CHAPTER 13

DO SIGNALS HAVE POLITICS? INSCRIBING ABILITIES IN COCHLEAR IMPLANTS

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Introduction: The Neural-Computer Interface

In 1998 roboticist Hans Moravec published a millennial prediction about the imminent convergence of humans and machines—based on evidence from the evolution of sound technologies:

> In a few decades, people may spend more time linked than experiencing their dull immediate surroundings . . . Linked realities will routinely transcend the physical and sensory limitations of the "home" body. As those limitations

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become more severe with age, we might compensate by turning up a kind of volume control, as with a hearing aid. When hearing aids at any volume are insufficient, it is now possible to install electronic cochlear implants that stimulate auditory nerves directly. Similarly, on a grander scale, aging users of remote bodies may opt to bypass atrophied muscles and dimmed senses and connect sensory and motor nerves directly to electronic interfaces. Direct neural interface would make most of the harness hardware unnecessary, along with sense organs and muscles, and indeed the bulk of the body. The home body might be lost, but remote and virtual experiences could become more real than ever. (Moravec 2000, 169)

Electroacoustics has been at the forefront of signal engineering and signal processing since "the transducing 1870s," when the development of the telephone marked the first successful conversion of a sensuous phenomenon (sound) into electrical form and back again (Hunt 1954, 37). By the second half of the twentieth century, acoustics research centers in the United States, such as Bell Telephone Laboratories, the Harvard Psychoacoustic Laboratory, and Bolt, Beranek and Newman, had made central contributions to the digital coding of signals and to computer networking; the "overarching themes," as John Swets has argued, were "information processing and man-machine integration."[1]

In 1984, after FDA (U.S. Food and Drug Administration) approval of the 3M cochlear implant for adults, neuroprosthetics entered the commercial sphere.[2] The cochlear implant (CI) delivers electrical signals directly to the auditory nerve. With approximately 200,000 users today, these devices remain the most common neural-computer interfaces in the world.[3] The current technology includes an external microphone and a speech processor—a tiny computer with hardware and software that can be upgraded. The processor variously transduces, samples, and codes environmental sound in order to transmit it to the auditory nerve through up to twenty-four electrodes, which functionally replace the thousands of hair cells in the inner ear.

Concurrent with their entrenchment in futurist discourse, cochlear implants quickly entered the canons of bioethics and disability studies, raising questions about the definition of impairment, the feasibility of pediatric informed consent, and the cost-effectiveness of neuroprostheses. Many bioethicists have taken up the Deaf culture or linguistic minority critique of implantation, which situates this technology in the long history of eugenicist attempts to promote oralism through the medical eradication of deafness and through pedagogical bans on sign language (Beard 1999; Berg, Alice, and Hurst 2005; Crouch 1997; Levy 2002; Sparrow 2005). Despite the prominence of the cochlear implant in disability studies, bioethics, and science fiction, however, it has inspired little research in science and technology studies (STS). Stuart Blume, a sociologist of science and parent of a deaf child and a hard-of-hearing child, conducted the most substantial fieldwork in the 1990s on the reception of implants in France, the United States, England, Sweden, and the Netherlands (Blume 2000). Blume detected "two very different accounts of cochlear implantation":

One is a tale of medicine's triumph, akin to many other such tales: a tale of courageous pioneers, of the wonders of medical science and technology.

The other is in a genre which has emerged only in the past two decades and which highlights the subordination of medicine to surveillance, social control and normalisation. This a tale of the oppression of the deaf: of hearing society's inability to accept deaf people for what they are.[4]

Yet more than one identity group is accommodated within the category of deafness. It includes members of Deaf culture, self-defined as linguistic minorities who sign (and whose "disability" is largely an effect of the built environment and social stigma); late-deafened adults, who tend to claim disability from hearing loss; and oral deaf and hard-of-hearing individuals of all ages.[5] Without rejecting Blume's assertions about the Deaf response to cochlear implants, it is possible to write a third history of this technology—a history that includes the active participation of late-deafened volunteers in research and development and at the same time depicts their distinctive patterns of stigmatization and exclusion. In *The Artificial Ear: Cochlear Implants and the Culture of Deafness*, published in 2010, Blume largely maintains his focus on Deaf culture and the debate surrounding pediatric implantation. He concludes, "The demands of Deaf community leaders and advocates had little or no effect either on development of the cochlear implant or on the beginnings of local implantation practices. The experience of deaf people was not accepted as essential or even as relevant" (Blume 2010, 197).[6]

Reflecting on the participation of cochlear implant users (including himself) in trials of sound-processing software, technology theorist Michael Chorost offers a different perspective on the relevance of deaf experience to the making of this technology:

Even without being able to write code themselves, implant users do have a crucial impact on how the code is written. When engineers write new code, they have to test it on implant users to see if it helps them hear better. They also have to find out if implant users like it and can get used to it. To do that they need to recruit articulate users and convince them to offer their time. It's a highly collaborative process and is integral to how the field makes new advances. (Michael Chorost blog, comment posted January 5, 2006)[7]

In this chapter I follow some of the trajectories by which the autoexperiments, field notes, and laboratory tests of early users have left traces in the hardware, as well as the software, of cochlear implants. A species of "the co-construction of users and technologies" genre in STS, this chapter also considers the distant but intimate relations between lead and end users (Hippel 1986; Bijker 1995; Oudshoorn and Pinch 2003).

On the one hand, the anatomy and phenomenology of experimental research participants exert a subtle influence on the experiences of users downstream. STS scholars have noted that "scripts"—defined by Madeleine Akrich as "the representations of users" embedded within technology—often materialize during the research and development, clinical trial, or testing phases of technical development.[8] Designers do not simply "project" users into cochlear implants; from surgery to speech processing, these devices are inscribed with the competencies, tolerances, desires, and psychoacoustics of early users.

On the other hand, the recommendations of test subjects have as often been expunged as built into cochlear implants. In what I am calling *cross-purpose collaboration*, social norms, medical ideals, and commercial interests have vied with the needs and preferences of deaf people in the construction of implant technology. In 1980 Langdon Winner asked whether artifacts had politics; for present-day electronic and digital media, politics can be found at the level of signals. Specifically, CI signal processors embody a range of cultural and economic values, some of which are deliberately "scripted" into design, others of which accrete inadvertently. These scripts include the privileging of speech over music, direct speech over telecommunication, nontonal languages over tonal ones, quiet "listening situations" over noisy environments, and black-boxed over user-customizable technology.[9] All technical scripts are "ability scripts," and as such they exclude or obstruct *other* capabilities. Due to the complexity and opacity of electronic technology, these constraints often prove impossible for users to circumvent. The "home body" is thus not lost with this new medium; practices of listening are radically materialized. Users, moreover, experience their devices across the corporeal registers of hearing, vision, and tactility.

Bionic Rhetoric

According to Bonnie Tucker, a deaf legal scholar, "The hatred with which Deaf culturalists view cochlear implants is expressed in the ASL sign for the cochlear implant, which includes a two-fingered stab to the back of the neck, indicating a 'vampire in the cochlea' " (Tucker 1998, 9). Although the sign language community is more diverse than is often acknowledged—and increasingly includes bicultural users of cochlear implants—existing animosity toward these devices derives from countless disappointments in Western science and medicine, accumulated over the last two centuries. Harlan Lane, a hearing author who earned a MacArthur Award for his philosophical histories of signing Deaf culture, has detailed the repeated scientific victimization of deaf individuals—from Jean-Marc Gaspard Itard's application of leeches and electricity to his students' ears in the nineteenth century, to Alexander Graham Bell's prohibitions on deaf intermarriage, to Nazi sterilizations and executions (Lane 1993). Harry Lang, a deaf professor at the Rochester Institute of Technology, tells of the more subtle losses that have attended scientific "progress" for deaf people:

> A glimpse into history also provides some understanding of why there is so much emotion attached to technological advances. "Advances" in voice telephony led to a ninety-year delay in access to the telephone for deaf people. "Advances" in adding the sound track to silent movies led to more than forty years of lost access to films. For hundreds of years, deaf people, viewed as "disabled," have been treated with chemical and electrical "cures," sent up for airplane dives, and subjected to a multitude of other medical fixes. (Lang 2002, 91–92)

Equally sobering, cochlear implants have been correlated to sign language death and "cultural genocide," especially since 1990, when the FDA approved them for children (Wrigley 1996; Ladd 1985). In 2004, Australian linguist Trevor Johnston, whose parents are deaf (and sign), published a demographic survey in the *American Annals of the Deaf* (with the bittersweet title "W(h)ither the Deaf community?"), which predicted an end to Australian Sign Language (Auslan) within "half a lifetime" as the result of "improved medical care, mainstreaming, cochlear implants, and genetic science" (Johnston 2004, 370). *Sign Language Studies* dedicated its Winter 2006 issue to the international "comments" spurred by this chapter; authors reported comparable situations in Norway and—with a more gradual timeline—the United States. Teresa Blankmeyer Burke, a professor at Gallaudet University, insisted upon the resilience of sign language and Deaf culture; she noted that if Johnston's forecast turned out to be true, however, it would constitute a novel "instance of scientific progress directly threatening a linguistic community" (Burke 2006, 175).

Stuart Blume has examined the establishment of "clinical feasibility" and respectability for cochlear implants throughout the 1970s and 1980s. He concludes that most Deaf people were initially indifferent; their response "was quite unlike that of actual or potential AIDS patients, who (at least in the United States) stressed the right to earliest possible access to what might prove a life-saving drug" (Blume 1997, 33).[10] Blume acknowledges that *deafened* individuals "deluged" electroacoustic and otological researchers with inquiries; deafened advocates in fact urged physicians in France, the United States, and Australia to develop the first implants and offered themselves for surgery (Blume 2010, 31, 33). Blume argues that these physicians subsequently deployed "bionic rhetoric" and sensational performances by early volunteers to convince further test subjects that implants were beneficial. While Blume does not explain this ostensible drop-off in interest among deafened people, I suspect that the invasiveness of the experimental procedure and the limited definition of the first cochlear implants were deterrents, not to mention the outspoken skepticism of many others in the medical community. Moreover, after the 3M/House implant gained FDA approval in 1984, "the market grew far more slowly than had been anticipated," an outcome due in part to the tremendous expense of the device (Blume 1997, 38; see also Blume 2010, 51; Zeng 2007).

The rhetorical promotion of cochlear implants as "bionic ears" (as opposed to imperfect prostheses) unintentionally generated a counterrhetoric among Deaf activists. In the 1990s, Blume concluded that the force of their counterrhetoric was such that this "stigmatized and relatively powerless group [became] a significant actor in the process of technological change" (Blume 1997, 46). The contributions of Deaf actors were, in Blume's account, inhibitory—discouraging implantation rather than affecting the design and fabrication of these devices. However, with the global escalation of implant adoption (due to factors ranging from improved technology to lowered age limits for legal implantation), Blume (2010) has reevaluated the protests of the Deaf community as disappointingly ineffectual. He registers a nearly impassable ethical predicament: When hearing parents choose implants and mainstream (oral)

education for their deaf children, they diminish the population of native signers. One solution, Blume suggests, entails "rewriting kinship"—rethinking the imperative of common ability within the family and imagining linguistic communities external to family or nation.[11] At the most basic level, some of this work could occur through changed counseling practices in otolaryngology clinics.

Single Channel

For the most part, the first implantations were conducted with late-deafened individuals; those born deaf were not considered good trial candidates because they could not compare the electronic "ear" to prior experiences of hearing. From the outset, a tension has existed between normalizing therapeutics and the unexpected effects of the technology. Implants provide a novel mode of auditory perception, and, at once, they often socially disable those who wear them. Although cochlear implants seem to promise the replacement of a lost sense, by audiological standards implant users continue to have a hearing impairment.

Direct electrical communication with the human auditory nerve dates to 1957, when Charles Eyriès and André Djourno implanted "Monsieur G." at l'Institut Prophylactique (Arthur Vernes) in Paris. The patient—an engineer—had lost hearing in both ears after a surgical procedure.[12] Eyriès was a practicing otolaryngologist, Djourno a trained physician who had turned to basic research in medical electricity. Djourno studied electrocution and electroshock in animals and cadavers, funded by Électricité de France, which was interested in potential countershock applications. To this end, he constructed a number of induction coil implants ("microbobinages") for muscle and organ telestimulation.

Earlier, in 1953, Djourno had met a deaf man who "had considered suicide" and "said that it was utterly unbearable, this condition of no longer hearing . . . he said: 'I would prefer any noise . . . even if it's far from a real sound.' " Djourno stimulated the man's ears temporarily with electrodes, and he heard a few sounds. In a published article soon thereafter, Djourno speculated that the implants he had designed might be appropriate for treating deafness.[13]

Djourno and Eyriès claimed that Monsieur G. had similarly "requested that the impossible should be tried in order to correct—even to the most limited degree— his total deafness. He was so insistent in his desire that we decided—in spite of the possibility of a failure, as we informed the patient—to embed an induced coil" (Djourno, Eyriès, and Vallancien 1957).[14] They implanted one of Djourno's coils through the skull to the eighth nerve on February 25, 1957. During postoperative testing, Monsieur G. heard a number of high chirps and whistles (Seitz 2002, 81). He participated in "reeducation" four times a week for several months; when delivered speech signals through a microphone, he perceived low tones as the tearing of "jute cloth," higher tones as that of "silk."

Despite the incredible acoustic distortion, Djourno and Eyriès reported:

> He very much likes to have the apparatus working for the pleasure of hearing people come and go, slamming the door, or listening to conversation going on around him. Turning off the apparatus plunges him into a silence which he finds unbearable for a few minutes. In contrast, an unfortunate bump against the microphone results in a violent noise which deafens him for several seconds. (Djourno and Eyriès 1957, 1417)

When the implant ceased functioning after some months, they repeated the procedure. This, too, failed, at which point Eyriès abandoned the project (see figure 13.1).[15]
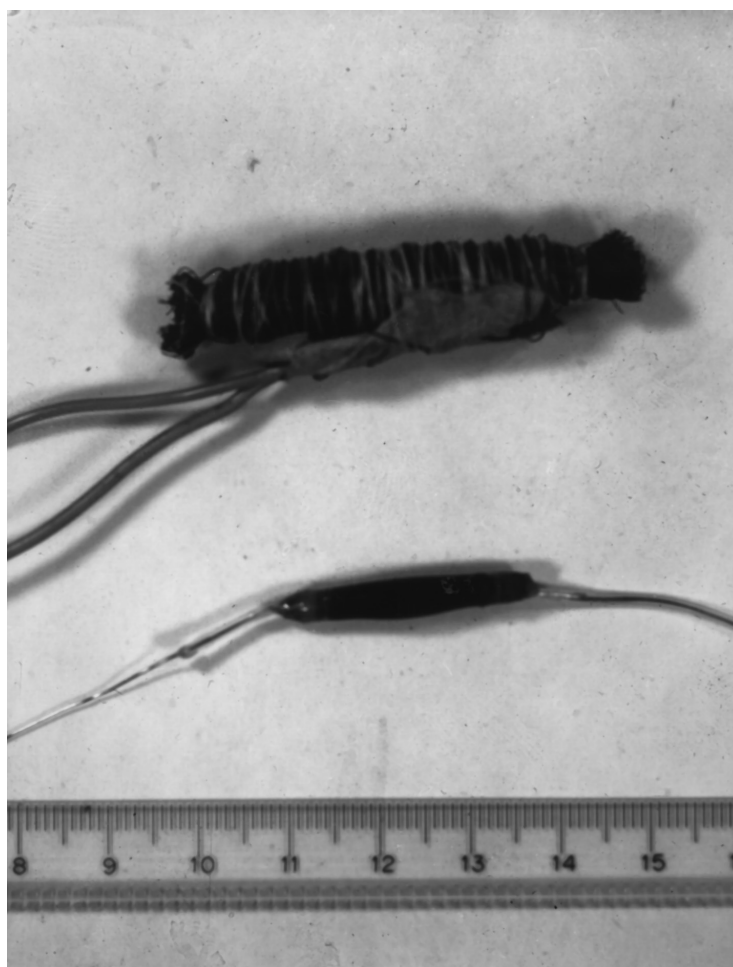

Figure 13.1 The lower "microbobinage" is the implant, the upper is the (external) signaling coil, which attached to a microphone transmitter. Designed by Djourno (France, 1950s). Photograph courtesy of the John Q. Adams Center for the History of Otolaryngology, Head and Neck Surgery, Alexandria, Va.

Djourno performed one final implantation, collaborating with otolaryngologist Roger Maspétiol. This second patient, N.T.L., was a Vietnamese girl who had lost her hearing after taking streptomycin for tuberculosis. She, however, was "reluctant" to undergo the surgery ("it was her father who had committed her to this operation").[16] Afterward, she disliked the "low moaning sound" produced by her implant. She also disliked wearing the external transmitter, even after they attached it to a headband so her hair would conceal it. "She spoke impeccably," Djourno commented, "yet complained a lot all the time because Indochinese men and women do not have the same accent or manner of speaking. She said 'It's a catastrophe, because when I begin to speak, it sounds like a man.' "[17] Over the course of two years N.T.L. visited the clinic only occasionally. When she and her family returned to Vietnam, they never contacted the doctors again. Djourno then began planning a multichannel implant, based on the Fourier analysis seemingly performed by the human ear, but in 1959 the institute stopped funding this line of research (Seitz 2002, 84).

From the outset, then, implants and their electroacoustic signals had "politics." Implantation began as a response to *deafening*—a condition at once physical and social—caused, in these first cases, as a by-product of modern medicine. Whereas the adult engineer voluntarily immersed himself in a world of strange and even painful sounds, this capacity for self-determination was denied to the child. The assistive device easily became a stigma symbol, drawing attention to an otherwise invisible disability. Moreover, linguistic politics transferred instantly to this technology for communication: Which sounds counted as linguistic? How did tones correlate to gendered social norms? Should language be prioritized over other kinds of sounds? These early experiments raised the question of whether auditory cues, no matter how uncanny or uncomfortable, were in fact preferable to "unbearable" silence. In an interview near the end of his life, Djourno acknowledged that implants were not appropriate for everyone: "There are deaf [people] who do not want to be equipped with devices, who are happy with sign language, lip reading; they consider devices as a bother . . . I knew a family like that, [who used] a very complicated and perfected sign language, they fared much better than with any kind of electric stimulation . . . To impose a single solution on all the deaf, that's nonsense."[18]

In the United States, early volunteers also faced the difficult choice between impairment in sonic social settings, or surgical pain, atypical audition, and visible stigma. At the same time, a number of these volunteers were technical experts and enthusiasts. William House, who designed the 3M device (the first to be granted FDA approval), began his research in 1957, when a patient gave him a newsclipping about Djourno and Eyriès.[19] House and his brother owned a private ear institute in Hollywood, founded in 1946 by their father, Howard.[20] In early 1961 House collaborated with brothers John Doyle and James Doyle, a neurosurgeon and an engineer, respectively, to run preliminary tests on E.K., a deaf patient. House and the Doyles placed an electrode in E.K.'s inner ear, and the man—himself an engineer at a plastics plant—was able to describe the distinct sounds resulting from inputs such as pulses and square waves.[21] E.K. then tested a single-electrode implant for

three weeks, followed by an insert of five gold wires that had to be surgically removed after two weeks due to allergic reaction.[22] Through these bodily demonstrations, it became evident that wires required insulation to prevent electrode failure; gold, moreover, was not a tolerable material.[23]

John Doyle soon disclosed these experiments to the press, and House dissolved their partnership.[24] House recalls, "We began to be deluged by calls from people who had heard about the implant and its possibilities. The engineer who had constructed the implant exercised bad judgment and encouraged newspaper articles about the research we were doing" (House and Urban 1973, 505). *Space Age News* was a particularly enthusiastic venue for these reports; by and large, cochlear implantation was unpopular with the medical establishment throughout the 1960s.[25]

When Dr. F. Blair Simmons of Stanford entered into cochlear implant research shortly after House and the Doyles, Blume notes, "The American Otological Society rejected presentation of this work at their 1965 meeting, while an application for funding to the National Institutes of Health (NIH) was turned down" (Blume 1995, 101–102). Simmons conducted an exploratory multichannel implant surgery on a human volunteer in 1964, but then turned to animal research to investigate such factors as surgical approach and ideal number of electrodes.[26] Simmons' move from clinical to basic research garnered respectability—and, by the 1970s, NIH funding—for further work on the electrical stimulation of the auditory nerve.

Robin Michelson, who began his career in private practice and then moved to the University of California-San Francisco (UCSF), similarly became interested in the possibility of cochlear implantation through clinical work, which he combined with animal research in the mid-1960s. Working with an engineer at Beckman Instruments, Michelson implanted several patients with single-channel devices around 1970 (Michelson 1971). He subsequently collaborated with a UCSF team that included Michael Merzenich and Robert Schindler to conduct basic research toward the development of multichannel implants (this research would lead to the Clarion model from Advanced Bionics). The UCSF group insisted that this animal research eventually be paired with psychoacoustic studies of human subjects. (Loeb et al. 1983, 252).

According to a report written by Caroline Hannaway of the NIH Office of History, House resisted animal studies and continued to feel "that at some point risks had to be taken. He believed the reluctance of scientists to pursue work involving human beings, and what he perceived as the greater readiness of granting agencies such as the NIH to support projects involving animal experimentation, to be a response to the Nuremberg trials" (Hannaway 1996, 6). House worked in a clinical context rather than a university one, and his early research preceded many of the current laws regarding human experimentation, such as the requirement of ethical review. Extensive records of this research are available in the archives of the American Academy of Otolaryngology-Head and Neck Surgery, including rare first-hand accounts from test subjects regarding their auditory sensations, personal experiments, and proposals for future technology. House's patient Charles Graser

received one of the first portable cochlear implants, a trial device assembled by electronics technician Jack Urban.[27] Graser, who is still alive, has permitted me to quote extensively from the journals of his field-tests.

A high school social science teacher and ham radio operator, Graser drove an oil rig in the summers to earn extra money to support his family. In 1959 his truck caught fire, and he was severely burned; over the course of several months in the hospital, he lost his hearing from the mycin drugs he was given. As a man in his forties, he had seen sign language only a few times; he once mentioned that he found it "beautiful," but his family, friends, and employment moored him in the English-language world. As a patient at the House Ear Institute in 1961, he first learned of the implant experiments; that summer he wrote to William House and volunteered to enroll.

House, at that point, was reluctant to proceed too quickly or to publicize his work. Graser wrote to him every six months until the end of the decade, inquiring about the possibilities for another experiment. Not until 1968, with advances in surgical plastics and miniaturized transistors—as well as the development of other medical electronics components in the growing field of artificial pacemakers—was House willing to make another attempt (House and Urban 1973). That year, he invited Graser to participate in an exploratory surgery with local anesthetic. He tried a temporary implant in several locations to determine its ideal placement and number of wires. He also tested the maximum intensity of the stimulus, noting, "When an intensity of two volts was introduced, he [Graser] responded by jumping, indicating that the pain threshold had been reached."[28] This new round of human experimentation met with more public criticism, most notably from Dr. Nelson Kiang of the Massachusetts Institute of Technology, who called the work "premature" (Kiang 1973, 512).

In 1970 Graser received a permanent "button" implant behind his right ear. Having five input wires, it divided the signal into separate bandwidths. Over the next four years Graser spent thousands of hours with House and Urban in the lab, testing different circuits, carrier waves, and modulation schemes. House remarked that "many of these devices took months to construct and proved worthless after a few hours of testing" (House and Urban 1973, 505). Graser, he attested, was a genuine collaborator (see figure 13.2):

> As an ex–ham radio operator he was a sophisticated listener and could fully describe the different signals presented as stimuli . . . He is an ambitious and goal-oriented individual who is tenacious in his desire to maximize the use he can derive from the implant . . . In addition, he is both articulate and an excellent observer. C.G. has been able to communicate to us much valuable information concerning his experience with the implant and has made thoughtful suggestions concerning ways of upgrading the system.[29]

Graser, on the other hand, was eager to have greater jurisdiction over the experimental process. In his own log, he recorded the following: "This electronic cochlea testing does bother you. It's like having someone say, 'Have a seat in the electric-chair while I fiddle with controls.' It may not hurt, but it is sometimes frightening

Figure 13.2 **Graser (left) and House (right), c.** 1972. **Photograph courtesy of the John Q. Adams Center for the History of Otolaryngology, Head and Neck Surgery, Alexandria, Va.**

in its intensity and your inability to control it. Even to begin with, you don't know how much you can take."[30] He was finally allowed to field-test a portable implant in 1972 even though House and Urban were not certain it was safe. There was a risk of infection; moreover, fluorescent lights, electrical wires, and highway radar traps caused interference.

Graser was aware that this prototype was never expected to provide "normal" hearing. In his field notes he commented, "You would probably describe my current progress as changing from profoundly deaf to just hard-of-hearing, but difficulty hearing and comprehending is in a completely different league from silence. For instance, tonight I can finally hear the bell that indicates that I am at the right hand margin, as I type this letter." In many respects, this early implant was a radically different and limited kind of ear: "I used to be a radio operator, and sometimes I would get a distant signal that I couldn't really hear. It sounded dim and garbled. That's the way this sounds. It's definitely an electronic sound." Yet in some ways, Graser's acoustic sensitivity exceeded that of his wife: "I will be startled by a brief exhaust sound of a car going by outside the house. Barbara doesn't even hear the car."

Graser began tinkering with his processor at home and recorded his findings about battery lifespan, microphone type and placement, and signal modulation. "I am constantly experimenting with the device," he wrote to Dr. House (House and Urban 1973, 510). He painstakingly documented the transformations of his domestic soundscape: "Walking on the floor in the house is not just padding sounds,

but is more of a hammering with an echo for each step. Sound is too sputtery."
"You can hear water run into the sink. Almost too noisy." His first transmitter had
multiple dials for control over features such as carrier amplitude and frequency,
modulation, microphone sensitivity, and high-filter cutoff. Graser recommended
against standardizing the design: "I would have as many manual controls on the
instrument as possible so that each patient could customize sound, much as if they
were using a short wave receiver."[31] His field tests led to a number of concrete and
lasting improvements: carrier waves that received less interference from environ-
mental electricity; microphones worn at the head rather than in the pocket (where
they picked up too much "clothing noise"); continued miniaturization, so the pro-
cessor could also be worn behind the ear.[32] Like other lead users, Graser also con-
tributed physically (if not deliberately) to surgical procedure; the determination of
suitable implant materials; protocols for minimizing the destruction of hair cells;
and evidence for the ability of the inner ear to withstand electrical stimulation over
a period of many years.

In 1972 an electrode short damaged Graser's skin, causing House to work
toward a fully implanted stimulator to replace the "button" model. As part of this
restructuring, House decided to convert to a single-channel implant. Graser's "skin
began to show evidence of retracting and reacting to the external button. Some
leaking and shorting of the electrodes was observed. House secured all wires into a
single bundle to prevent loss of the whole system. This event made it urgent that the
electronics be converted into a single electrode system."[33] Graser received a fully
implanted induction coil (as opposed to "hard wires") at his left ear in 1972, and in
1974, as a result of "secretions and debris around the button causing the wires to
fail," his right ear was finally reimplanted.[34]

Blume regards William House as critical in establishing an international clini-
cal reputation for cochlear implants. Before FDA approval of the single-channel
implant (and before the FDA became responsible for medical devices), a very few
volunteers participated in clinical experiments—each potentially having a large
impact on design. Throughout the early 1970s Charles Graser served as House's
primary evidence in publications and presentations.[35] In those years Nelson Kiang
rebuked House for assuming that his trials with Graser were valid: "Enthusiastic
testimonials from patients cannot take the place of objective measures of perfor-
mance capabilities" (Kiang 1973, 512). Nevertheless, Blume contends that House's
"early successes with a simple implant aroused the interest of clinicians in many
countries, as well as of potential manufacturers" (Blume 2010, 173). Furthermore,
as Hannaway points out, when the National Institute of Neurological and
Communicative Disorders and Stroke (NINCDS) "sought the first objective evalu-
ation of cochlear implantees in the United States" in 1975, it sent just thirteen indi-
viduals with single-channel devices—Charles Graser among them—to the lab of
Robert Bilger at the University of Pittsburgh. "Bilger was a known skeptic about
cochlear implants, and, as the result of the investigation, he was converted to being
a modest supporter. So were the others who had previously opposed cochlear
implants" (Hannaway 1996, 23).

Not all of Graser's recommendations survived in commercial versions of the technology. In the most significant enduring design shift, House began to build portable models with a single control dial, "eliminating the necessity for frequent fine adjustments"—in other words, eliminating the personal control and auditory customization that Graser so appreciated.[36] This black-boxing of the technology compounded disability, implying a lack of technical facility among users, as well as an obligatory dependence upon physicians and medical engineers. Moreover, although Graser strongly preferred receiving signals at both ears, bilateral cochlear implants would largely be refused by insurance companies for the next thirty-five years. Here, the drive toward normalization crossed purposes with the economics of health care (see figure 13.3).

Signal Processing

House eventually partnered with 3M Corporation to produce a commercial device; in 1984 their single-channel model was the first cochlear implant to receive FDA approval. By that time, investigators in Australia, France, Austria, England, and elsewhere in the United States had taken up cochlear implants, mostly with an interest in marketing a multichannel device. At the University of Melbourne, Graeme Clark (whose father was deaf) began work on a multichannel implant in the 1970s; he claims that his subjects *solicited him* after a 1977 news brief in the Melbourne *Herald*. Clark arranged for an ethics committee to oversee his research, following the 1975 Declaration of Helsinki amendment regarding biomedical experiments on humans. Working with a single patient implanted in 1979, Clark concentrated on the problem of signal processing: what information to extract from the sonic environment for transmission down a limited number of channels; the rates at which to stimulate the auditory nerve; the placement of electrodes:

> In theory, the coded signals should simulate in the auditory nerve fibers the temporal and spatial patterns of action potentials seen when sounds excite the normal cochlea . . . Therefore, it is necessary to know if speech processors can present speech as coded signals with a more limited number of stimulus channels and still adequately simulate the physiology. Alternatively, the speech processors should extract only the essential speech information that can be processed by the auditory nervous system via a relatively small number of stimulus channels.
> (Clark 1992, 95)

Clark tested a number of processors on this first patient, who had been deafened as an adult due to a head injury, and he evaluated each strategy according to the man's self-reported ability to perceive speech. Clark ultimately decided, in phonetics terms, to build a processor that extracted fundamental frequency and one to two speech formants.
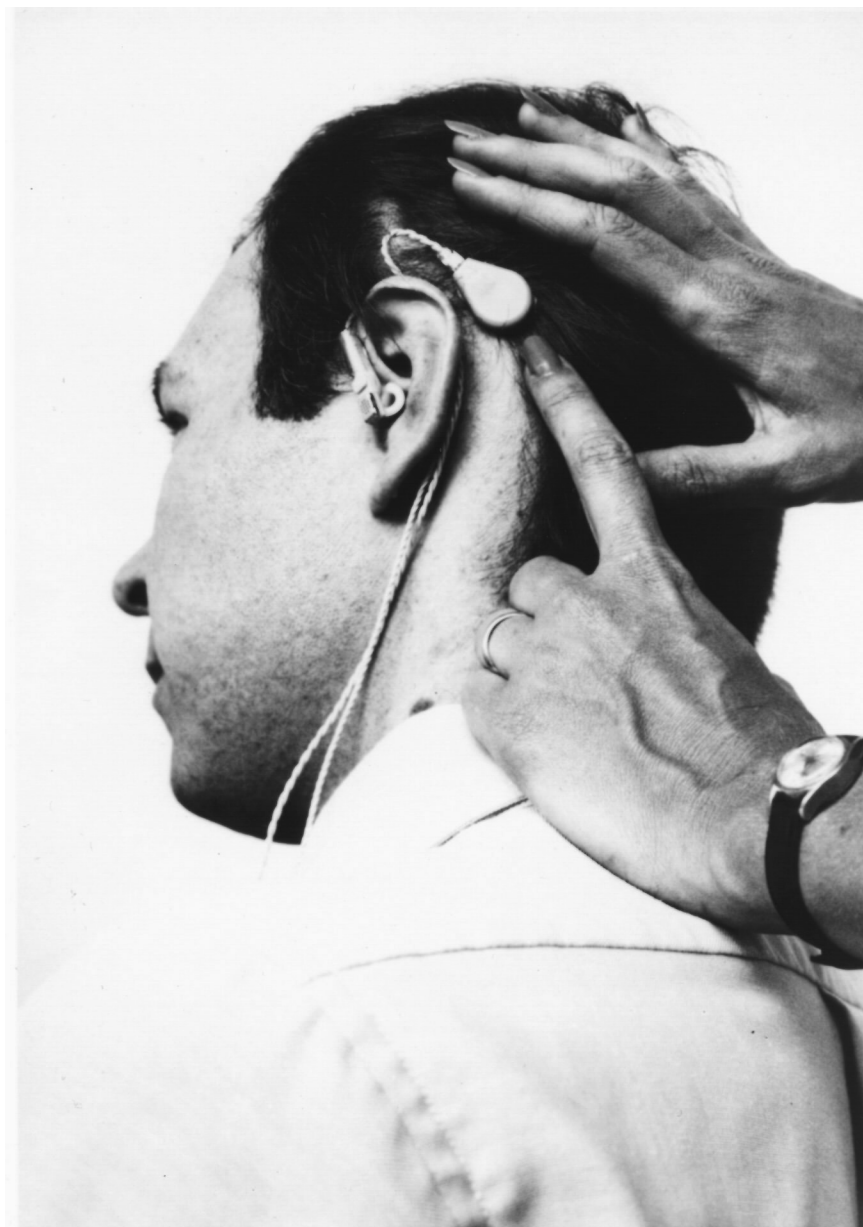
Figure 13.3 Early single-channel implant with fully implanted electrode. (The superfluous pointing finger objectifies and diminishes the user of this device.)
Photograph courtesy of the John Q. Adams Center for the History of Otolaryngology, Head and Neck Surgery, Alexandria, Va.

After implanting a second person in 1979, Clark determined to proceed with a commercial device, necessitating a series of clinical trials on deafened adults. With no government funding, Clark could afford to give free implants to only his first six patients. Subsequent "volunteers" paid a minimum of $10,000 to participate in

experiments that their health insurance would not cover. In 1985 the Australian (Nucleus) twenty-two-channel implant was approved by the FDA.

In the United States, researchers at UCSF, MIT, the Research Triangle Institute, and the University of Utah—often in collaboration with one another—generally departed from the feature extraction approach in the 1980s. Rather, they attempted to build multichannel speech processors, both analog and digital, that simply filtered and compressed incoming sound waves, with a focus on the frequencies of speech. Although the implants developed during this time varied in their numbers of electrodes, they shared many other hardware features. Users of experimental implants often tested multiple speech processors (eventually instantiated as software), and processing schemes in turn shared emerging psychoacoustic data. In *Rebuilt: How Becoming Part Computer Made Me More Human*, a "scientific autobiography" of obtaining an implant, Michael Chorost acknowledges his own debts to this second generation of user-researchers, who helped establish how to increase the number of electrodes; how to prevent crosstalk between those channels; and how best to dissect a signal. He specifically recognizes Michael Pierschalla, who participated in the clinical trials of Ineraid—the third implant to receive FDA approval—at the Massachusetts Eye and Ear Infirmary and the Research Triangle Institute. "His feedback integrally shaped most if not all of the software that is widely used today, not just in my own implant but in those of other manufacturers as well . . . Just as the DNA of all my ancestors lives on in me, a bit of his sensibility lived on in my software. My own body bore the stamp of his intelligence and generosity" (Chorost 2005, 106).[37] Signal processing continues to be the major site of cochlear implant development today, and it develops with a nonlinear incrementalism.

Pierschalla had lost his hearing suddenly at the age of twenty, an effect of Cogan syndrome. He studied at the Rochester Institute of Technology and became an artist and a noted furniture craftsman. While living in Cambridge, Massachusetts, he read a news article about local cochlear implant research. A friend wrote on his behalf to Dr. Donald Eddington of the Massachusetts Eye and Ear Infirmary; by June 1985 Pierschalla had obtained an experimental six-electrode Ineraid implant.

Pierschalla lamented his estrangement from the hearing and the sign language worlds even as he embraced his implant:

> I came to my hearing loss late, too late to abandon my hearing ways, too old to change the culture of my nativity, and too resistant to losing the remnants of my identity. Thus, I tried to tell them I was like a man without a home. Looked on as deaf by those who hear, and as Hearing by the native Deaf, and so for years have existed between those worlds, knowing much of both, but embraced and understood by neither, longing for the seamless brotherhood of either one, but incapable of owning that due to circumstances . . . Finally, one day in the laboratory, a man turned on a switch and my head lit up with sounds and alien noise and before long I went home and for the first time in years, I called my momma on the phone and we both cried like babies, and things have been very different after that.[38]

Pierschalla participated in laboratory as well as field tests of this device: independently trying out different microphones from Radio Shack; documenting the recharge times of his batteries; recording environmental sounds (subways, busy streets) to play back in the laboratory. While watching a film, he would estimate speech intelligibility for off-screen voices and under conditions of theater noise, multiple talkers, and "background" music. Lecturing at the Museum of Fine Arts in 1992, he reflected on his interactions with physicians and scientists: "As a craftsman and an armchair philosopher, I've sometimes wondered where the tool ends and the art begins. In the same way, when I'm in the lab with these scientists, we at our opposite ends of the same wire, I wonder where the observer ends and the subject begins. And I don't have an answer."[39] On multiple occasions, he co-presented cochlear implant findings with otolaryngologists at medical conferences.

Shortly before Pierschalla's death in 2002, science writer Victor Chase interviewed him over the phone. Chase noted the man's transition from *patient* to *expert*:

> Pierschalla's knowledge and success was widely known within the cochlear
> implant community. As a result, in 1995 Med-El, a cochlear implant manufac-
> turer based in Innsbruck, Austria, asked him to establish its North American
> office in Boston, as an organization of one. He accepted, and shortly thereafter he
> relocated the company's office to Research Triangle Park, North Carolina. He
> then worked on obtaining FDA approval for sale of the Med-El implant in the
> United States. (Chase 2006, 26)

In 1995 Pierschalla served as a member of the second NIH Consensus Conference on Cochlear Implants in Adults and Children. The panel concluded that the population of implant users was steadily growing, that the device seemed to be successful in children, and that "cochlear implants should be made available to adults with severe hearing loss," as well as those who were "profoundly" deaf (Hannaway 1996, 53). Along with this medical consensus, one by-product of the many years of advocacy by late-deafened implant users was thus a renewed medical encroachment upon the Deaf world.

Chorost worried that his own perception—and, in turn, his perspectives— might be unduly influenced by the anatomy and predilections of the test subjects whose "scripts" he had inherited. He quickly learned that the prosthesis "doesn't change your values in the slightest"—although it does embody an "epistemology," complete with certain biases (Michael Chorost blog, comment posted March 2, 2009). The drive of early investigators toward *speech* processing, for instance, is inscribed into his implant. Thus, music sounds "flat and dull . . . flutes and soprano saxophones sounded as though someone had clapped pillows over them . . . oboes and violins had become groans" (Chorost 2005). In an article written for *Wired* magazine ("My Bionic Quest for *Boléro*") Chorost discusses his own participation in numerous software upgrades and engineering experiments in order to expand the frequency range of his sixteen channels. He further suggests that by flying "to labs around the country with [his] own agenda—to try out their software specifically with music," he's "gotten them to focus on music sooner than they might have otherwise" (Michael Chorost blog, comment posted January 5, 2006).

Philip Loizou, an electrical engineer at the University of Texas, Dallas, notes that speech-processing strategies also contain biases against environmental sounds, noisy environments (often due to unrealistic laboratory testing situations), and tonal languages (which convey information through pitch rather than simply formants/timbre) (Loizou 2006).[40] Furthermore, the endemic electromagnetic interference between implants and wireless or cordless phones indicates the primacy of face-to-face communication for implant design—not to mention the long-standing disregard for hearing aid and implant users within the telecommunications industry.[41] Finally, Chorost reminds that the design of cochlear implants is of course constrained by economics. Although his initial device allowed him to switch between two speech processing strategies, one analog and one digital, an upgrade reduced him to just one, "because audiologists simply don't have the time to fit all of their patients with two different kinds of software." (Chorost 2005, 189).

Deaf Futurism

Narratives that depict the history of cochlear implants as a binary conflict between Deaf culture and normative biomedicine additionally obscure the radical aspirations of a minority of deaf implant users. In a 1999 *Hastings Center Report*, G. Q. Maguire and Ellen McGee contended that cochlear implants had "set the stage" for neuroenhancement:

> 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 step 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 implanted computing and communication devices 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. (Maguire and McGee 1999, 9)

This linear evolutionary trajectory assigns deaf people to the primitive state and suggests a structural need for individuals with disabilities to serve as test beds for new technologies. It ignores the possibility that *any* person might desire "enhancement" rather than therapy from a prosthetic device.[42]

A small subset of "deaf futurists" has always maintained an investment in technical innovation and posthumanism. Unlike the futurist art movements of the early twentieth century—which tended to reject the poor, the nontechnological, and the unfashionable, along with the "traditional"—minority futurisms counter histories of exclusion in science and engineering.[43]

Often unrecognized, deaf scientists and technophiles number among the leading theorists of implant futurity. Internet founder and Google vice president

Vinton Cerf, who wears two hearing aids, previously asserted an enduring relationship between deafness and computer networking. "In creating the Internet with my colleagues," he has testified, "in part I wanted to help people with hearing loss as well as other communication difficulties" (Better Hearing Institute 2007).[44] Years later, for the *Time* magazine special report on "visions of the 21st century," Cerf predicted web-enabled implants: "The speech processor used today in cochlear implants for the hearing impaired could easily be connected to the Internet; listening to Internet radio could soon be a direct computer-to-brain experience!" (Cerf 2000, 103).

Cerf's wife, Sigrid, whom he met at a hearing aid center, acquired an implant in 1996. In a short story written for *The Little Magazine*, he lists the ways "the little deaf girl" had grown up and begun experimenting with technology:

> Her aggressive approach to hearing led her to obtain and in some cases invent assistive methods to augment the basic speech processor/implant combination. She had patch cords made to connect her speech processor to the armrest of airplane seats so she could hear the movie sound track *directly* rather than through audio headphones. She obtained books on tape and listened to them too through a patch cable connecting the sound output of the tape recorder directly into the auxiliary audio input of her speech processor. She had numerous microphones made on wires ranging from six feet to sixty feet in length so she could put a microphone close to the speaker at lectures or at the dinner table. She obtained FM transmitters with microphones built in, so she could put the transmitter on a lectern and then, using an FM receiver, listen to the speaker—again using direct audio input into the speech processor. She obtained infrared receivers to pick up the sound track in movie theatres which are equipped to transmit this signal to receivers for the hearing impaired.
>
> She had patch cords made to plug into her mobile telephone and used magnetic telephone coils with patch cords for use with ordinary telephones. The list goes on and on. (Cerf n.d.)

Sigrid herself has intimated that she would one day like to link to the Internet via her implant (Hamilton 2002).

Similarly, Mike Chorost comes out as a cyborg in his autobiography—which was endorsed by Manfred Clynes. Part human and part machine, he describes himself as at once limited and endowed with new capacities. His implant is an object lesson about the imperfections of the technology, the ways normalization can be desired alongside enhancement, and the fact that "posthumanism" can coexist with impairment. He marvels about patching into his Walkman and "hearing music that never actually exists as sound. This could be evidence of a profound transformation in how human beings take in information from the world around them." He continues, reflecting on the inevitable domestication of his device, "Or, it could just be a cozy domestic scene: a cyborg and his cat" (Chorost 2005, 58).[45]

In a piece for *The Futurist* magazine, Chorost muses, "While my friends' ears will inevitably decline with age, mine will only get better." He warns of the potential costs to privacy and security of networked implants: "Neural devices such as cochlear implants are computers and can be wirelessly networked. People's bodies

and brains could become visible to the global network in ways we can only dimly imagine now, much the way people could barely imagine the impact of computer networking back in the age of Apple IIs" (Chorost 2006, 68).[46] At the same time, Chorost criticizes the escalating barriers to users' control. Present-day implants allow users to adjust volume, microphone sensitivity, and "private tones" (which give cues about the functioning of the device), as well as to choose among three or four "customized" programs based on highly generalized listening environments (i.e. "quiet," "noisy," and "focus"). Parents and teachers can use a remote control to set these programs at a distance for children wearing implants. For adults and children alike, choice of speech-processing software is limited and software settings (i.e. amount of stimulation per electrode) must be set by a clinician.

Responding to a blog entry by Cory Doctorow titled "Deaf hacker rewrites implant-firmware so he can enjoy music again," Chorost counsels:

> I didn't actually rewrite the software. To do that I'd need a degree in electrical engineering, an insider's knowledge of the code, and an understanding of how electricity interacts with body tissues. If I broke into Advanced Bionics in the dead of night, fired up the computers, hooked up the interface gadgetry to my processor, and started changing code at will, I could cook my inner ear or electrocute myself. Much more likely, my processor would crash and I'd slink out in total humiliation. I'd be deaf until I went back to my audiologist to have the software re-uploaded . . . Cory is right that the more control a person can have over his or her prosthesis, the better. I would love it if Advanced Bionics built a gadget that let me change some of my parameters on my own. While I have a lot of control over the device through my audiologist, it's control that takes weeks and months to unfold and explore. My audiologist and I experiment with various parameters during fitting sessions, and it always frustrates me that we only have a few hours in each session to try to find the best values for 20 or more variables. I would love to have the freedom of playing with them on my own. That would considerably accelerate the process. But it is possible in principle to hack one's own implant. (Michael Chorost blog, comment posted January 5, 2006)

The complexity of electronic objects such as cochlear implants means that most users will not be able to modify them at will. Moreover, the drive to standardize medical devices means that most examples of "deaf futurism" exist in theory rather than being instantiated in the material-semiotic register of signals.

Conclusion

A comprehension of the politics of circuitry and software enables, on its own, a small measure of perceptual control. Along these lines, media theorist Vilém Flusser once argued that the very *constructedness* of his hearing aids provided an advantage over "normal" hearing. Having fled to Brazil in 1940, Flusser managed a radio and transistor factory before turning to the philosophy of communication.

In a manuscript titled "Hoerapparate," he suggested that "the hearing aid is freedom"—and he wondered "why there has not been more philosophical writing on the subject." Deafness plus a hearing aid meant that he had "ear-lids"; he could choose when to be immersed in the world's noises and voices. More important, he felt that his hearing aid helped him *to see and hear better*: on the one hand, to be aware of the manufacture and obstructions present in all communication; on the other hand, to understand the programming behind his own auditory perception:

> If you are listening to the world, you will notice that sounds are "instrumentized." Not a white buzzing that comes to the ears, but an orchestrated swinging. A programmed noise. Therefore it must be supposed that between you and the world there is a sound-sieve turned on, a hearing aid. The unpleasant, even unacceptable thing about this apparatus is that one cannot see it. Therefore one cannot know who programmed it. If its program is coming from the world out there or from you yourselves, for instance through the way your ear is built. Even good old Kant puzzled his head on this subject. My own hearing aid is visible. One knows who programmed it, a Japanese company. And this finally is an advantage I have in comparison to you. I can, better than you are able to, see through my hearing aid. And therefore hear better than you.[47]

In much the same terms, Chorost recognizes the epistemological value of the cochlear implant. After an extended analysis of Donna Haraway's "Cyborg Manifesto," he weighs in against "the blithe assumption that one's sensory organs deliver a truthful representation of the universe…people with normal ears are not off the epistemological hook, because their "software" was written haphazard by millions of years of evolution and has no greater claim to reality" (Chorost 2005, 147).[48]

The history and consequences of communication engineering, particularly with regard to electrical signals and machinic filters, must be considered more broadly within sound studies. Electroacoustic devices—with sleek casing, miniaturized circuitry, and confidential corporate histories—increasingly resist "seeing-through." Yet in the case of cochlear implants, the desires of early users, the conflicting demands of mainstream medicine and economics, and the mediated features of electrical listening—in other words, the politics attendant upon communication—can be found embedded in the design of electroacoustic objects.

NOTES

1 At BBN, Swets notes, researchers "thought of computers as symbol processors—for example, theorem provers and pattern recognizers—rather than as number crunchers . . . these psychologists would lend what they knew about human perception, thinking, language, and motor control to the design of computers that would augment or supplant human behavior in, for example, libraries, process control, and robotics" (Swets 2005, 15, 18). Paul Edwards traces the Harvard PAL transition "from wartime work on human-machine integration to postwar concerns with information theory to the computer as a metaphor for the human mind." The PAL scientists investigated problems such as communication between humans and complex military machines (e.g., submarines, airplanes); the transmission of

speech in battlefield noise; the jamming of enemy communications; training in listening and articulation for military personal. These scientists "made no distinction between the technology of hardware and the technology of language and listening" (Edwards 1996, 210, 214).

2 Approval followed for children over the age of two in 1990 and for twelve-month-olds in 2000.

3 These users are mostly wealthy individuals or citizens of countries with socialized medicine, as the procedure costs approximately $30,000 (Spelman 2006). On poverty and the global distribution of implants, see Zeng (2007). The NIDCD website maintains current statistics on cochlear implant use: http://www.nidcd.nih.gov/health/hearing/coch.asp.

4 "It is an unequal battle since the two accounts differ greatly in their authority. The medical understanding draws on and reflects the authority of science and the promise of medicine, both of which have become fundamental components of modern industrial culture. The deaf perspective draws on and reflects the experience of a traditionally marginalised and stigmatized group" (Blume 1999, 1265–66).

5 Brenda Jo Brueggemann has recently suggested that the deaf/Deaf distinction has been ineffective and might even be unrealistic. In this chapter, however, I follow these conventions of capitalization when referring to the audiological ("deaf") versus linguistic minority ("Deaf") definitions of deafness (Brueggemann 2009, 9–15).

6 In this book, Blume includes a short section on "adult implantees" and the potential for their experiences to complicate the Deaf/hearing binary, as well as any reductive audiological definition of deafness: "The boundary between deafness and hearing is a complex region, marked by values, memories, histories, and commitments, and to be crisscrossed in many ways." See pages 163–70.

7 To the contrary, Blume insists that patients are "typically not seen as competent interlocutors in the innovation process" (Blume 1997, 32).

8 Trevor Pinch and Nelly Oudshoorn elaborate as follows:

> [I]n the design phase technologists anticipate the interests, skills, motives, and behavior of future users. Subsequently, these representations of users become materialized into the design of the new product. As a result, technologies contain a script (or scenario): they attribute and delegate specific competencies, actions, and responsibilities to users and technological artifacts. (Oudshoorn and Pinch 2003, 9)

See the chapters by Oudshoorn and Blume and Rose regarding the significance of clinical trials or research and development to user configuration.

9 Helen Nissenbaum asserts that "computer and information systems can embody values," and these must be considered in tandem with their "social effects" (Nissenbaum 2001, 120).

10 Blume surmises that the initial disinterest of the Deaf community led implant manufacturers to direct marketing pressure *toward* the hearing parents of deaf children. The marketing focus has since expanded to include late-deafened seniors, by far the largest population with severe hearing loss (Blume 2010, 116–117, 144).

11 Here he draws on the work of Rayna Rapp and Faye Ginsburg (Blume 2010, 162).

12 Bernard Frayssend to Dr. House, June 11, 1978, "Djourno/Eyriès Publications" Folder, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center. Drawing on this collection, Marc Eisen (also an otolaryngologist) has written two short articles on the early French implant (Eisen 2003, 2006).

13 Phillip Seitz, "Interview with André Djourno and Danièle Kayser 1/12/1994," 612-OH-11, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center. See also Seitz (2002).

14 As Eisen narrates, Djourno and Eyriès ran into each other at the medical school morgue, where Eyriès was looking for a potential nerve transplant for Monsieur G. Djourno convinced him to try an implant instead (Eisen 2006, 3).

15 Eisen explains that Eyriès would have preferred to contract an engineering firm to manufacture the implant (Eisen 2003, 503). Blume offers a different interpretation of the conclusion to this experiment; he says the patient "decided that he had had enough: it was not worth the investment of so much time and emotion" (Blume 2010, 32).

16 Phillip Seitz, "Interview with André Djourno and Danièle Kayser 1/12/1994," 612-OH-11, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center.

17 Ibid. Djourno also claimed that the implant allowed her to "hear her own voice for the first time in eight years" (Djourno and Vallancien 1958, 555).

18 Phillip Seitz, "Interview with André Djourno and Danièle Kayser 1/12/1994," 612-OH-11, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center.

19 William House, "Cochlear Implants: The Development of an Idea," February 1976 (typescript), p. 9, 921-HSB-2, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center.

20 For the story of Howard's own unconventional approach to medicine, see Hyman (1990).

21 The year before, James had designed similar equipment to record the sounds produced by the auditory nerve of a person with tinnitus. At the time he realized, "Well, gee, if we can do this, we ought to be able to reverse the process and make the person hear that's deaf." Even though the biophysics of hearing had not been clearly determined, James felt that "as an engineer you always look for a practical way of making something work, whether it's the absolute truth or not." Phillip Seitz, "Interview with John and James Doyle (8/22/93)," 612-OH-9, Cochlear Implants 1961–1995 Collection, John Q. Adams Center.

22 A woman, S.S., was implanted at the same time, but her electrode had to be removed almost immediately due to poor insulation.

23 In 1973 E.K. volunteered for another round of experiments, this time with new materials.

24 John Doyle claimed his slides had been stolen from a meeting of the American Medical Association (Schmeck 1962). The Doyle brothers continued with this research for several years until lack of funds forced them to abandon the project (Doyle et al. 1963).

25 "California Electronics Firm Readies 'Artificial Ear' Implant," *Space Age News* 3(18) (1961): 1; "Electronic Firm Restores Hearing with Transistorized System in Ear," *Space Age News* 3(21) (1961): 1. *Radio-Electronics* carried many of the earliest reports of the French implant. For instance, "News Briefs: Electronic Ears," *Radio-Electronics* 29 (December 1958): 6.

26 These first experiments by Simmons did not result in take-home implants.

27 Credit for the first functional portable implant remains controversial within the otolaryngology community. Although House is often recognized for developing the first successful take-home implant technology, Michelson's experimental devices, described in a 1971 publication, were close competitors.

28 William House, "Cochlear Implant: Hope for the Nerve-Deafened Person: A Decade of Progress" (typescript, n.d.), p. 4, 921-HSB-2, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center.

29 Ibid., 27, 29.

30 Charles Graser Papers, 921-HSG, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center. For a similar sentiment two decades later, see Chorost 2005, 163.

31 For all quotes in this section, see Charles Graser Papers, 921-HSG, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center.

32 Today, some processors are again available as body-worn devices, marketed for their relative invisibility.

33 William House, "Cochlear Implants: The Development of an Idea," February 1976 (typescript), p. 28, 921-HSB-2, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center. House and Urban had, moreover, not been able to eliminate crosstalk between electrodes.

34 They found that the silver wire had not corroded after four years. William House, "Cochlear Implants: The Development of an Idea," February 1976 (typescript), p. 36, 921-HSB-2, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center.

35 C.R., who was implanted at the same time, had late-stage syphilis and moved away from the Los Angeles area.

36 William House, "Cochlear Implant: Hope for the Nerve-Deafened Person: A Decade of Progress" (typescript), p. 8, 921-HSB-2, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center.

37 In Cambridge, the cochlear implant program was a joint effort of the Infirmary, Harvard Medical School, and M.I.T., coordinated by Dr. Donald Eddington. Another physician described Pierschalla as "more than a test subject . . . he was a valued colleague, an integral contributor, and a friend" (Chorost 2005, 106).

38 Michael Pierschalla, 1990, typescript in the author's possession.

39 Ibid., 4.

40 Biases against tonal languages within signal processing have long been of concern in the hearing aid industry. See as one example McCullough, Tu, and Lew (1993).

41 See Goggin (2006, ch. 5). "Politics" also reside in the medical determination of implant candidacy: psychological criteria, as well as willingness to maintain a relationship with the clinic for implant maintenance, are often taken into consideration. As a last example, experimental devices were designed with more or less flexibility for upgrades by test subjects.

42 For a more thorough discussion of the ways the same technology can be used for either treatment or enhancement, see Parens (1998, 1–2).

43 A different iteration of this concept can be found in Afrofuturism, defined by sociologist of science Alondra Nelson as instances of "sci-fi imagery, futurist themes, and technological innovation in the African diaspora" (Nelson 2002, 9). The heterogeneity of the deaf community means that examples of "deaf futurism" vastly exceed cochlear implants. Members of Deaf culture who reject cochlear implants, for instance, may embrace a range of "deaftechs" from wireless relay services to videophones to motion capture to ASL vlogs. More important, Brenda Jo Brueggemann calls attention to the fact that the number of Gallaudet students with cochlear implants "has virtually doubled itself each year" in recent times; the relationship between Deaf culture and this technology is not inevitably one of opposition (Brueggemann 2009, 16–17).

44 In 1978 Cerf reported on "The Electronic Mailbox: A New Communication Tool for the Hearing Impaired" to the readers of *American Annals of the Deaf*. At that time, the U.S. Department of Health, Education, and Welfare (in collaboration with Bolt, Beranek, and Newman) was testing email on the deaf population of Framingham, Massachusetts (Cerf 1978, 771).

45 Chorost's current implant model allows him to use standard earbuds and skip the patch cord step. Mike Chorost, in discussion with the author, June 17, 2009.

46 On this note, Chorost's forthcoming book examines the emerging technology of optogenetics. On controlling genetically altered neurons with light see Chorost (2007).

47 Vilém Flusser, "Hoerapparate" [Hearing Aids], trans. Silvia Wagnermeier. Vilém Flusser Archive, Berlin University of Arts. Thanks to Siegfried Zielinski for alerting me to this document and Silvia Wagnermeier for providing the translation.

48 Chorost disagrees with Haraway's expansive definition of "cyborg," preferring to apply the term only to cases of cybernetic technology—that which "exerts control over the body" (Chorost 2005, 41).

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