidating technical and biological hurdles (on-board signal processing, radio transmittability, learning how to translate neuronal communications), the long-term future of this technology is exciting. Within several decades, "active" versions of these chips could provide a direct neural interface with prosthetic limbs, and by extension, a direct human-computer interface.

While a composite image of all these technologies might portray the bionic humans of SF, the practical limitations and technological obstacles are still sobering. Very few of these technologies are in approved clinical use, and most of them will not be for a decade or two. One of the main things frustrating this research is finding (or developing) materials that are not toxic to the organism and that will not be degraded by the organism. The human body has formidable defenses against invading hardware.

Besides the material and physical hurdles, this technology raises tremendous ethical and social issues. Many critics say that neural implants are impractical at best, if not downright irresponsible. These critics contend that implants are bioengineering marvels looking for a justifiable use, rather than appropriate technology for the disabled. Other naysayers argue that these unproven prosthetic devices give experimental subjects unreasonable expectations of sight, sound, and independence. Scott Bally, assistant professor of audiology at Gallaudet University, points out that auditory implants are very controversial in the deaf community. "Many deaf people feel as though deafness is not a handicap. They are culturally deaf individuals who have successfully adapted themselves to being deaf and feel as though things like cochlear implants would take them out of their deaf culture, a culture which provides a significant degree of support".

William Sauter, head of prosthetics at MacMillian Medical Center in Toronto, also has reservations. "A patient must go into surgery again, and I think most amputees don't like to be opened up", he observes in a May 1990 *Science* article on the Stanford research. In thinking of a future populated by machine-grafted humans, questions are raised as to how society as a whole will relate to people walking around with plugs and wires sprouting out of their heads. And who will decide which segments of the society become the wire-heads ? "People are just not ready for cyborgs", says the implanted John Anderson.

And the moral issue of animal testing cannot be overlooked. Society as a whole, and armchair "neuronauts" in particular, should be aware that this research is totally dependent on the extensive use of laboratory animals. Legions of cats, monkeys, rats, rabbits, bullfrogs, and guinea pigs have been poked, prodded, zapped, and stuffed full of experimental hardware in the name of progress.

Basement Neurohackers

Perhaps more within the realm of science fiction than science fact, "neurohackers" are the new do-it-yourself brain tinkerers who have decided to take matters into their own heads. "There is quite an underground of neurohackers beaming just about every type of field imaginable into their heads to stimulate certain neurological structures (usually the pleasure centers)", a neurohacker wrote to me via e-mail. Several of these basement experimenters were willing to talk.

Meet Zorn. I got his name (which has been changed) from another neurohacker who told me a wild tale about a device that Zorn had recently built. "It's got an electrode ring situated over the pleasure centers of the brain. I know someone who tried it and he said it was like having a continuous orgasm". My God, you mean this guy's invented the Orgasmatron ? I immediately called Zorn, but at the suggestion of the other hacker, I only talk to him generally about basement brain tech.

Zorn's a psychologist by trade and a weekend electronics hobbyist. He tells me about several sound and vision devices (brain toys) he's built, similar to those now commercially available. He seems entirely sane; he's full of cautions. When I tell him about some of the other neurohacks I've heard about, he expresses deep concern. "If these people are going to mess with neuroelectric or neuromagnetic stimulation, they should build in more safety devices. There's a tremendous potential for harm : brain damage". When I ask him what he's been doing recently, he becomes quiet. "Well, it's something I'd rather not talk about. It's a device I built that could very easily be abused" (hmmm... my mind flashes with perverse images of twitching orgasmo-junkies permanently jacked into the Zorn Device).

"Why would it be abused ?" I ask.

"I really can't say anything more about it. It would be a disaster if it got out into the world". Definitely an Orgasmatron... or perhaps just another piece of cybernetic mythology.

David Cole of the non-profit group AquaThought is another independent researcher willing to explore the inside of his own cranium. Over the years, he's been working on several schemes to transfer EEG patterns from one person's brain to another. The patterns of recorded brain waves from the source subject are amplified many thousands of times and then transferred to a target subject (in this case, Cole himself). The first tests on this device, dubbed the Montage Amplifier, were done using conventional EEG electrodes placed on the scalp. The lab notes from one of the first sessions with the Amplifier report that the target (Cole) experienced visual effects, including a "hot spot" in the very location where the source subject's eyes were being illuminated with a flashlight. Cole experienced a general state of "nervousness, alarm, agitation, and flushed face" during the procedure. The results of these initial experiments made Cole skittish about attempting others using electrical stimulation. He has since done several sessions using deep magnetic stimulation via mounted solenoids built from conventional iron nails wrapped with 22-gauge wire. "The results are not as dramatic, but they are consistent enough to warrant more study", he says.

Part of the danger of monkeying with one's brain, especially with little or no knowledge of neuroscience, is that most individuals do not have access to the sophisticated testing and feedback devices that are available to legitimate researchers. Through devices like the Mindset, a "desktop EEG", Cole and other researchers hope to change that (see *Going Mental*, page 106). "It is imperative that neuroscience research is not limited to large organizations with big budgets", insists Cole. The further I got out on the fringes of neurohacking, the more noise overcame signal. I heard rumors of brain-power amplification devices, wire-heading (recreational shock therapy), and most disturbing of all, claims that people are actually poking holes in their heads and directly stimulating their brains (kids, don't try this at home).

Jacking in ? Please stand by...

We know the future will be wired. Hardwiring of neural prosthesis is already here and will continue to develop towards completely implantable systems controlled by the user's brain. Most researchers, perhaps over-cautiously, contend that these advanced systems are 10-20 years in the future. Whatever the date, this technology will eventually become a common enabling option for the disabled, and at that point, people will surely start talking about using the same technology for elective human augmentation.

But even when that day comes, many questions will remain. Will people really want to have their heads opened and wired ? How will they pay for what will certainly be expensive procedures ? And what about obsolescence ? Technology moves at light speed now. How fast will it move a decade from now ? In that accelerated future, today's hot neural interface could become tomorrow's neuro-trash. "Look, Jimmy's still got the version 1.1 Cranium Jack" (titter, titter). Certainly, even the most enthusiastic neuronauts will not want to subject themselves to repeated brain surgery in the pursuit of the latest hardware upgrade.

For the near future, the bulk of elective interface options will continue to be softwired ones, mainly via the sophisticated neural transducers we already have : our five senses. Likely directions include more immersive 3D, voice input/output, and a whole wardrobe of VR work and leisure suits. The sexiest, most SF interfaces of the next decade will include EEG-controlled/radio transmitted input devices.

Certainly the mythic desire for the bionic human, whether to restore what was lost or to add on what is desired, will continue to drive much of this inquiry. What direction such desires will take is anyone's guess. Professor Idhe : "I think a lot of this is conceptualist stuff, wishful thinking. These are fantasies that may have nothing to do with what eventually gets developed and used. As Avital Ronell points out in *The Telephone Book: Technology*, *Schizophrenia*, *Electric Speech*, the phone was originally intended as a prosthetic device for the hard of hearing. Technology will always develop as the society decides what it's to be used for, not necessarily what the designer or visionary had in mind".

The Desire to Be Wired

Zachary Margulis

Let Your Neurons Do the Typing

Psychic Labs fills the crowded front room of a seventh-floor flat in a posh Park Avenue apartment building. Stacks of data tapes containing recordings of brain waves compete for wall space with four video screens, professional sound equipment, and a bookshelf stuffed with programming manuals and arcane psychic literature. Since the apartment doubles as the home of psycho-engineer Masahiro Kahata and his family, visitors are asked to remove their shoes in keeping with Japanese custom. In this humble little room, say neuro-hackers, the revolution is taking place.

Using simple little boxes and electrodes, Kahata offers a new twist on "jacking in". First, hook a MIDI controller to your head, then plug it into your Macintosh and watch your own brain waves go by in full color.

A well-credentialed software engineer in Japan, Kahata came to New York in 1989. He is universally acknowledged as a visionary for his Interactive Brainwave Visual Analyzer (IBVA). Six years in the making, the IBVA is a $1000 Mac-based system that picks up brain waves and translates them into colorful 3D graphs on the computer screen.

Kahata and like-minded researchers say that one day, keyboards and mice will be unnecessary - commands will be fed to the computer merely by thinking them.

Unfortunately, that day is not yet here. According to David Cole, director of research and development for Chinon America and an independent researcher in the field of mental computing, advances in direct-brain input to personal computers are akin to the replacement of clunky old typesetting machines with fast, cheap desktop publishing equipment. If Cole is right, the results might be the desktop equivalent of the electroencephalograph (EEG). But for now the equipment is more reminiscent of the early Apple IIs. In those days, you had to buy an extra board to make lowercase letters.

The principle of direct brain-input systems is simple. Your nervous system generates electric wavelengths with frequencies ranging from one-half cycle to more than 30 cycles per second. An electrode attached to your forehead picks up these waves as complex electrical signals, which it then transmits via radio signals to the computer. The computer uses a mathematical routine, called a "Fourier Transform", to break the signals into different wave components. Each component has a frequency of its own. Its amplitude can be graphed in near real time. According to neuroscientists, the level of "activity", or the strength of the waves at each frequency, has neurological meaning - it tells you what your brain is doing. Sort of.

This is about where science ends and, er, wacko-ism can set in. Doctors can certainly use brain-wave data for certain things. An epileptic seizure, for example, would show up quite dramatically. Intense concentration or even a sudden realization might manifest itself as distinct patterns in the graphs. But beyond that, any claims that people use brain waves to send messages, elegantly control computers, or bend spoons is speculation, if not pseudo-scientific fraud. Simply put, most neurologists would not ascribe that kind of power to brain waves.

Kahata's work evolved from a fascination with the psychic trickery of Israeli birthday party magician Uri Geller and other self-described psychics who preyed upon gullible Japanese (and Americans) in the 1970s. He was intrigued by a spoon-bending trick Geller performs, and decided to measure brain-wave activity of psychics. He found, indeed, a significant increase in the brain activity of psychics as they plied their trades.

Science writer and magic teacher Dorion Sagan (son of Carl) analyzes the situation this way : "If there is a tightly correlated increase in mental activity while a psychic is bending spoons, it is probably because he is nervous he is going to get caught".

But such psychic tomfoolery fostered the development of what could be a great tool, in the right hands. The IBVA - a two-component system packaged in plastic boxes the size of card decks; one strapped to your head, one to a receiver that sits on top of a computer - can use brain input for almost anything. Kahata's partner, Drew DeVito, has hooked it up to a MIDI interface to produce low, soothing music correlated precisely with brain activity from the frontal lobes. You can send brain-wave data over a modem. You can even record the data on a Walkman and analyze it later. Because the IBVA system is wireless, you can walk around and look out at Park Avenue while the computer records your brain waves. And while first-timers often have trouble with the device (mastery takes practice), recordings of LSD-promoter Timothy Leary's brain waves show that he is able to increase or decrease activity in any one part of the brain almost at will.

Mindset, an even more advanced IBVA-like instrument developed by AquaThought, Cole's non-profit group, is now on the market. While the IBVA looks at either one or two parts of the brain, Mindset, with the aid of a gooey, electroconductive gel, maps the whole brain at sixteen spots, thus reproducing on a laptop what was once possible only in a hospital or medical lab with a bulky and expensive EEG. The package will come with its own programming language which, according to software developer Sunil Gupta of Baltimore's Monsoon Software, will provide total control of the computer based on sixteen-channel brain input. "You do, of course, have the option of shaving your scalp, and then you wouldn't need the jelly", Gupta said. With personal-computer-based flexibility and a list price of around $1,500, Mindset could have far more mass appeal than a $20,000 EEG.

While skeptics will be singularly unimpressed by the present technology (the IBVA is a long way from transferring thought to the screen), the implications of IBVA and Mindset are astounding. The possibilities for enlightened medical use are numerous : with something like IBVA, some day a quadriplegic could "push buttons" by thinking. BioMuse, a more advanced and elaborate system from BioControl Systems in Palo Alto, California, has already shown some impressive test results in this field.

Medical student and neuro-hacker David Warner of Loma Linda University Medical Center puts it this way : "If you consider the keyboard and mouse as a unit, when we put the body into the cybernetic loop, human-computer interaction time will increase a thousandfold".

Warner predicts a change in the structure of human communications as a result. "Natural language is based on a physiological optimum", Warner says. "There is nothing optimum about little letters. The Gutenberg paradigm is dead".

At the cutting edge, in the distant future, that may be true. In the meantime, however, inexpensive equipment like the IBVA should increase access to brain-computing for hackers - the driving force behind most electronic innovation. That should speed things up; but don't toss out your keyboard - or shave your head - just yet.