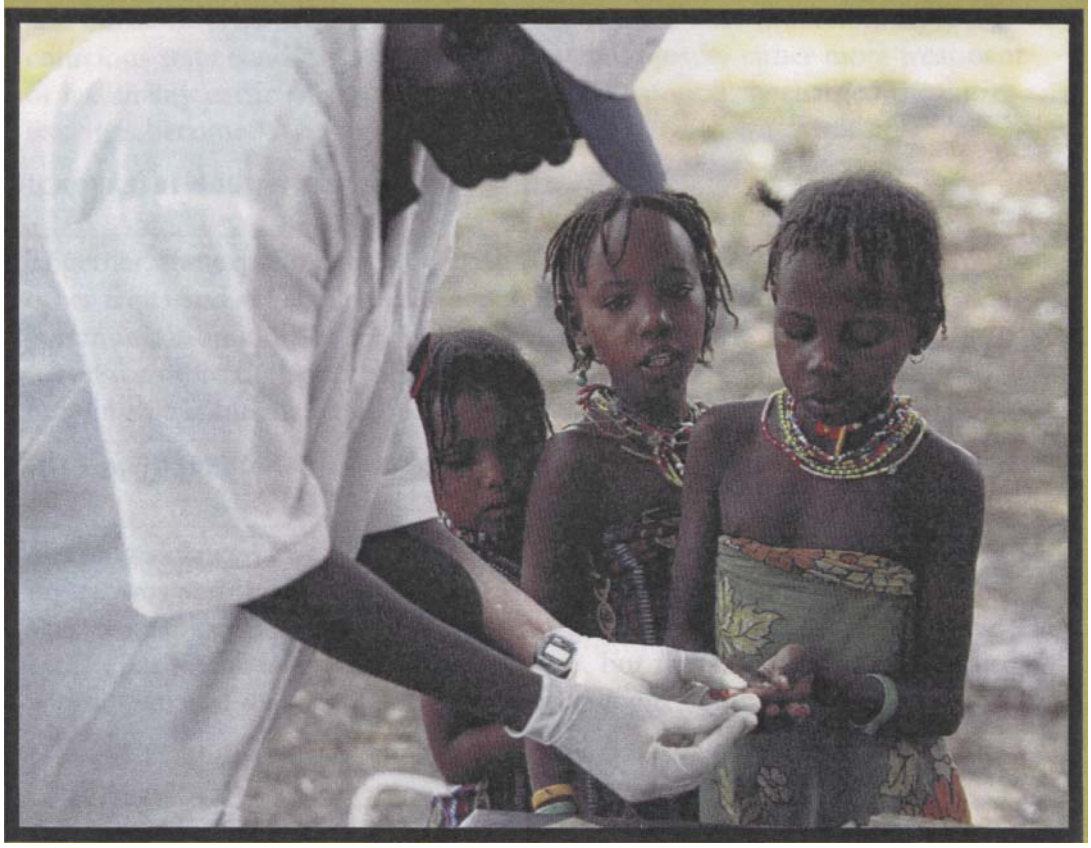
THE DANA FORUM ON BRAIN SCIENCE

Cerebrum



A Wake-Up Call About Sleeping Sickness
PETER G. E. KENNEDY

Hope for "Comatose" Patients
NICHOLAS D. SCHIFF AND JOSEPH J. FINS

Feeding the Aging Brain
JAMES A. JOSEPH, MARK A. SMITH, AND BARBARA SHUKITT-HALE

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I. RAYMOND DEPAULO, JR., STEVEN M. POTTER, TODD E. FEINBERG AND GUY M. McKHANN

Inside Cerebrum:

"We support both the right to die and the right to appropriate medical care. We do not see these rights as mutually exclusive, and we view decisions to pursue or refuse care as a matter of ethically balancing the potential benefits and burdens. What is interesting about the discord over the minimally conscious state is not that the designation could justify either more treatment or less in any particular case, but, rather, how emotionally charged the entire issue has become."

NICHOLAS D. SCHIFF AND JOSEPH J. FINS

"Together, the experiments suggesting that the blueberry, and very possibly other fruits and vegetables, can directly affect signaling and neuronal communication indicate for the first time that as we age, nutrition may be useful for more than preventing disorders associated with malnutrition or building up someone to withstand surgery."

JAMES A. JOSEPH, MARK A. SMITH, AND BARBARA SHUKITT-HALE

"Sleeping sickness. For many readers, the words conjure up images of a mysterious and terrifying disease of the jungle and veldt, afflicting intrepid Western explorers and rural native Africans with scant access to medical care. That image is not entirely inaccurate, but this disease is staggeringly widespread and its potential for harm is no longer limited to Africa."

PETER G. E. KENNEDY

"It is intriguing that hand-brain influence works in both directions. Active use of one hand, or one side of the mouth, can call into action its opposite brain hemisphere. Repeated clenching of the left hand or prolonged pulling back of the left side of the mouth produces feelings of sadness—in some subjects to the point of weeping—whereas the same movements of the right side lead to feelings described as positive and 'sarcastic, cocky, good, smug.' '

LESLEY J. ROGERS

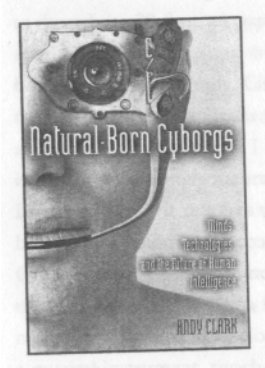
"If we embrace the notion that all humans are natural-born cyborgs and cannot avoid being in a symbiotic relationship with technology, the way we live will be changed profoundly, and mostly for the better. As Clark puts it, in one of his many quotable lines, 'Our most significant technologies are those that allow our thoughts to go where no animal thoughts have gone before.' "

STEVEN M. POTTER

ISSN 1524-6205

REVIEW

When Technology Becomes Us



Natural-Born Cyborgs: Minds, Technologies and the Future of Human Intelligence
by Andy Clark
Oxford University Press, 2003
240 pages $26.00 hardcover
Reviewed by Steve M. Potter, Ph.D.

The Terminator, Robo-Cop, the Borg, HAL9000, and Oliver Stone's "Natural-Born Killers" are some of the creepy images that came to my mind when I first heard about *Natural-Born Cyborgs.* The macabre cover of cognitive scientist Andy Clark's new book does not exactly evoke warm fuzzy feelings, either. In the introduction, Clark admits to "courting [our] immediate disapproval" by playing on our deep-seated fears of half-human, half-machine cybernetic organisms, popularly known—and feared—as "cyborgs." But this is merely a ploy to make us pick up the book and read a few pages.

Most readers who do so will be caught up in the delightfully readable, fascinating prose, perhaps unaware that they hold in their hands a philosophical treatise, not the **futurist** manifesto or science fiction novel they were led to expect. Despite its brevity, *Natural-Born Cyborgs* explores many pertinent ideas, all connected by the premise that the very core of human nature is to incorporate technology into ourselves—and the sooner we realize it, the better. "We are 'soft-selves,' " says Clark, "continuously open to change and driven to leak through the confines of skin and skull, annexing more and more non-biological elements as aspects of the machinery of mind itself." My research in the Laboratory for Neuroengineering at Georgia Institute of Technology involves what some have called cyborgs (to avoid the negative connotations of that word, I prefer "hybrots" or "neurally-controlled animats"). Because Clark in this book describes our laboratory's creations as "truly strange," the book was on my personal required reading list. After reading it, I think it should be required reading for all thinking people. It is a remarkable book.

The diversity of the topics testifies to the power and wide applicability of Claris thesis. If we embrace the notion that all humans are natural-born cyborgs and cannot avoid being in a symbiotic relationship with technology, the way we live will be changed profoundly, and mostly for the better.

This did not surprise me, as I was already a fan of Clark, based on his book *Being There: Putting Brain, Body,, and World Together Again* (MIT Press, 1996). That book, like this one, is a well-written synthesis of ideas gleaned from many researchers in many fields. The basic premise *of Being There* was that, to understand how brains work, we must appreciate how important it is that they are embodied and situated.

Unlike traditional philosophers, who can go on for pages without using a single concrete noun, Clark makes his points with real-world examples and funny, sometimes personal stories.

All the complex interactions between a brain, a body, and the world with which they interact constitute intelligence. Those themes are reiterated in *Natural-Born Cyborgs,* but now connected at every step with how technology (very broadly interpreted) makes us smart—and has done so since the first proto-humans came up with language.

At first glance, Clark's story may seem to leap about randomly, one moment delving into the body-transforming art of Australian performance artist Stelarc, the next moment alighting on the quest for the true nature of consciousness. But the diversity of the topics testifies to the power and wide applicability of Clark's thesis. If we embrace the notion that all humans are natural-born cyborgs and cannot avoid being in a symbiotic relationship with technology, the way we live will be changed profoundly, and mostly for the better. As Clark puts it, in one of his many quotable lines, "Our most significant technologies are those that allow our thoughts to go where no animal thoughts have gone before." He believes that "The most significant 21st-century frontiers... are those not of space, but of the mind."

TRANSPARENT TECHNOLOGIES

Part of the appeal of this book, and Clark's writing in general, is its down-to-earth accessibility. Unlike traditional philosophers, who can go on for pages without using a single concrete noun, Clark makes his points with real-

world examples and funny, sometimes personal stories, like how his obsession with "retro-technology" led him to go through airport security with an A-bomb trigger he found at a Los Alamos junk yard.

This anecdote is part of a discussion of technologies that Clark calls "transparent" in contrast to "opaque." Opaque technologies require constant attention, reading of manuals, and much fiddling to master—like old gadgets with lots of knobs or like the computer I am using to write this. Transparent technologies blur the lines between user and tool.

It was nice to have these labels for my own experiences. I like to zoom on my Rollerblades or mountain bike, ski down a deserted run at the beginning or end of the day, or soar aloft in a hang glider. When I am really enjoying myself, part of the pleasure is feeling at one with the vehicle. As I lug my 70-pound glider to the launch ramp, sweating and grunting in my *bulky* harness, the glider is cumbersome and awkward. But as soon as I am airborne, it seems weightless and nimble, as though its 30-foot wingspan had magically shrunk to about 6 feet and become part of my body. Circling through the sky on thermal updrafts with the hawks and clouds, the glider and I are one; it is the most supremely natural experience I have ever had. It requires technology, but the technology has become transparent. Other one-with-the-machine experiences that Clark mentions, which feel completely natural but require technology, are playing a musical instrument, touch-typing, and driving.

"MINDWARE" AND IMPLANTS

Our brains are plastic in the original sense of that word: easily reshaped and molded, like modeling clay. Clark uses many examples to illustrate how good we humans are at morphing our own body image. One comes from V. S. Ramachandran and Sandra Blakeslee's excellent book, *Phantoms in the Brain* (William Morrow, 1998). It is an entertaining parlor trick that will make you experience your nose as two feet long (and without even telling lies). Just close your eyes while someone sitting in front of you holds your finger and moves it to tap his nose. At the same time, he taps your nose in exactly the same random pattern. The matching taps all feel as though they are on your own nose, by your own finger; yet, the position and movement of your elbow is telling you that your arm is fully extended. Why? Your brain has come up with the only consistent explanation: Your nose must now be two feet long! To your brain, that is more likely than a random sequence of taps being identical in two different locations. So it is that, by changing the nature of our sensory feedback, our very perceptions of ourselves can be dramatically altered. This kind of plasticity allows us

A theme of Natural -Born Cyborgs *is that it matters not whether the technology penetrates our skin, but only whether it transforms our abilities. This idea counters the prevailing notion that a cyborg must have all sorts of machinery implanted in it.*

easily to use tools, by incorporating them into our body image. Research by Michael Merzenich at the University of California, San Francisco, has demonstrated that the brain's somatosensory cortex can rapidly re -map which cells do what, to deal with changes in sensory-motor demands. Merzenich has described his own research in terms of an adaptation for dealing with injuries (say, losing a finger). However, the larger implication — which I think Clark would support — is that this kind of plasticity evolved not so much to help amputees, but to be useful every day, for everyone, whenever we use a tool. This ability of our brains is part of our tool-using nature, which is far more sophisticated than that of any other creature we know of. (A recent hilarious satire in *The Onion* described some terrified marine biologists who had discovered dolphins with opposable thumbs; our presumed superiority was threatened.) A theme of *Natural-Born Cyborgs* is that it matters not whether the technology penetrates our skin, but only whether it transforms our abilities. This idea counters the prevailing notion that a cyborg must have all sorts of machinery implanted in it. Clark mentions that his cat has an ID microchip implanted under its skin, but that the cat's life is not at all altered by this microchip. In contrast, he says, the world is changing fundamentally through the increasing use of cell phones. We may someday have phones implanted in our heads, but even the ones clipped to our pants allow new forms of communication to occur and give us new capabilities, such as sending a snapshot of a funny sign to

I was an early adopter of "mind-ware upgrade" technology, carrying a PDA (personal digital assistant) on my body daily for 10 years, now. I consider it an important part of my brain.

a friend across the world, just a few seconds after discovering it. Those people packing the cell phone shops that line the streets of Clark's hometown (Brighton, England) are "buying *mindware upgrades* [his emphasis], electronic

prostheses capable of extending and transforming their personal reach, thought, and vision."

I was an early adopter of "mindware upgrade" technology, carrying a PDA (personal digital assistant) on my body daily for 10 years, now. I consider it an important part of my brain. When PDAs were less common, so that people would ask, "What's that hanging from your belt loop?" I would answer, "My porta- brain." Clark mentions that when he recently lost his laptop, he felt as though he had suffered a mild stroke, "a sudden and somewhat vicious type of (hopefully transient) brain damage." He "was left dazed, confused, and visibly enfeebled." I suffered a similar injury when I foolishly inserted a battery backwards in my PDA, erasing its memory. I was at a demanding course at Woods Hole, "Analysis of Neural Data," and I felt my IQ plummet 30 points in an instant. I had to wait until I could sync to my backup at home before I felt "normal" again. Because "cyborg" does usually evoke the notion of implants, this book would have benefitted from more discussion of serious scientific research on this front by real neurobiologists such as Miguel Nicolelis at Duke University, Richard Normann at the University of Utah, and Gyorgi Buzsaki at Rutgers University (to name just a few of my respected colleagues). Instead, Clark dwells at length on the pipe dreams of British professor of cybernetics Kevin Warwick, who repeatedly claims he is about to create a neural interface with his own nervous system that will be capable of communicating feelings to his wife, outfitted with a similar system. Because Clark failed to make it clear, I will state that this is science fiction. Any of us on

the front lines of neural interfacing research will tell you that scientists know very little about the internal language of the brain. Our electronic interfaces are rudimentary; we are only beginning to comprehend

It will be decades, if not centuries, before implants can improve on our good old biological interfaces to our brain cells: eyes, ears, hands, skin, speech, and our natural senses.

what we can record with them. We are still less successful in using these artificial interfaces to influence neural activity. It will be decades, if not centuries, before implants can improve on our good old biological interfaces to our brain cells: eyes, ears, hands, skin, speech, and our natural senses.

HUMAN-COMPUTER SYMBIOSIS

I appreciate — and share — Clark's guardedly optimistic perspective on where human-technology mergers will take us. The chapter called "Bad Borgs?" is a discussion of how cyborgs might cause inequality, loss of control, contact overload, alienation, deceit, degradation, and disembodiment. These are serious concerns that we should ponder as we boldly "think where no animal has thought before," but Clark suggests sensible ways to deal with them. Discussing increasing intrusions into our privacy, for example, he reminds us that many people willingly relinquish privacy when they see a clear benefit. Every day, I notice more and more cameras ever where: Orwell's Big Brother coming true a few decades late, yet few people seem to mind. Before heading home from work, we like to log onto the Web to see if the freeway is flowing smoothly; we forget that a few minutes later, as we pass the same cameras, we are being watched. "The Net is watching you." I love how Amazon.com tracks my book purchases. Thanks to this invasion of privacy, which I allow, the software agent is good at suggesting other books I might like, and I benefit from its tracking customers with interests similar to mine. The inventor of Amazon's system of "collaborative filtering" was Patti Maes at the Massachusetts Institute of Technology Lab (with her student, Carl Feynman, who created a collaborative music-recommending system called "Ringo"). Maes warned that such software agents sometimes lead to "communal tunnel vision," a narrowing of interests. In the real world, randomness plays a bigger role in determining the things and people to which we are exposed. Clark wisely recommends that if we know our technology and its limitations well, we can change it or change our behavior to fix these problems. It seems to me it would not be difficult to develop software that could emulate chance meetings or the experience of browsing the shelves of a poorly sorted used bookstore.

BECOMING OUR TECHNOLOGY

On Clark's list of "bad borg" issues, I was surprised not to see the "Evil Cyborg Takes Over" fear. Perhaps Clark realizes that that

fear is the purview of science fiction and the occasional futurist manifesto. I like the optimistic image painted by artificial intelligence expert Ray Kurzweil in his 1999

We need not fear the Us versus Them scenario as computers get smarter, because we will be them. We will continually incorporate more and more computer technology into ourselves and our lives, until we become one with it.

book, *The Age of Spiritual Machines* (Viking

Press): We need not fear the Us versus Them scenario as computers get smarter, because we will be them. We will continually incorporate more and more computer technology into ourselves and our lives, until we become one with it. The transparent merger of human-computer symbiosis will allow us to soar high above present-day humans intellectually, as I do physically in my hang glider. This symbiosis is already under way, praise Google. One of my graduate students, Peter Passaro, carries his small wireless computer to our laboratory meetings (and everywhere else). When someone has a question no one can answer, in just a few seconds Peter conjures up the answer with Google. Clark presses home an interesting distinction between knowing something and having access to that knowledge with this fascinating comment on the history of time measurement: "In a mere five hundred years, the opaque, unreliable, fixed-location tower clocks of the Middle Ages gave way to the reliable, cheap, personal timekeepers that we now take so much for granted. Along the way our relationship to time itself was irrevocably changed and transformed." He points out that when someone asks you if you know what time it is, you often say "Yes" before looking at your watch. Because the link between you and your watch is so reliable and quick, it doesn't make sense to say "No, but I will look and find out." How long before we have Google on our watches? I see an empowering transformation about to happen, when access to the whole World Wide Web is so easy, like glancing at your watch, that we already "know" it. My grad student Peter is almost there. As Tim Berners-Lee, the creator of the World Wide Web, describes it in *Weaving the Web* (Harper San Francisco, 1999), he was driven by a similar vision, which included easy collaboration between any two people.

THE WEARABLE REMEMBRANCE AGENT

A band of geeks, whom I regard as pioneers and heroes, have been wearing computers since they (the computers) were big and clunky, with heads-up visual displays. In doing so, these pioneers augmented themselves and their realities by means of a continuous connection to the Internet. Now that computers are smaller, with displays easily hidden in regular eyeglasses, there are many of this breed of human-computer symbionts. Clark describes the proposal of one of them, Bradley Rhodes, for a "wearable remembrance agent" that would be similar to having Google at your fingertips, except that, instead of searching through everything on the Web, it "knows" about all your personal stores of information. On the basis of how much Mac OS's powerful and very fast search engine, Sherlock, has transformed my world, I can attest that such a tool would make a huge difference in our capabilities.

One of the most limiting constraints of our brains is what philosopher Daniel Dennett calls its Joyce and Machine quality. Like novelist James Joyce's stream-of-consciousness narrative, our conscious stream seems able to handle only one thing at a time. In that sense, it is like a digital computer.

If I could instantly look up details in any of the many research articles in my filing cabinet and know how they related to details in other papers, I could be a much more effective scientist. One of the most limiting constraints of our brains is what philosopher Daniel Dennett calls its Joycean Machine quality. Like novelist James Joyce's stream-of-consciousness narrative, our conscious stream seems able to handle only one thing at a time. In that sense, it is like a digital computer. Once we are good enough at something and can do it "automatically," we can do several behaviors at the same time, like driving while singing our favorite song. But our conscious mind, that "tip of the Iceberg" of all our mental activity (as Clark eloquently put it), constitutes our most immediate awareness and seems to direct our actions. Until we can expand our consciousness to be able to take in and consciously process multiple disparate ideas simultaneously, we will continue to make poor decisions about what to do next. How often are we able to trace, and consider, all the possible consequences of an action before we take it? Usually, it is simply too much. I believe the wearable remembrance agent has the potential, without ever requiring any "implants," to overcome this limitation and transform humanity into a more compassionate, responsible species.

EXCERPT

From *Natural-Born Cyborgs: Minds, Technologies and the future of Human Intelligence,* by Andy Clark. © 2003 by Andy Clark. Reprinted with permission of Oxford University Press.

My body is an electronic virgin. I incorporate no silicon chips, no retinal or cochlear implants, no pacemaker. I don't even wear glasses (though I do wear clothes), but I am slowly becoming more and more a cyborg.

So are you. Pretty soon, and still without the need for wires, surgery, or bodily alterations, we shall all be kin to the Terminator, to Eve 8, to Cable...just fill in your favorite fictional cyborg. Perhaps we already are. For we shall be cyborgs not in the merely superficial sense of combining flesh and wires but in the more profound sense of being human-technology symbionts: thinking and reasoning systems whose minds and selves are spread across biological brain and non-biological circuitry. This book is the story of that transition and | of its roots in some of the most basic and characteristic facts about human nature. For human beings, I want to convince you, are *natural-born* cyborgs. This may sound like futuristic mumbo-jumbo, and I happily confess that I wrote the preceding paragraph with an eye to catching your attention, even if only by the somewhat dangerous route of courting your immediate disapproval! But I do believe that it is the plain and literal truth. I believe, to be clear, that it is above all a SCIENTIFIC truth, a reflection of some deep and important facts about (a whiff of paradox here?) our special, and distinctively HUMAN, nature. Certainly I don't think this tendency toward cognitive hybridization is a modern development. Rather, it is an aspect j of our humanity, which is as basic and ancient as the use of speech and which has been extending its territory ever since. We see some of the "cognitive fossil trail" of the cyborg trait in the historical procession of potent cognitive technologies that begins with speech and counting, morphs first into written text and numerals, then into early printing (without moveable typefaces), on to the revolutions of moveable typefaces and the printing press, and most recently to the digital encodings that bring text, sound, and image into a uniform and widely transmissible format. Such technologies, once up and running in the various appliances and institutions that surround us, do far more than merely allow for the external storage and transmission of ideas. They constitute, I want to say, a cascade of "mindware upgrades": cognitive upheavals in which the effective architecture of the human mind is altered and transformed. It was about five years ago that I first realized we were, at least in that specific sense, all cyborgs. At that time, I was busy directing a new interdisciplinary program in philosophy, neuroscience, and psychology at Washington University in St. Louis. The realization wasn't painful; it was, oddly, reassuring. A lot of things now seemed to fall into place: why we humans are so deeply different from the other animals, while being, quite demonstrably, not so very different in our neural and bodily resources; why it was so hard to build a decent thinking robot; why the recent loss of my laptop had hit me like a sudden and somewhat vicious type of (hopefully transient) brain damage. •