

IMPLANTABLE BRAIN CHIPS? TIME FOR DEBATE¹

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ABSTRACT

We have long used mechanical devices to compensate for physical disability. Soon, however, it may be possible to augment mental capacity--to add memory or upgrade processing power. We should ponder the enormous moral implications of the machine-assisted mind now, before it is accomplished. Today's mail brings a catalog advertising a sweatshirt emblazoned with the slogan, "In my next life I'm going to have more memory installed." Most of us can relate to this desire. As it happens, it might not be so farfetched. Computer visionaries predict that within our lifetimes, implantable computer chips acting as sensors, or actuators, may not only assist failing memory but even bestow a variety of capacities. With their aid, we may acquire fluency in new languages or "recognize" people we have never met. The possibility exists that the increasingly common replacement of body parts with mechanical items will lead eventually to the creation of cybernetic organisms--beings that intimately mix man and machine. If this trend is taken to its limit, computer chips and other electronic equipment implanted within human bodies might replace, augment, and enhance those most human of faculties, our memory and our ability to reason. We could see the coming to be of science fiction's cyborg, a person who has an intimate, perhaps necessary relationship with a machine. The fantastic depictions of bionic man in science fiction tend to deflect serious discussion of this possibility. Robocop's enhanced humans and The Terminator's stainless steel robots with living human skin make the topic seem laughable. Star Trek's depiction of the evil race of cyborgs known as "The Borg" prejudices reasoned discussion of the "cyborgization" of humankind. The possibilities envisioned by William Gibson's novel *Neuromancer* of a world where the human mind and electronic technology interface in a seamless continuum of consciousness seem remote. Hence, while cyborgs get attention in science fiction, scholarly analysis of the media, and in the writings of a few bold pioneers, for the most part there has been no serious discussion of whether we should move in the direction of such interfaces, whether we can control this technology, whether it will be progress or peril, and who should control it. It is the purpose of this paper to awaken the consciousness of the bioethics community to this field, to urge that a forum for societal deliberation be created, and to pose some preliminary questions.

A QUIET REVOLUTION

Bioelectronics combines advances in prosthetic technology and in computer science. Given this origin, it has a long pedigree, since the use of prosthetic devices to rehabilitate and restore function spans human history, proceeding in stages from simple external extensions of the human body--crutches and peg legs--through "energy storing" feet and devices controlled by muscle contraction to the current work involving direct brain interfaces. Worldwide there are at least three million people living with artificial implants.(FN1) They use breast, penile, pectoral, testicular, chin, calf, hair, hormonal, medicinal, and dental prostheses. They also use bionic limbs, cardiac pacemakers, small implantable pumps to assist in pulmonary or systemic circulation of blood,(FN2) and automatic biochemical pumps that either replace or augment parts of the nervous or neuroendocrine systems and also provide sensory substitution.(FN3)

These bioelectronic developments, combined with progress in facilitating interfaces between neural tissues and substrate micro probes, are setting the stage for implantable brain chips. The first steps have already been taken in research on the cochlear implant and on retinal vision. Cochlear implants enable totally deaf people to hear sound by directly stimulating the auditory nerve. In a similar way, retinal implantable chips for prosthetic vision may restore vision to the blind. Work on prosthetic vision was begun in the 1960s, when Giles Brindley attached eighty electrodes to miniature radio receivers and implanted them into a sightless volunteer's brain, hoping to remotely stimulate the visual cortex. In the 1970s, William Doherty carried the work a step further.(FN4) The subjects of Doherty's experiments reported seeing phosphenes, or points of

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light, akin to the signals received by a functioning visual system. In 1992, a blind volunteer at the U.S. National Institute of Neurological Disorders and Stroke learned to recognize phosphene letters.(FN5) Subsequent research on prosthetic vision has proceeded along two paths, employing either retinal implants, which link a miniature camera to healthy nerves, or cortical implants, which directly stimulate the visual cortex.(FN6)

Such "applied neural control" technology has already been put to other uses. It has been used, for example, for bladder control, and to contract paralyzed muscles.(FN7) In August 1997 the Food and Drug Administration approved a pacemaker-like brain implant to help Parkinson's patients and those with essential tremors.(FN8) The operation involves a hole drilled in the skull to implant an electrode in the thalamus to block tremors by emitting a constant stream of small electrical shocks from a "pulse-generator" implanted around the collarbone. This intervention seems to provide relief of the symptoms of Parkinson's disease without the adverse results of levodopa, the leading pharmacological intervention.

What makes these developments possible is the incredible miniaturization of information technology. Computer systems have progressed from mainframes to desktops, then to luggables and portables, now to pocket-size and even wallet- and ring-size models. Meanwhile, in communications technologies, macro cellular systems have led to micro cellular and cordless technologies and are moving toward pico cellular systems. Combined, these technologies enable users to access information and communicate anywhere or anytime using equipment that is wearable and nearly invisible, so that individuals can move about and interact freely while supported by a personal information structure.(FN9) For example, Thad Starner, a Ph.D. candidate in Media Arts and Sciences at Massachusetts Institute of Technology, dresses in a wearable computer and lives connected to the Internet using a miniature computer terminal at all times. His device is the first stage of what he calls "the BodyNet, a computer network wired through human bodies."(FN10) And Steve Mann, a professor of electrical and computer engineering at the University of Toronto, has developed an Internet-connected computer that he has dubbed "WearCam." By combining wireless communication with information systems, WearCam allows one to augment and enhance experiences and, through networking, share them with others. Writing of its future impact, Mann claims, "The boundaries between seeing and viewing, and between remembering and recording will crumble. When we purchase a new appliance, we will 'remember' the face behind the store counter. A week later, our spouse, taking the appliance back for a refund, will 'remember' the name and face of the clerk she never met."(FN11)

What is being developed is a "second brain." Already, researchers have developed a pair of eyeglasses equipped with a display, a camera and microphone, a handheld control, and a computer worn in back under the shirt. The system can be worn as "computer clothing" that works as a visual memory prosthetic and perception enhancer.(FN12) Using different filters, the wearer can augment normal vision and, by freezing images, see the previously unseeable, the lettering on moving automobile tires and the blades of a spinning propeller. In the future, it is proposed that two individuals similarly equipped could experience exactly the same reality and that eventually a networked community of individuals could be in perfect congruence, sending data, voice, and video to each other. The wearable computer project envisions users accessing the "Remembrance Agent"--a large, communal data source.(FN13) Linking a global positioning system and mapping software to the wearable computer would allow users to find their way in unfamiliar territory.(FN14)

Such constant access to information could benefit doctors, lawyers, stockbrokers, and many others. One project has examined whether wearable computers might help aircraft maintenance workers. The researchers conclude that the technology will "improve organizational effectiveness by: (1) spreading organizational expertise among workers, (2) providing fast access to procedural process, and schematic information for problem solving, (3) supporting process reengineering, (4) and improving organizational memory."(FN15) Additionally, researchers have developed wearable computers linked to a wireless local area network to collect data at chicken processing plants(FN16) and to implement employee training.(FN17) The military envisions using such devices to simplify repairing equipment on the battlefield. Indeed, the military is transforming itself through the use of electronics on the theory "that more brains, not more bullets will win the next battle."(FN18)

IMPLANTABLE BRAIN CHIPS

Wearables and bodynets are intermediate technologies. The logical next step, long anticipated, is direct neural interfacing in the form of an implantable brain chip. As early as 1968, Nicholas Negroponte, director of the Media Lab at the Massachusetts Institute of Technology, first prophesied this symbiosis between mankind and machine.(FN19) His colleague, Neil Gershenfeld, has asserted that "in 10 years, computers will be everywhere; in 20 years, embedded by bioengineers in our bodies."(FN20) Neither visionary professes any qualms about this project, which they expect to alter human nature itself. "Suddenly technology has given us powers," says Negroponte, "with which we can manipulate not only external reality--the physical world--but also, and much more portentously, ourselves."(FN21) The result will be a "collective consciousness," "the hive mind." "The hive mind ... is about taking all these trillions of cells in our skulls that make individual consciousness and putting them together and arriving at a new kind of consciousness that transcends all the individuals."(FN22)

Most researchers do not dwell on this future, however. They concentrate on developing corrective tools for physical disability. Richard Norman, a researcher at the University of Utah, is developing an array of microelectrodes that when placed in the visual cortex could be used to electronically stimulate the brain to "see" scenes from a miniature camera.(FN23) The array could also be used to present a completely synthetic scene. If such electrodes were placed in the motor cortex area, it could be possible to use the brain to control external devices, such as wheelchairs. The proposed procedure is far less invasive than the surgical implantation of cochlear devices, as it involves simply blowing an array into the brain via a small hole. The development of these technologies is currently supported, in some cases by the National Institutes of Health, under protocols envisioning medical devices that restore vision and hearing to the blind and deaf, or movement to the paralyzed.(FN24) These types of arrays have been implanted in animals and tested in short- and long-term experiments.(FN25) In one example, researchers at the NIH implanted a thirty-eight-electrode array into the visual cortex of a blind woman, enabling her to see simple light patterns, even identify crude letters, when the electrodes were stimulated.(FN26) Other systems producing functional neuromuscular stimulation are being used experimentally in cases of spinal cord severance.

Clearly, the technology for implantable devices is becoming available, at prices that make it cost effective. Three stages in the introduction of such devices can be delineated. The earliest adopters will be those with a disability who seek a more powerful prosthetic device. The next stage represents the movement from therapy to enhancement. One of the first groups of nondisabled "volunteers" will probably be in the professional military, where the use of an implanted computing and communication device with new interfaces to weapons, information, and communications could be life-saving. The third group of users will probably be people involved in information-intensive businesses who will use the technology to develop an expanded information transfer capability. The first prosthetic devices should be available in five years, with military prototypes starting within ten years, and information workers using prototypes within fifteen years; general adoption will take roughly twenty to thirty years.

As intelligence or sensory "amplifiers," the implantable chip will generate at least four benefits: (1) it will increase the dynamic range of senses, enabling people to see currently invisible wavelengths, for example; (2) it will enhance memory; (3) it will enable "cyberthink"--invisible communication with others when making decisions; and (4) it will enable consistent and constant access to information where and when it is needed. For many these enhancements will substantially improve quality of life, survivability, or job performance.

The implantable brain chip will probably function as a prosthetic cortical implant. The user's visual cortex will receive stimulation from a computer based either on what a camera sees or on an artificial "window" interface. But the latter need not be anything like the two-dimensional interface that we use today; the user is going to have to learn to "see"--that is, use the interface--from the ground up. Just as Morse code has nothing to do with the strokes of English letters, so the interface of a cortical implant will have nothing in common with today's computer interfaces. The user will ask for information via a keyboard, a spoken command, a muscle movement, or even a "thought command" (analogous to a decision to move a muscle but without actual movement of a muscle). A small computer nearby, perhaps worn in or near the body, will connect to other information systems via communication links. The "windowing" system for direct neural interfaces is currently unexplored, but it is estimated that this aspect of the technology will be developed by

2003. The system could "provide voice communications and an 'eyes-up' display which would superimpose text and pictures on our normal vision."(FN27)

THE MORAL DEBATE

Not every computer scientist views such prospects with equanimity. Michael Dertouzos, director of the MIT Laboratory for Computer Science, writes in *What Will Be* that "even if it would someday be possible to convey such higher-level information to the brain--and that is a huge technical "If"--we should not do it. Bringing light impulses to the visual cortex of a blind person would justify such an intrusion, but unnecessarily tapping into the brain is a violation of our bodies, of nature, and for many, of God's design."(FN28)

This succinctly formulates the essentialist and creationist argument against the implantable chip. Fears of tampering with human nature are widespread; the theme that nature is good and technology evil, that the power to recreate oneself is overreaching hubris and that reengineering humanity can result only in disaster, is a familiar response to each new control that man exercises, from life-prolonging technologies to reproductive techniques and the tools of genetic engineering. The mystique of the natural is fueled by the romantic world view of a benign period when humans lived in harmony with nature.

However attractive, this vision is probably faulty, inasmuch as man has always used technology to survive and to enhance life. Indeed, the use of technology is natural to man. Thus this negative response to the prospect of implantable chips is certainly inadequate, although it points to a need to evaluate the technology in terms of the good or evil ways that people might use it.

The call not to "play God" relies on a religious sense that improving on the design of creation insults the Creator. In particular, it proposes that altering the functioning of the brain to create a superior human being usurps God's power. To be persuasive, this argument requires a view of creation that acknowledges no role for human creativity, and would logically also preclude curing disease and disability. Such a view is extremely restrictive.

The argument against wiring brains to a computer also involves a desire for bodily integrity and intuitions about the sanctity of the body. Many people accept invasion of the organic by the mechanical for curative purposes but feel that using technology for enhancement is wrong. For them, respect for humans requires the physical integrity of the body. Using this standard, Carson Strong has explained the distinction between therapeutic and enhancement-oriented procedures: "An intervention that is life-saving, rehabilitative, or otherwise therapeutic can be consistent with the principle that the physical integrity of the body should be preserved even if it involves a bodily 'mutilation' or intrusion, provided that it promotes the integrity of the whole."(FN29) Implantable chips that amplify the senses or enhance memory or networking capacities would thus be suspect.

For others, however, there is no bright line between therapy and enhancement. How deficient does my memory have to be before it would be ethical to wire my brain to a computer? If the therapy/enhancement distinction is hard to pin down, then the argument from bodily integrity is too weak. It cannot succeed any more than analogous arguments could proscribe cosmetic surgery or mood-improving drugs. The crucial question is then whether the technology's benefits outweigh its risks.

Even if we discount these three arguments--from nature, God, and bodily integrity--there are a myriad of other technical, ethical, and social concerns to consider before proceeding with implantable chips. The concerns involve risks, appropriateness, societal impact, costs, and equity issues. Further, they require multidisciplinary evaluation, including at least the fields of computer science, biophysics, medicine, law, philosophy, public policy, and international economy. Unlike the scientific community at the advent of genetic technologies, the computer industry has not as yet engaged in a public dialogue about these promising but risky technologies.

Avoiding discussion, simply relying on the principles of free scientific inquiry, is itself a moral stance, of course. If those involved in developing this technology allow themselves to compartmentalize and rely on hierarchical authority for moral direction, or to focus solely on the technical challenges, then this new

technology may become a consumer item before proper safeguards have been devised to protect the public.(FN30) Specialists have a responsibility to evaluate the broader implications of their work. As is the case in evaluating any future technology, it is unlikely that we can reliably predict all effects. Nevertheless, the potential for harm must be considered.

Safety. The most obvious and basic problems involve safety, since both the implantation surgery and the long-term use of implants may introduce risks. Indeed, it may prove difficult to develop nontoxic materials that will allow long-term use. It might be that long-term use is most appropriate when the technology offers therapy rather than enhancement. However, it is also conceivable that there should be a higher standard for safety when technologies are used for enhancement rather than therapy. These issues need public debate.

There are a variety of related concerns. The kinds of warranties users should receive and the liability responsibilities for defective equipment could perhaps be addressed by manufacturing regulation. Manufacturers should also make provisions to facilitate upgrades, since users presumably would want neither to undergo multiple operations nor to possess obsolete technology. Further, manufacturers must understand and devise programs for teaching users how to implement the new systems. Other practical problems with ethical ramifications include whether there will be a competitive market in such systems and whether there will be industry-wide standards for the devices. And to approach these questions, we need data on the usefulness of the implants to individual recipients and on whether all users benefit equally.

The Effect on the Self. Fascinating and vital questions surround the psychological impact of enhancing human nature. Will the use of computer-brain interfaces change our conception of man and our sense of identity? If people are actually connected via their brains, the boundaries between self and community will be considerably diminished. The pressures to act as a part of the whole rather than as an isolated individual will be increased. The amount and diversity of information might overwhelm one, and the sense of self as a unique and isolated individual might be changed.

We should also think about the implications of creating human beings with augmented sensory capacities. People with supersensory sight will see radar, infrared, and ultraviolet images, and those with augmented hearing will detect softer, higher, and lower sounds. Enhanced smell will intensify our ability to distinguish scents, and an amplified sense of touch will enable us to discern environmental stimuli such as changes in barometric pressure. These capacities could change our conception of "normal" human functioning. As the numbers of enhanced humans increase, today's normal might be seen as subnormal, leading to the medicalization of another area of life.

Thus substantial questions revolve around whether there should be any limits on the modification of essential aspects of the human species. Although defining human nature is notoriously difficult, rationality has traditionally been viewed as a claim to superiority and the center of personal identity. Discussing the possibility of repairing brainstem functions, Stuart Youngner and Edward Bartlett argue that mechanically mediated cognition would render the continued existence of a person problematical because it might subtly change the person's thoughts and feelings.(FN31) But their position is certainly open to debate. In a paper prepared for the Second International Symposium on Brain Death, James Hughes claims that "Younger's rejection of the possibility of personhood in a cybernetic medium is a common, but minority, position in the field of artificial intelligence and cognitive science. Most cognitive scientists accept the materialist assertion that mind is an emergent phenomenon from complex matter, and that cybernetics may one day provide the same requisite level of complexity as a brain."(FN32)

Plainly, these technologies will affect the nature of personal identity and of the traditional mind-body problem. Modifying the brain and its powers could change our psychic states and alter the self-concept of the user, indeed our understanding of what it means to be human. The boundary between me "the physical self" and me "the perceptory/intellectual self" will change as the ability to perceive and interact at a distance expands far beyond what can be accomplished with video conferencing. The boundaries of the real and virtual worlds may be blurred. A consciousness wired to the collective and the accumulated knowledge of mankind will surely transform the individual's sense of self. Whether the transformation would shift greater weight to our collective responsibilities--and whether this would be beneficial--are unknown.

Beyond these imminent prospects is the possibility that in thirty years, as a Business Week reporter stated, "it will be possible to capture data presenting all of a human being's sensory experiences on a single tiny

chip implanted in the brain."(FN33) This data would be collected by biological probes receiving electrical impulses and would enable a user to recreate experiences, or even to transplant memory chips from one brain to another. In this eventuality, the psychological continuity of personal identity would be disrupted, with shocking ramifications. Would the resulting person have the identities of other persons?(FN34)

Children and Equity. Changes in human nature would be even more pervasive if the altered consciousness were that of our children. Ours is an intensely competitive society, where knowledge is often power. Parents are driven to provide the very best for their children and to help them excel. Will they be able to secure implants for their children, and if so, how will that change the already unequal lottery of life? School entrance standards, gifted programs, spelling bees--all would be affected. The inequalities produced might create a demand for universal coverage of these devices in health care plans, further increasing costs to society. In a culture such as ours, however, with different levels of care available on the basis of ability to pay, it is plausible to suppose that the technology will be available as enhancement only to those who can afford a substantial investment, and that this will further widen the gap between the haves and the have-nots. A major anxiety should be the social impact of implementing a technology that widens the divisions not only between individuals and genders, but also between rich and poor. As enhancements become more widespread, enhancement becomes the norm, and there is increasing social pressure to avail oneself of the "benefit." Thus even those who initially shrink from the surgery may find it a necessity. As a society, then, we need to think carefully about the wisdom of leaving development and dissemination of this technology to market forces.

Alternatively, the technology might enable those who are cognitively less well endowed to participate in society on a more equitable basis. Certainly, the technology could remediate retardation or replace lost memory faculties for those with progressive neurological disease. Perhaps this sort of use will even be covered by health care plans. Enabling humans to maintain species-typical functioning would probably be viewed as a desirable, even required, intervention, even though the notion of species-typical functioning may be a constantly changing standard.

Dangers to Autonomy. The most frightening implication of this technology is the grave possibility that it would facilitate totalitarian control of humans beyond anything portrayed by Orwell. In a prescient projection of experimental protocols, George Annas writes of the "project to implant removable monitoring devices at the base of the brain of neonates in three major teaching hospitals.... The devices would not only permit us to locate all the implantees at any time, but could be programmed in the future to monitor the sound around them and to play subliminal messages directly to their brains."(FN35) Governments could control and monitor citizens.

In a free society, this possibility may seem remote, but it is imaginable that we would employ just such controlling technology on children, and this might be a first step in the direction of the Orwellian nightmare. In the military environment, too, the advantages of augmenting capacities to create soldiers with faster reflexes, or greater accuracy, would exert strong pressures for enhancement. When implanted computing and communication devices with interfaces to weapons, information, and communication systems become possible, the military even of a democratic society will have to employ them to stay competitive. Mandated implants for criminals are also foreseeable, even in democratic societies, if and when it becomes possible to alter specific behaviors, for example, to make criminals less violent. And since not all countries place an equally high priority on autonomy, the potential for sinister invasions of liberty and privacy is alarming. A paramount worry, then, centers on control of the technology and of what will be programmed.

Should the development and implementation of bioelectronics technology be prohibited, in view of its potentially devastating implications? This is, of course, the question we need to address. And if the technological development cannot be resisted, if we are already on a slippery slope toward using the technology, then we must consider whether and how to regulate it. Whether the informed consent of recipients should be sufficient for permitting implementation is questionable in view of the potential societal impact. Yet decisionmaking in public policy and biomedical ethics seems to opt for process rather than content. Rights assume precedence over the good. It may well be that in bioelectronics, too, substantive agreement on the good will be elusive. What makes the issues raised by the prospect of implantable brain chips hard is that the possibilities for both good and evil are so great. The problems are too significant to leave their outcome to happenstance.

FOOTNOTES

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