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On Disability and Cybernetics: Helen Keller, Norbert Wiener, and the Hearing Glove

"The electrical engineers of today," he said, "are only talking baby talk. They know how to handle resistances and even capacitances and inductances, but these speak much too childish a language. If you put two messages side by side in such a piece of apparatus, they stay side by side and merely add to each other. Now a steam engine or an electric generator or an electric motor speaks a much more complicated language, with a really difficult syntax to it. [. . .] Of course we know a little bit of their language, but we haven't learned its grammar as yet and it is on that that I am working."
—Wiener, *The Tempter*

Teacher gave me an instrument covered with soft polished leather and containing coils of wire varying in thickness and sensitivity. "Observe this carefully, Helen," she said, "and it will help you keep your speech at its present level of excellence. It will also bring you different sounds from a distance just as we get them through the ear." I placed my hands on the instrument. To my astonishment each wire coil vibrated with a sound easily distinguishable from the rest—cars and teams going by, passing footsteps, birds singing, running water. [. . .] I have yet to find out whether the instrument she showed me is an encouragement or a prophecy of new victories over limitations.
—Keller, *Journal*

The Industrial Conception of Language

In the acoustic "dead room" at Bell Telephone Laboratories during the summer of 1949, Helen Keller experienced a new kind of silence: "Language has no equivalent for the absolute physical silence that burst upon me in that fantastic, baffling chamber. [. . .] I have known many kinds of silence—the silence of early morning, the silence of remote mountain summits, the silence of gently falling snow. [. . .] Shut in by floor, ceiling, and walls of fiberglass, I throbbed with the silence of the dead and the silence that covers buried peoples and ages without a history."[1] The anechoic chamber shielded occupants from outside noises and stilled

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Figure 1
Helen Keller and her assistant Polly Thomson examining a telephone at Bell Laboratories in 1949.

Photograph courtesy of AT&T Archives and History Center.

internal reverberations. In a typical room, walls and furniture would have variously reflected and absorbed sound waves, and the floor carried the aftereffects of movement. As John Cage would discover in the Harvard anechoic chamber two years later, a "silenced" environment opened up the sense of sound, whether tactile or auditory, to the throbbing of one's own body.

Although deafness was popularly associated with the "dead world" of soundlessness, telephone engineers were interested in the ways deaf and deaf-blind people took in information from environmental vibrations—in particular, the ways "speech" could be converted from one medium or sensory domain to another. The telephone itself relied upon the ability of sound waves to be transferred from a mechanical medium (the air) to an electrical one. Similarly, Keller described herself as a "vibroscope": like the telephone and other electro-acoustic technologies, she was a partial translator of sensuous phenomena, themselves connected through the universal language of physical oscillation.

Bell Telephone Company, the corporate predecessor of American Telephone and Telegraph (AT&T), was founded in Boston in 1877,

Figure 2
Harvey Fletcher addresses Helen Keller before the statue of Bell at the labs.

Photograph courtesy of AT&T Archives and History Center.

financed by Gardiner Greene Hubbard and Thomas Sanders, two men whose deaf children were tutored by A. G. Bell.[2] Bell Labs, the research and development arm of AT&T, was the largest industrial laboratory in the world at the time of Keller's commemorative visit. In addition to her encounter with the dead room, Keller inspected a bust of Bell in the foyer of the labs, held the earliest telephones and compared them to mid-century models, and attended lectures on miniaturization and the new transistor, for which she had been briefed with Braille translations.[3]

Communication engineering had long since exceeded the construction of telephone sets and wires; speech and hearing themselves were submitted to the procedures of mechanization. Like the motor functions and the other senses, speech had been analyzed, subdivided, reproduced, rationalized, and streamlined through the joint forces of psychophysics and industrialization, which fused in the medium of the telephone.[4] What Walter Benjamin described as the "bourgeois conception of language"—in which "the means of communication is the word, its object factual, and its addressee a human being"—emerged in tandem with an *industrial conception of language*, in which speech is a material good and a saleable commodity (65). According to Karl Marx's formulation, commodities "are something twofold, both objects of utility, and, at the same time, depositories of value" (55). Likewise, a particular message from a unique voice, sent as a signal through the telephone system, could at once be treated in abstract mathematical and economic terms: quantified in terms of relative volume and information or priced in terms of time.[5]

Telephone signals were electrical representations, at first analogous to the airborne speech wave (analogs), but soon more loosely correlated as telephone engineers devised new ways to securely and efficiently transmit their commodity—and still reproduce intelligible speech at the receiver.[6] In the interest of efficiency, electromechanical media began to process communications—imagined as deliveries—between human senders and receivers. The verb form of the word *process*, meaning "to operate on mechanically, according to a set procedure," came into use in the late nineteenth century in the context of food processing. Following the industrialization of agriculture and diet, speech, data, and other signals also came to be processed. Indeed, Claude Shannon worked out his communication theory at Bell Labs the year prior to Keller's visit, partly as a way to quantify the information content of a given telecommunications signal and thus code it economically (generally by removing irrelevant information and redundancy).

One of the interventions of this essay, then, is to place technologies for speech transmission—the telephone and kindred phonetic technologies—at the center of “new media” history. Written text and other visual recordings are assumed by the majority of scholars to be the underpinnings of digital technology.[7] Yet oral communication was an obvious foundation for early communication theories, which emerged in the context of telephone engineering. AT&T was, of course, also concerned with telegraphy, the electrical transmission technology that set many standards in terms of coding, compression, and error correction.[8] However, the extensiveness and density of the telephone network, and its automatic conversion of a continuous phenomenon (speech) into electrical signals, created the demand for the first digital sampling technology (pulse code modulation [PCM]) and for Shannon’s information theory.[9] This history does not ultimately recuperate “natural” orality; to the contrary, telephony expanded the technification of speech from its precedents in phonetics and deaf education, often supporting “orality” with recording and reproduction technologies, and finally defining speech as essentially mechanical.[10]

As a second intervention, this essay examines one of the speech machines developed within the telephone system: a device for converting sound into tactile vibrations. Building on the material or object-voice long familiar in deaf oral education, this “hearing glove” was used for vocal regulation as well as speech transmission. It played a secondary role in the field of haptics and the optimization of tactile communication. It was part of the milieu of early information theory, and it also became a feature of early cybernetics, where it raised interest in information compression and the automation of communication. The glove was eventually tested by Helen Keller during a visit to another laboratory—Norbert Wiener’s at the Massachusetts Institute of Technology (MIT).

In media and science studies, the hearing glove has often served to illustrate claims about the dematerialization and/or disembodiment of information in the cybernetic paradigm. From the first telephonic voices to the current proliferation of digital media, a series of commentators has worried over the physical and temporal separation of signals from embodied sources, material channels, and architectural spaces. Although a growing scholarly corpus has now demonstrated the materiality of electronic/digital/computerized media, most authors continue to attribute a fantasy of disembodied communication to early cyberneticians and electrical engineers.[11] In *How We Became Posthuman*, for instance, N. Katherine

Hayles insists that information theory "disembodied" information from its carrier media, conceiving of it as "a pattern rather than a presence" and thus creating "the illusion of erasure" of "the material world" (28). Her argument encompasses posthuman threats to "the body," to media "materiality," and to "embodiment." The fixation on message transmission in communication engineering did often lead to a disregard for the uniqueness of individual embodiment and interpretation; nevertheless, the industrial conception of communication treated the voice as a material good, and it remained committed to conventional bodies.

From metaphysics to deconstruction, as shown by Adriana Cavarero, the voice has been widely regarded as immaterial and semantic, with "acoustic materiality" ignored in favor of "mental signifieds" (57). In the context of communication engineering, however, it was precisely acoustic materiality—and the materiality of electrical signals—that underpinned the reproduction and simulation of the voice. In the first decade of the twentieth century, as telephone engineers began to theorize the speech signal and its economy, linguist Ferdinand de Saussure worked out his own theory of semiology, based on a "speaking-circuit" seemingly modeled upon a telephone call. The speaking circuit isolated the communication between two individuals, which was sent via "impulses" along imaginary wires from mind through mouth, to the ear of the other, and so on (11). Saussure divided speech according to "the physical (sound waves), physiological (phonation and audition), and psychological parts (word-images and concepts)" (12). Only the "psychological parts" truly mattered for Saussure's semiology, which took as its focus the study of "the sign": "The linguistic sign unites, not a thing and a name, but a concept and a sound-image [signified and signifier]. The latter is not the material sound, a purely physical thing, but the psychological imprint of the sound, the impression it makes on our senses" (66). The rest of the speech circuit, as far as Saussure was concerned, could be left to phonetics and psychophysics (18).

Indeed, drawing on those two disciplines, telephone engineers obsessively examined "phones"—the elemental possible sounds of human speech—moving them from the air into electrical media, as well as building ideas about human physiology into transmission apparatus.[12] In contrast to scholars of "the sign"—and even to phonologists who studied "meaningful" sound differences—engineers of the phone were not interested in signification or meaning.[13] The physical properties of sound waves formed the basis for telephone signals, at first quite directly (indexically) as the vibration of the diaphragm in the transmitter generated an analogous electrical current. In the digital coding that preceded information theory (i.e., PCM), the signals and their material channels were still treated as physical things. After Shannon, the segregation of "information" from "redundancy" and "irrelevancy" in a signal was linked to the parameters of the source and the receiver—in the case of speech, statistical norms of articulation and human hearing.

In Hayles's account of the post–World War II emergence of "the posthuman," early cyberneticians and information theorists dematerialized signals and "privileged information" in a manner comparable to Saussure's semiotics and the strong constructionism that followed.[14] Science fiction authors and techno-futurists, she explains, have extrapolated from the seeming "disembodiment" of information in signal transmission to "virtual bodies": at worst, a future of "posthumans who regard their bodies as fashion accessories" to be jettisoned as needed through the downloading of patterns from minds to machines (5). The counterargument of *How We Became Posthuman*—a venture that Hayles compares to the "rememory" work of Toni Morrison's *Beloved*—is her own insistence that "for information to exist, it must *always* be instantiated in a medium" (192).

In an article dismissing the significance of cyborgs to early cybernetics, Ronald Kline has contested Hayles's move from information abstraction to radical bodily mutability and human-machine fusion. With "present-mindedness," he contends, Hayles has "read later concerns about cyborgs as the next step in evolution back into the early history of cybernetics." He continues: "The role of the founders of cybernetics is to set the cybernetic wave in motion, to disembody information so that it can travel across boundaries between the organic and mechanical, to create the material and metaphorical figure of the cyborg. The cyborg can then disrupt old notions about human autonomy, especially in the science fiction analyzed so well in Hayles's book" (335).[15] Kline argues that early cybernetic research mostly developed human and machine analogies concerning the principles of "feedback control, homeostasis, and information processing," leading to a focus on "automata, neural nets, biological systems, and social systems" rather than bodily transformations (351). The few cyborgs that Kline discovers in the history of cybernetics derive from the "minor research area" of "medical cybernetics," one of his prime examples being the hearing glove presumably invented by Wiener as a sound-to-tactile prosthesis for deaf people (331).[16]

Curiously, Kline states that "the hearing glove is a good example of what Hayles calls technical cyborgs, although she does not mention the device," nor did Wiener use the word *cyborg* to describe the glove (338). In fact, Hayles depicts the glove as paradigmatic of Wiener's analogical reasoning *and* the ways analogy enabled human-machine fusions: "As data move across various kinds of interfaces, analogical relationships are the links that allow pattern to be preserved from one modality to another. Analogy is thus constituted as a universal exchange system that allows data to move across boundaries. It is the *lingua franca* of a world (re)constructed through relation rather than grasped in essence" (98). For Hayles, analogical reasoning extracts patterns, coordinates, or equations from material things—it is another means by which information "loses its body" (98).[17]

Like Hayles, Kline reads the glove as a disembodying device: "Information is extracted from sound waves in a disembodied form" (338). Because speech waves inherently escape the human body—most often carried by the medium of the air, understood to be a form of matter in this period—we might instead interpret the glove to be part of the unremitting modern *materialization* of speech. The hearing glove was a "strong analogy," a concrete analog that replicated the speech processing performed by the inner ear. Although the glove was not a digital device (it did not quantize speech waves), it did parse the "information" from the "noninformation" or redundancy in speech. This abstraction of information from speech waves was not abstract in the sense of being immaterial: the frequencies subtracted from the human-generated speech wave were transferred directly to other material media. Moreover, the information transmitted by the glove was defined with reference to certain physiological parameters.

To "read" the hearing glove, and its history, is to unavoidably encounter the material interfaces of communication, the ways media systems incorporate the bodies of users. Signals themselves, I argue, are best understood as concretized abstractions, material-semiotic objects. In 1944, Ernst Cassirer would include signals within the typology of signs in *An Essay on Man,* which contrasted signals and symbols as "operators" versus "designators," the one physical and the other meaningful (37). (As operators, signals triggered responses from machine or human receivers.) By the latter half of the century, signals began to be described within communication engineering and semiotics alike as material mise en abyme:

electrical "carriers" of other signs, encoded transmitters of messages (these codes often obtaining from the quantified information content of the message). With signal processing, and in the wake of information theory, signals were complexly designed—in this sense they are representations. The pattern of the signal—the physical variations of electrical current or voltage—embodies ideas about faithful, efficient, or robust transmission or synthesis. As Wendy Chun summarizes, signals "have a double nature, both as a physical event and as a symbolic value" (156).

Although signals have been catalogued within semiotics since the first half of the twentieth century, they remain understudied compared with other types of signs. At the same time, they are ideal objects for the material-semiotic analyses favored within science and technology studies. In their "A Summary of a Convenient Vocabulary for the Semiotics of Human and Nonhuman Assemblies," Madeleine Akrich and Bruno Latour explain that "semiotics is the study of order building or path building and may be applied to settings, machines, bodies, and programming languages as well as texts; [. . .] the key aspect of the semiotics of machines is its ability to move from signs to things and back" (22). Timothy Lenoir has expanded this approach to include material considerations of language, "the notion missing in the work of earlier structuralist semiotics: language itself is not pure sign, it is also a thing. Language is tied to voice, to bitmaps on a screen, to materiality. The word is thus partly object, partly sign" (122).

Working within this line of reasoning, Hayles credits only Warren McCulloch, among Shannon and Wiener's contemporaries, for recognizing "the entanglement of signal and materiality," the fact that "information moves only through signals and that signals have existence only if they are embodied" (62). The history of the hearing glove, however, suggests that signal materiality was a basic element of cybernetics. (Outside the realm of science fiction and the "virtuality" craze of the 1990s, I would argue that the majority of communication engineers have understood information to "always be instantiated in a medium.") Information theory and cybernetics emerged in a milieu committed to the materialization and control of communication, rather than the "erasure" of materiality and bodies. As a consequence, these fields prioritized certain kinds and arrangements of bodies above and beyond the sheer isolation or transfer of information.

In the remainder of this essay, I take up the hearing glove in order to clarify my arguments about the central importance of speech research to the history of communication engineering as well as the continued relevance of bodies and materiality (if not singular embodiment) to the early cyberneticians and information theorists. By focusing on disability rather than science fiction, and by taking the glove to belong to a familiar genre of communications technology rather than being a new example of "medical cyborgs," I show that the early cyberneticians paid an obsessive attention to embodiment—through a policing of human difference that required as much physical labor as information exchange—as well as to physical media, which were evaluated in terms of their efficiency for carrying signals and their compatibility with human norms.

Keller/Wiener: Prodigies of Communication

At the time of her visit to Bell Labs, Keller had recently returned from a peace mission to Nagasaki and Hiroshima. AT&T greatly underwrote World War II, contributing to radar, weaponry, and field communications. With a combination of discouragement and optimism, Keller thanked the engineers for inviting her to take part in their celebration of telephone progress: "Everything I saw at the Bell Laboratories bespoke the civilization to which Dr. Bell looked forward that would unite mankind in one great family by the spoken word. It is true, we are still far from peace despite wider, more swift communications [. . .]. If we only use the advantages worthily that cybernetics is placing within our reach, science will, I am confident, elucidate to us relationships more marvelous than any we have yet comprehended."[18] Cybernetics—the science of "control and communication in the animal and the machine"—promised more widespread communications, along with intelligent machines. These new machines would themselves have sensory organs, they would converse with one another or fuse with humans, and they would self-regulate or self-correct through internal messaging systems.

The following February, Keller met "the father of cybernetics" himself. While traveling to New Jersey to see family, Wiener and his wife stopped at Arcan Ridge, Keller's home in Connecticut. Keller had taken an interest in Wiener's new project, a glove that converted sounds into tactile vibrations (*Journal* 24). Wiener had followed Keller's career since his childhood. His tutor Helen Robertson, who knew Keller at Radcliffe, used to captivate him with stories of the blind and deaf woman's phenomenal learning (Wiener, *Ex-Prodigy* 74). Half a century later, when the two ex-prodigies met in person, Wiener told Keller that the hearing glove was his first "constructive application of cybernetics to human beings."[19] He invited her to his laboratory at MIT to try the apparatus in person.

Although media theorists have taken the glove to be exemplary of early cyborg engineering or the disembodying (and even "disabling") effects of information technology, other historians have dismissed the device as a postwar compensating gesture, an addendum to the theory of messages and feedback that Wiener tested in the domain of anti-aircraft weaponry. Steve Heims, for one, relegates Wiener's glove to a belated attempt "to turn swords into ploughshares. It reveals a gentleness that was often hidden by his awkwardness, a wish to heal, to repair the kinds of damage done by the weapons of war on which he had worked" (214). Heims's sentimental rhetoric conjures a helpless deaf audience, with the notion of rehabilitation doubling Wiener's technical heroism.[20] This account disregards the long history of the hearing glove concept, not to mention the significance of this technology to the very emergence of modern definitions of information, compression, and feedback. To explain the glove as an afterthought obscures the debts cybernetics itself owed to the study of speech communication and deaf education.

The scientific study of speech and hearing, intensified by telephone engineering, provided a significant growth medium for cybernetics.[21] Speech served as a metaphor, and speech processing as a model, for later forms of signal transmission and communication engineering.[22] Wiener recognized telephony as "the best studied and most familiar technique of communication" (*Human Use* 167). One ambition of cybernetics was to draw computers and other machines into the category of communications technology. "The theory of the telephone is, of course, communication engineering, but the theory of the computing machine belongs equally to that domain. Likewise, the theory of the control mechanism involves communication to an effector machine and often from it" (Wiener, "Time" 202). Wiener extrapolated certain elements of machine communication from literal speech and hearing. He compared the "pruning" or compression of sounds that takes place in the auditory system to the coding required for machine languages.[23] The hearing glove—a speech technology modeled on the cochlea but constrained by the limited sensitivity of human skin—tested the limits of signal extraction and information compression. Far from being incidental, the glove epitomized many principles of Wiener's science of control and communication.

Despite Wiener's theoretical interest in the glove, he was in fact neither the inventor nor even a technical contributor to the device.

AT&T had sponsored electrical-glove research as early as the 1920s that strikingly prefigured the cybernetic paradigm. One model attempted to extract the essential information from a speech wave and convert it into mechanical vibrations. Understanding feedback to be an essential property of human speech, other AT&T engineers hoped deaf people might modulate their voices by comparing their own spoken vibrations to those of "normal" orators. This technology was transferred to MIT by Jerome Wiesner and then developed by Edward David and Leon Levine, only later to be publicized by Wiener. The "cybernetic" glove combined the same two functions of speech translation and voice regulation; in other words, it was designed at once with a concern for information and its medium.

The AT&T-sponsored project, in turn, reworked nearly a century of talking glove and touch alphabet development by deaf and deaf-blind inventors. These alphabetic gloves were not designed for articulation rehearsal, although they often embodied their own theories of efficient communication. The fascination that "Wiener's hearing glove" holds for so many media theorists and historians of technology thus calls into question the role that disability is forced to play in narratives about cybernetics.

Wiener became interested in auditory prosthesis as he finished writing *Cybernetics* in 1948. Wiesner, associate director of MIT's Research Laboratory of Electronics (RLE), returned from a visit to Bell Labs early that year with a proposal to construct a "tactile vocoder." In the 1920s, Homer Dudley of AT&T had designed the vocoder (Voice-CODER) as a tool for sampling and reconstructing speech, hoping to squeeze as many telephone calls as possible through a transatlantic cable. The vocoder mimicked the inner ear's own analysis by filtering a complex wave into a series of narrower frequency bands. Unlike the ear, it sampled each band, extracting the "parameters" (amplitudes) of each and discarding the rest as redundancy.[24]

At Bell Labs, Wiesner had examined the sound spectrograph, a vocoder by-product that inscribed speech waves and was designed as a means of "visual telephony" for deaf people.[25] Wiesner faulted the spectrograph for not being portable and for preoccupying the sense of vision. His proposed device—a project soon assigned to graduate student Leon Levine—would use the vocoder's analyzer to deliver speech extracts to the sense of touch. This "sensory substitution" was hardly a plan for radical reconfigurations of the body; it was premised, rather, on the indispensability of the conventional senses. The decision to occupy a hand during conversation followed from the longstanding "hierarchy of the senses,"

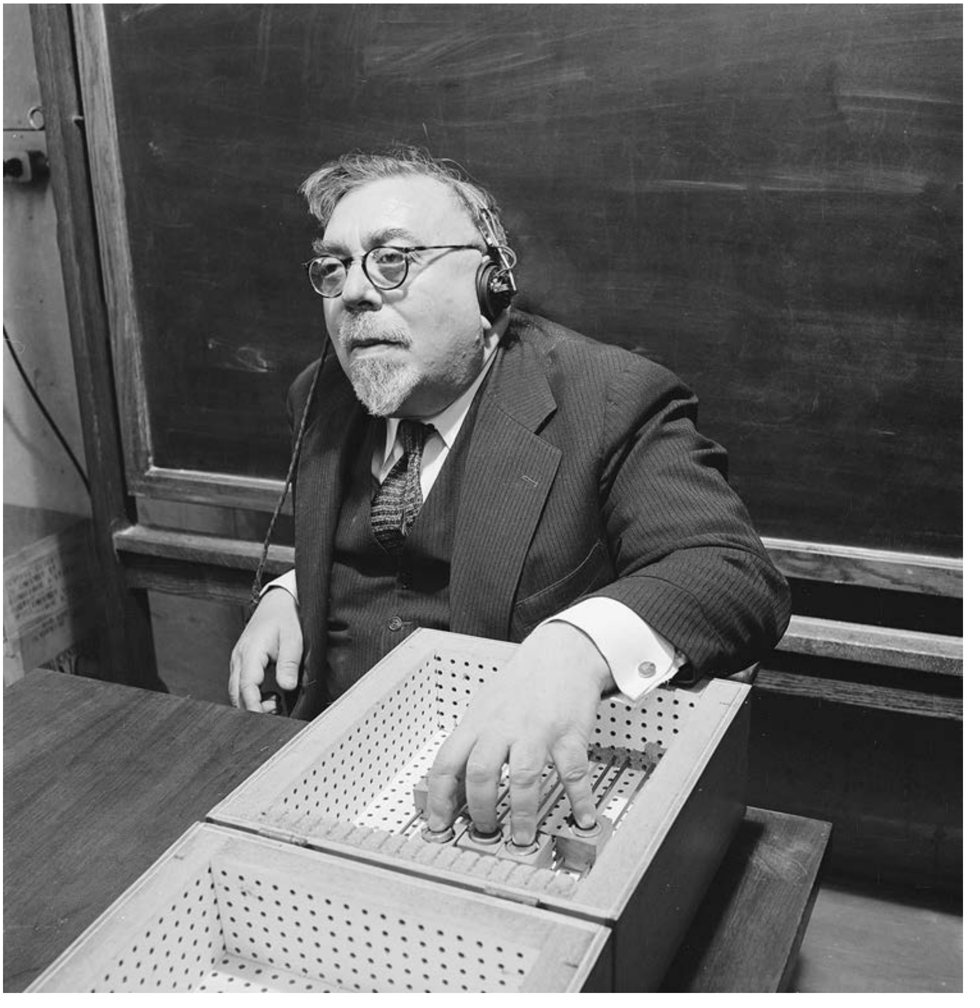


Figure 3
Norbert Wiener with an early prototype of the translator, which he hoped would ultimately be worn as a "glove." 1949.

Photograph courtesy of Getty Images.

with touch subservient to vision and hearing (Jutte 61). The fact that hands might communicate more rapidly through other tactile and visual means—sign language, hand spelling, the touching of lips, reading Braille—suggested that "mainstreaming" outweighed even efficiency.

Subsequently Wiener theorized that the vocoder's analyzer could be adapted for great feats of compression: a stream of speech might be diverted into five channels, one for each finger, and the "envelopes" of each channel used to modulate five sources of vibration. The glove need not assist with music or ambient sound; Wiener considered deafness to be disabling only as it affected speech. He defined deafness not as the absence of hearing but as exclusion from mainstream communication: "A person who can follow speech on the basis of sound carried by the air, and can do this with a reasonable proficiency, can scarcely be considered socially deaf" ("Hearing Fingers" 3). Defined in terms of communication, hearing switched from an "immersive" sense to a directional one.

Beyond tactile hearing, Wiener conceived of the glove as a feedback device to correct what he called the "grotesque and harsh intonation" of deaf speakers.[26] As carriers of speech information, certain voices operated like noisy channels, jittery signals, or otherwise distorting media: "A highly inefficient form of sending a message" ("Sound Communication" 260). Throughout the 1940s, hard of hearing activists themselves had urged their peers to acknowledge how uncommon pronunciation might distort communication: "We underhearing people are apt to forget what a strong influence sound has on the emotions [. . .]. And the effects our voices have on our normal hearing friends are too frequently boredom (from lack of color and inflection), fatigue (from straining to hear a low mumble-mumble), annoyance (from the nervous shock of being shouted at)" (Hazzard). Learning to use the glove would require effort on the part of deaf individuals, but the hearing world would be spared both translation and discomfort. At the outset of cybernetics, then, was an etiquette for acceptable and dysfunctional discourse. The ideal, which affected both human and machine communication, was universal, frictionless, instantaneous, and economical.[27] Sign language was unquestionably too minor to be efficient; oral deaf speakers impeded communication through the quality of their voices.

Wiener framed the hearing glove within his broader project to "admit machines to the field of language." He accounted for his interest in communication as an autobiographical effect: he had been "brought up the son of a philologist" (*Human Use* 77, 85). As a child, Wiener was immersed in debates about the "techniques" and "mechanisms" of language. His father Leo had been interested in universal languages; he was acquainted with the inventor of Esperanto and "was one of the first to study the new artificial language" (13). Wiener became convinced that "speech is the greatest interest and most distinctive achievement of man" (78). In this frame, deafness seemed profoundly disabling.[28]

Wiener's contemporaries did not appreciate the links between the hearing glove and his mathematical scholarship. At the 1949 Gibbs Lecture of the American Mathematical Society, called "Problems of Sensory Prosthesis," audience members heckled him for discussing "human values" rather than "harmonic analysis"—although the glove explicitly joined these two categories (Davis 2). Wiener had chosen to work on harmonic analysis (breaking complex oscillations into their component sine waves) in the 1920s at MIT, believing it to be "the proper foundation of communication theory" (*Mathematician* 77). Deaf scientist Oliver Heaviside had popularized this topic, the Fourier transform, at the end of the prior century; Wiener set out to prove his calculus and expand it with probability theory.[29]

Wiener also reworked Heaviside's life story, making it the subject of his 1959 novel, *The Tempter*. Heaviside lost much of his hearing as a result of childhood scarlet fever; he later worked in the field of telegraphy, following his uncle, Charles Wheatstone. Although his publications helped establish circuit theory, he was poor and unemployed most of his life. The injustices of his career were compounded when George Campbell and Michael Pupin, backed by AT&T, patented one of his obscure inventions that proved crucial for reducing distortion in long-distance telegraph signals.

"Cedric Woodbury," the protagonist of Wiener's novel, keeps one hand cupped behind his ear yet is the only person who can discover the "hidden language of machines" (*Tempter* 93). Woodbury was interested in control devices—translators between the human and machine worlds—such as the steering engines of ships.[30] While studying the conversations between humans and machines, the intelligence of the latter became evident to him: "The man doesn't merely give orders to the machine while the machine blindly obeys. There must be a dialogue in which the machine acquaints the machine-tender with the difficulties of the task to be accomplished and reinterprets the machine-tender's orders so as to perform these tasks in the best possible way" (93). Who better than a deaf scientist to search for automatic translators and alternate languages? Still, Woodbury's insight came at the cost of human companionship; moreover, his findings were easily stolen from him. Although machine languages need not be oral, Wiener believed that deaf people required translators to join them to the world of speech communication.

Despite transformations in the technology of communication during the twentieth century, rigid bodily and speech standards largely persisted for human beings. For this reason, relations between disability theorists and technology theorists have been vexed regarding the position of cybernetics vis-à-vis normalization and enhancement. Tobin Siebers, for instance, takes issue with Donna Haraway, who uses disability as an archetype in "A Cyborg Manifesto." He finds her to be "so preoccupied with power and ability that she forgets what disability is. Prostheses always increase the cyborg's abilities [. . .] the cyborg is always more than human. To put it simply, the cyborg is not disabled" (63). In *When Species Meet*, Haraway describes the wheelchair and crutches used by her father, due to childhood bone tuberculosis, as "companion species" or "cyborg" technologies, with which he had ambivalent relations (173). Nevertheless, her interest in the extended capacities produced by human-object relations seems bound to what Siebers calls "the ideology of ability."[31] Along a restrictive continuum of ability, normalizing technologies are read as "augmentations," while the imperfections of these technologies and the qualitative differences between bodies are overlooked. Wiener explicitly designed the hearing glove for rehabilitation, as opposed to enhancement; moreover, he soon recognized the limitations of auditory prostheses. In the 1960s, shortly before his death, he began to complain of hearing loss himself and purchased an electronic hearing aid (Conway and Siegelman 325). It was noisy, and it distorted sounds; he often left it turned off.

Disability theorists have also criticized the cyborg concept in futurist literature and media studies for exploiting disability as a metaphor or plot device. David Mitchell and Sharon Snyder argue that "disability underwrites the cultural studies of technology *writ large*," from Paul Virilio's anxiety about the disabling effects of future machines to Hayles's portrayals of disabled people as the quintessential cyborgs—all "without any serious effort to specify the nature of this usage [of technology] within disabled communities themselves" (8).

These ideological conflicts are exacerbated by the fact that the history of cybernetics so often depended upon disability. Siebers has elsewhere suggested that "the disabled body changes the process of representation itself [. . .] blind hands envision the faces of old acquaintances. Deaf eyes listen to public television [. . .] different bodies require and create new modes of representation" (54). Along these lines, D/deaf (referring to both the linguistic minority and disability constructions of deafness), late-deafened, and deaf-blind inventors and research subjects generated new media and methods for speech communication—including an array of gloves—in the nineteenth and early twentieth centuries. (Later, deafness prompted hearing engineers such as Wiener to identify the "essential" information in speech and to theorize the role of feedback in communication.) These new modes of representation occasionally exceeded oral speech, being intended for other means of communication or for "minor listening" rather than for normalization. At the same time, they provided analogies and inspiration for machine communication. Nonetheless, the rhetorics of charity, rehabilitation, and cybernetic enhancement have marginalized and even erased the specificity of disability in most historical accounts.

Touch Alphabets and Feelies

Despite Wiener's thinly veiled attack on the patent practices at AT&T, the MIT hearing glove duplicated a tactile vocoder that had been proposed by Homer Dudley in a 1937 patent.[32] Dudley's vibrotactile "signaling system"—his own adaptation of the vocoder—was intended to assist deaf people with lipreading. He theorized that "the information transmitted by speech" could be "described" by eight or ten bands, edited down from the original speech wave and corresponding to "the muscular parts making up the speech signal." Information was here defined according to the "source": the "motions of the lips, tongue and other vocal organs" (n.p.).[33] A prior "materialization" of speech thus enabled its concretized abstraction in the form of an electrical signal.

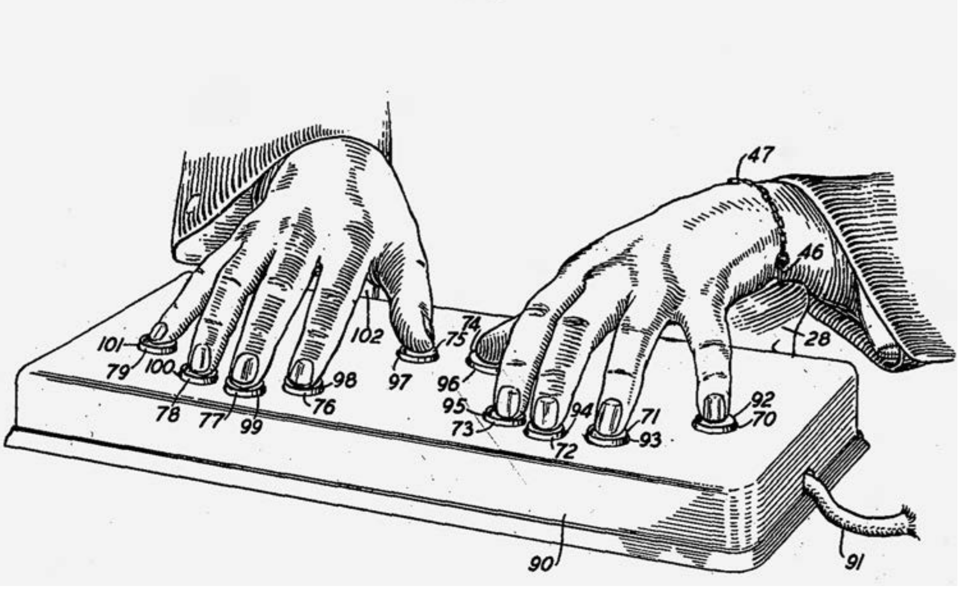
In fact, Bell engineers had been interested in tactile communication as early as the 1920s, when Northwestern psychology professor Robert Gault requested their assistance with his research. Gault had designed a range of tactile tools to aid deaf people with lipreading as well as voice control. He conceived of speech as something of a blunt object: "If the human voice can be made to break into them through their skins, well and good" ("Touch" 121). Tactile speech had been a preoccupation of deaf education since the field was formalized in the eighteenth century. Prior to Gault, this kind of research was conducted by Hermann Gutzmann and David Katz in Germany as well as Max Goldstein in the United States.

At first Gault believed that vibration—one component of touch—would allow the skin to access sound waves directly. The ear seemed to have evolved from the tactile sense; moreover, if every sensory phenomenon existed as a waveform, it should be easy to translate from one sense to another. Helen Keller, for instance, had been famously expert at detecting sound and motion in her environment as they vibrated through solid media. With a foot, she and her companions tapped Morse code across the floor to each other. When her friend Samuel Clemens spoke, the vibrations of his mouth and throat "modulated" the information on his lips and hands:

> *His voice was truly wonderful. To my touch, it was deep, resonant. He had the power of modulating it so as to suggest the*

Figure 4
H. W. Dudley, "Signaling System." U.S. Patent 2,150,364.

FIG. 2



*most delicate shades of meaning and he spoke so deliberately that I could get almost every word with my fingers on his lips. Ah, how sweet and poignant the memory of his soft slow speech playing over my listening fingers. His words seemed to take strange lovely shapes on my hands. His own hands were wonderfully mobile and changeable under the influence of emotion. (*Midstream *66–67)*

However, Keller was well aware that interpreting speech through vibration alone was impossible. Alexander Graham Bell once held her palm to a telephone pole and asked her what its quivering meant. She was not certain, so he explained, "[T]he humming which I felt in my fingers never stopped, that the copper wires up above us were carrying the news of birth and death, war and finance, failure and success from station to station around the world."[34] If oscillations were the language of optics, acoustics, and tactile vibration, they might be transferred from medium to medium or carried along the same electrical wire, but they were nevertheless processed quite differently by each sense organ.

Gault had begun his experiments in 1922 with a simple metal tube. He spoke through one end, and his subjects pressed their hands against the other opening, describing the bursts of air they felt (see "Tactual"). In 1925, he asked Harvey Fletcher, the director of speech and hearing research at AT&T, to equip several telephone sets with receivers that had exposed diaphragms.[35] These "teletactors" conveyed speech to the thumbs. Over the course of two years and hundreds of hours of practice, his subjects—volunteers from Gallaudet, as well as younger schoolchildren who were likely forced to participate—used the teletactor to rehearse the emphasis and tempo of their own voices (Gault, "Hearing" 1). Feedback theory was clearly in the air.[36]

By 1928, as Dudley was beginning his experiments with the vocoder, Gault "conceived of grafting a mechanical ear upon the skin." To make the individual words buried within vibrations distinguishable, Gault realized that it was necessary to reproduce the filtering actions of the inner ear (Gault and Crane 353). Speech was thus identified with the processing of sound waves by the cochlea rather than with sound waves as such.[37] Bell Telephone Laboratories soon offered him a "multiple unit" teletactor that split speech into frequency bands, one for each of the five fingers. The sense organs were no longer presumed to be exchangeable, as they had been in Keller's youth. Instead, machinic analogs were required to mediate between sensory domains. That year, Vern Knudsen, professor of physics at the University of California–Los Angeles, reviewed Gault's project by assessing the communication capacities of the tactile sense. Touch, he concluded, was not as discriminating as hearing: it was fairly sensitive to changes in intensity, but a change as great as 30 percent was required for a difference in frequency to be noticeable (Knudsen). The teletactor might reinforce lipreading or vocal rhythm, but even this new version could never fully convey complex speech to the hand.

Gault retired in 1940. In 1967, J. M. Pickett of Gallaudet wrote to him with an update about new, vocoder-based hearing gloves that not only analyzed but compressed speech. "The philosophy behind this work is that it is possible to abstract the information bearing elements in speech from the acoustic signals. These elements can then be changed, recoded, to new acoustic, tactual, or visual signals and after training it might be possible for the deaf or hard of hearing subject to perceive the recoded speech or to use the recoded information as a complement to the visual signals from the speaker's lips."[38] Compression of the speech signal might accommodate the parameters of the tactile sense, but use of the technology required training; communication was still understood to be a bodily act.

The team at MIT reinvented "skin hearing," based on the vocoder, in 1948. The hearing glove challenged them to determine the minimum amount of information contained within speech. Awareness and


Figure 5
Single-unit teletactor (“Phonotactor”). The student feels his teacher’s speech and then compares it with his own. Robert H. Gault, “Research Program in the Interest of Deaf, Hard of Hearing and Deaf-Blind Children” [c. 1939].

Photograph courtesy of Northwestern University Archives.

pain formed the absolute boundaries of tactile communication; in between there were a limited number of intensity and frequency changes the skin could detect. In his 1950 overview of cybernetics for the American Academy of Arts and Sciences, Wiener discussed the glove as a prime example of both feedback and information compression. He also pared down the phonetic aspect of speech—based on the source of the human vocal tract—to a fraction of the total information in a sound wave: “Not much more than from one-tenth to one-hundredth of the information contained in a sound, as sound, appears in the phonetics which we interpret” (“Cybernetics” 2).

Graduate student Leon Levine took over the details of the hearing glove project for his 1949 Master’s thesis in electrical engineering.[39] He called the machine FEELIES after the sensory cinema in Aldous Huxley’s *Brave New World*, with reference to multimodal communication rather than immersive spectatorship.[40] The MIT glove would later be claimed as an antecedent to the dataglove, a virtual reality accessory to which Ken Hillis attributes “the genesis of a belief in the body itself as only informational” (15).[41] Beyond virtual reality, other datagloves would abandon the linguistic project in favor of force-feedback for teleoperations, as well as the haptic enrichment of communication between humans and machines. Today gloves are portrayed as devices that more “naturally” convey input to computers than do mice or keyboards, the goal of electronic glove research being “to apply the skills, dexterity, and naturalness of the hand directly to the human-computer interface” (Sturman and Zeltzer 35).

Like the teletactor, Levine’s glove filtered microphone speech into five bands; it then converted only the envelopes of these bands into five streams of lower-frequency vibrations to account for the range of fingertip sensitivity.[42] Wiesner and Levine quickly concluded that FEELIES was “inadequate” for transmitting the speech information it pulled from a sound wave to the tactile sense (Levine 39). Levine insisted, however, that the glove's most imperative application was speech correction, through the feedback it provided about the tone and tempo of oral speech. As indicated by this early cybernetic device, the materiality of a signal (its frequency, its tactile rhythm) and its human "destination" might be prioritized over its often intractable information patterns. Left behind in this rigorous management of pronunciation, however, was an openness to the unique embodiment of voices. As argued by Adriana Cavarero in her critique of both metaphysics and poststructuralism for neglecting the material voice in the course of their deliberations over speech, "It is no longer a question of intercepting a sound and decoding or interpreting it, but rather of responding to a unique voice that signifies nothing but itself" (7).

A local deaf-blind man, Leo Sablosky, visited the RLE to practice speaking with the glove for a day in 1949. Sablosky already communicated with his brother by touch, holding his fingers to the latter's throat. He had also learned to say a few words, although his articulation was "very breathy and bad." With the hearing glove, Wiesner, Wiener, and Levine announced in *Science*, "the patient immediately begins to improve the quality of his speech by comparison and his voice begins to lose its deaf-mute deadness. We suggest these principles [i.e., feedback] as a basis for further work in sensory replacement" (512). Working with psychologist Alexander Bavelas, Levine continued with the project (renamed "Felix") until 1951. During those years, the *Quarterly Progress Reports of the RLE* reported on their ongoing troubles with the transmission of speech information to the tactile sense.

Nevertheless, the *New York Times* and *Life* published optimistic news briefs in 1950 about the glove and the future of tactile hearing. Letters arrived from all corners: Barcelona, Copenhagen, El Paso, Jerusalem, and Little Current, Ontario. Many correspondents were deaf scientists and engineers. Others had acquired an uncommon scientific literacy through their oral education or their participation in experimental studies.

David Mudgett of Florida, a former teacher at the Illinois School for the Deaf, wrote on February 1, 1950, regarding his own theory of tactile hearing, which he was preparing for publication in the *American Annals of the Deaf*:

> *I was delighted to read about your studies of methods of using the deaf person's tactile senses to detect the vibrations of speech and other sounds. It is exactly what I have been saying should be done. I am deaf (totally, from meningitis at 7 years) and have*

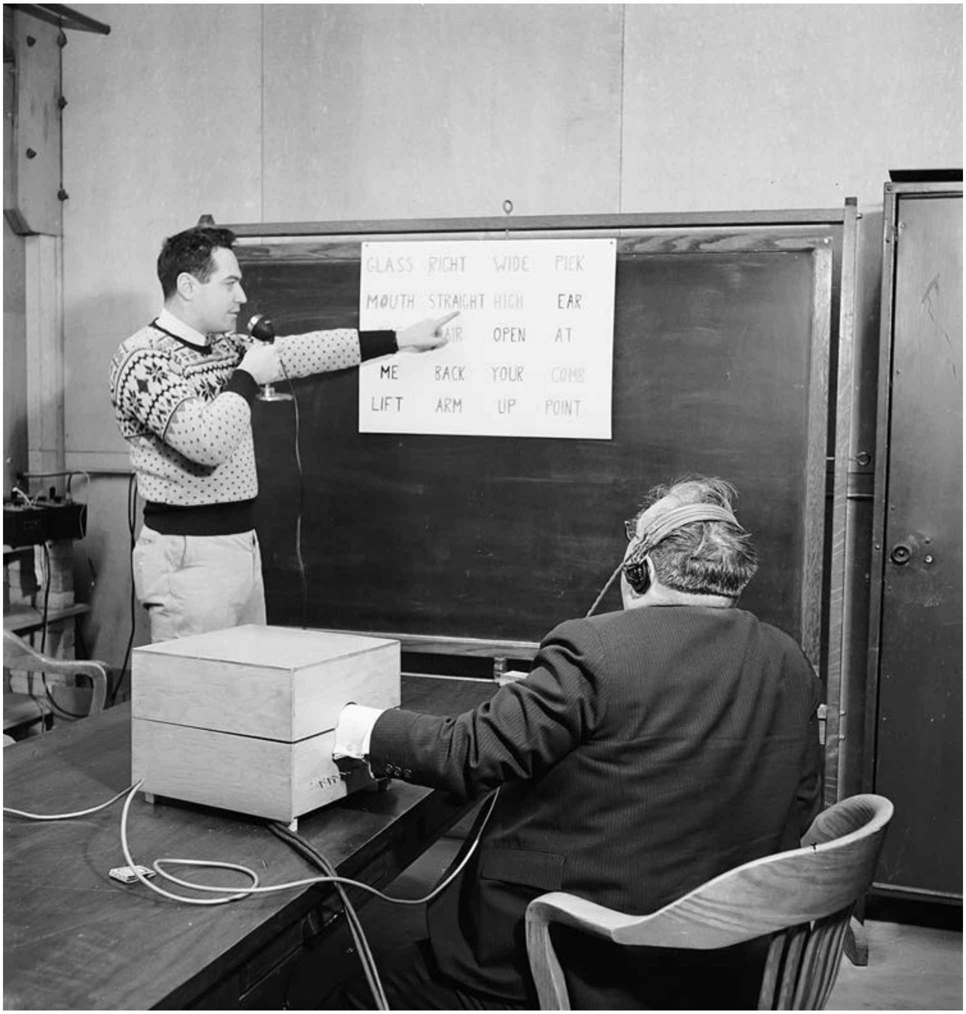


Figure 6
Norbert Wiener, feeling words. Earphones supply noise to mask sounds from the vibrations of the device.

Photograph courtesy of Getty Images.

often used bone conduction hearing aids held in the hands to catch the breaks and accents in speech, to "hear" music and sometimes just to enjoy the medley of sounds around me [. . .]. In this paper I am working on, I state that I believe the use of a hearing aid held in the hand would help to lessen this type of maladjustment but that the bone conduction type of hearing aid would have to have a larger vibrating surface to achieve greater tactile stimuli, and the instrument will have to rule out certain extraneous sounds that interfere with recognition of speech. Some years ago I had occasion to use Dr. Gault's "Teletactor" (Northwestern Univ.) and found it to be a wonderful tactile aid.[43]

For Mudgett, tactile sound translators were not inevitably new media within an old system of communication. They could allow new forms of sensory stimulation, as when they were used “just to enjoy the medley of sounds around.” And these media, rather than the ear, could become the primary sites for understanding sound.

P. G. McGowan, a lab manager for Gerber’s Baby Foods in Michigan, had also served as a research subject for Robert Gault. He offered Wiener his evaluation of the teletactor laboratory:

> *A sound proof room was constructed and the apparatus and the subject would be sealed in—you could not see out of the room and I recall it as being very very hot. Dr. Gault or one of his assistants would read off a prepared manuscript into the microphone and I, on the inside, would write down what I picked up (or thought I did) off the aluminum button. [. . .] I could pick up music quite well, at least I could identify the tunes.*
>
> *At any rate, this was all very encouraging at the time, but the apparatus was too cumbersome and expensive to be practical. [. . .]*
>
> *I would like to mention that when I used Dr. Gault’s telatractor my lip-reading efficiency was greatly increased. The same is true now if I place my fingers on the throat or chest of the individual I am conversing with. I have tried holding hearing aids in my hand, but they were not powerful enough, however, they did aid lip-reading if held in my teeth.*[44]

The use of this “glove” that was never a glove, that was not invented by Norbert Wiener, that did not erase the hand, the ear, or deafness, was remembered as a physical experience: in a small hot room, touching an aluminum button, picking up music. At the same time, technification entered routine conversations, with efficiency even present as McGowan touched another’s chest.

Helen Keller was among Wiener’s correspondents in those months. As a girl, Keller had learned to use hearing gloves of a different sort—white cotton ones on which the alphabet was printed. These models required two-way intimacy, effort on the parts of both conversants. The first hearing glove in the United States was designed in the 1870s by James Morrison Heady of Kentucky. Heady had lost his vision in a series of childhood accidents, then gradually became deaf as he aged. To communicate

Figure 7
James Morrison Heady's "Talking Glove."

Photography courtesy of Ken D. Thompson.

with his sister, he attached metal letters along the palm of a glove. This "Talking Glove," as Heady named it, allowed others to converse with him by pressing words into his hand, while he responded orally. As with all wearable media, the interface was essential; Heady soon switched to a printed alphabet when the metal injured his skin.

Twenty years later, a similar glove was patterned by William Terry, a surgeon who had been deafened in the Civil War and then lost his sight at age seventy. Terry painted his "touch alphabet" on a cotton glove, at the sensitive fingertips, joints, and creases of the palm. Through trial and error, he placed the vowels and other frequently used letters where they seemed to be most "readily found" by an interlocutor (Clark and Clark 10). Harold Clark suggested a further improvement to Terry's glove, in which not only the frequency of letter use would be considered but "the combinations in which they are most likely to occur, as is done in the universal keyboard of a typewriter or linotype machine" (17). This type of talking glove would be easy to use for people who knew how to type (and it would help its other users learn to type more quickly). Efficient encoding, tied to the parameters of the source and the destination,

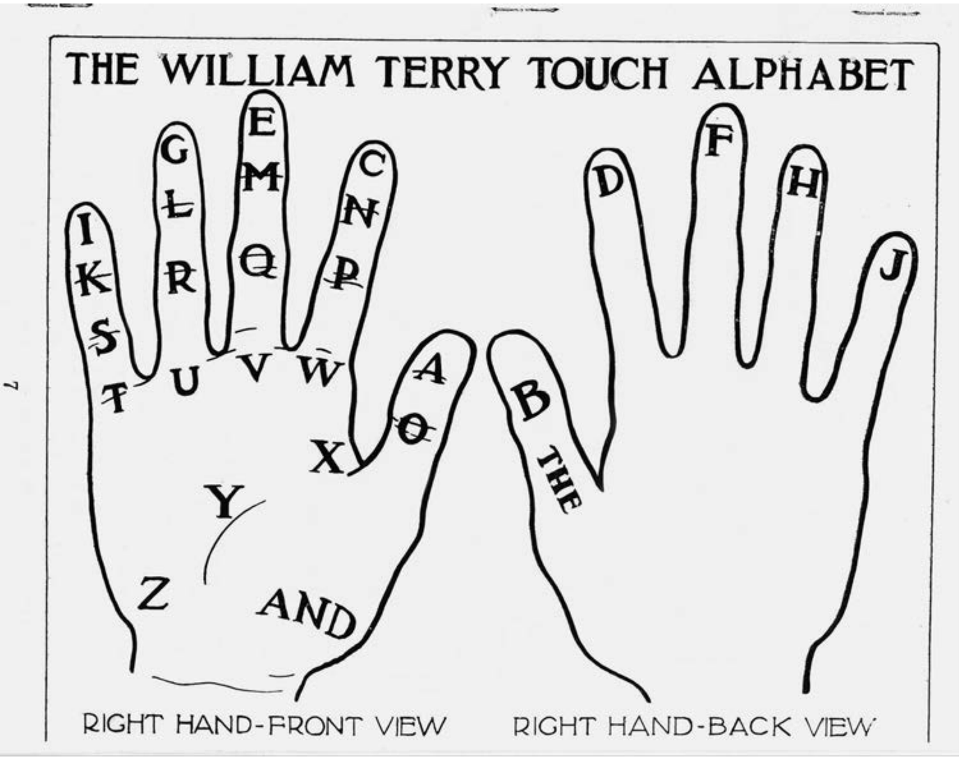


Figure 8
Harold T. Clark and Mary T. Clark, *The William Terry Touch Alphabet* (1917, 2nd ed.).

Courtesy of Gallaudet University Library.

was thus a long-standing principle of hearing glove design—although the scale of this efficiency would increase dramatically and would be applied to the voice itself in the case of automated devices.

Thomas Edison, himself hard of hearing, felt that even this rationalized glove would still be too slow for conversation. If efficiency were truly the goal, perhaps both speech and writing should be abandoned. He wrote to Terry's grandson in 1916 after the latter mailed a Touch Alphabet pamphlet to him: "It is quite an ingenious system, but I find the Morse Alphabet would be practicable also. I can read Morse at the rate of thirty-five words per minute, by touch only, and if the Associated Press abbreviations are used I can read one hundred words per minute" (Clark and Clark 17). Between two people, the code of the Morse alphabet afforded secrecy and speed. Edison's wife regularly translated speeches and plays against his knee. Edison tapped his marriage proposal upon her hand, delighting in the merger of efficiency with intimacy: "The word 'Yes' is an easy one to send by telegraphic signals, and she sent it. If she had been obliged to speak it she might have found it harder" (qtd. in Runes 54–55).[45]

In other instances, invisibility took precedence over efficiency. Alexander Graham Bell created his own finger-spelling glove in 1883 for George Sanders, one of his benefactor's children.[46] Bell's glove required his pupil to give up the use of signs and adopt the slow spelling-out of sentences in English. The purpose of this type of manual communication, as opposed to sign language, was visual normalization: "I could talk to him very freely in a crowd without attracting the attention of others. I took him to Barnum's museum and talked to him all the time the lions were being fed, and I am sure that no one among the spectators had the slightest suspicion that the boy was deaf" (Bell 136).

Keller evidently learned of these glove experiments when she was eight years old. Alonzo Garcelon, recently the governor of Maine, offered to bring her a doll, and she asked him instead for "some beautiful gloves to talk with" (Keller, *Story* 184). Keller became quite proficient with her new talking glove, but she abandoned it after the first year, preferring to read in Braille or converse through hand spelling and lipreading.

Intelligent Machinery

On March 1, 1950, Keller and her assistant Polly Thomson traveled to Cambridge eager to "present [them]selves for the tests" at the Research Laboratory of Electronics the following day.[47] Keller had been an experimental subject in some of the most prominent labs of the era. For psychologists, blindness and deafness served as independent variables for extracting data about the mind: the relationship of language to consciousness, for instance, or the specific influences of vision and hearing on knowledge. Engineers, on the other hand, were fascinated with Keller as an "engineering achievement" in her own right. Elmer Sperry, for instance—whose gyroscope company helped create the science of control systems that made cybernetics possible—invited Keller to his Brooklyn lab in 1930 to examine feedback apparatuses: "the gyroscope compass, turn indicator, the flight instruments that Lindbergh used in crossing, and the ship stabilizer which prevents all rolling of ships."[48]

Twenty years later, Wiener, Wiesner, and Levine greeted Keller at the RLE and helped her practice with their hearing glove for an hour or so. Unlike the cotton models with which she was familiar, this glove was automatic, demanding no attention on the parts of nondisabled speakers. Keller was not able to interpret the words on the finger pads, but she was able to recognize the tone and tempo of certain vibrations: "It is good to recall the hearty laughs ringing out in the machine at my blunders."[49] By three o'clock, she and Polly were on the train back to Connecticut.

Keller had dreamed in 1936 that Annie Sullivan, recently dead, returned to her with a strange leather and wire instrument. Each wire vibrated with a separate sound from the environment, which Keller could "hear" simply by touching the machine. She wrote in her diary that this dream was perhaps "a prophecy of new victories over limitations" (*Journal* 78). The MIT glove, like its electrical precursors, was not destined to succeed. The project ended in 1951 with a falling out between Wiener, Wiesner, and several other members of the RLE (Conway and Siegelman 217). Alphabet gloves continued to be used, and when subsequent researchers took up the hearing glove project, they mostly abandoned the aim of direct speech translation in favor of haptics, or skin-specific communication.[50]

The October following Keller's visit to MIT, she appeared—symbolically—at another epicenter of computing. Alan Turing published an article in *Mind* that month on the coming of "intelligent machinery." He used Keller as an analogy, to argue that the phenomenon of learning transcended specific body parts or physical forms.[51] In Turing's anecdote, however, even these future machines would be stigmatized for their physical "deficiencies":

> *It will not be possible to apply exactly the same teaching process to the machine as to a normal child. It will not, for instance, be provided with legs, so that it could not be asked to go out and fill the coal scuttle. Possibly it might not have eyes. But however well these deficiencies might be overcome by clever engineering, one could not send the creature to school without the other children making excessive fun of it. It must be given home tuition. We need not be too concerned about the legs, eyes, etc. The example of Miss Helen Keller shows that education can take place provided that communication in both directions between teacher and pupil can take place by some means or other. ("Computing" 457)*

Keller had haunted the pages of *Mind* since her childhood, often on this same theme of the endless varieties of "input" and "output." In 1893, when she was eleven, the journal reported on her use of typewriters, Morse code, and hearing gloves: "Her eagerness to use any means of intercourse with others is marvelous" ("Helen Keller" 282).[52]

In a portrayal of the assistive and domestic technologies at Arcan Ridge, Diana Fuss connects Keller to the "modern media revolution":

"Keller's fascination with machines, and her own allegedly mechanical nature, made her something of a national symbol for modern science's artificial reproduction of human sensation. Helen Keller, a woman both blind and deaf, became the chief cultural cipher for the new sight and sound technologies of the late nineteenth and early twentieth centuries" (135). Fuss bases her argument on the scores of photographs that framed Keller with the latest electrical technologies. According to popular understanding, "mechanical nature" was automatic or unthinking. Similarly, Fuss reads an image of Keller touching a radio as a comparison between two entities that "passively" received vibrations.[53]

Keller was also described in the popular press as a "second Galatea," an automaton, a statue that had been taught to speak.[54] Contemporary engineers did not see Keller as an automaton; moreover, they believed that machine intelligence could be achieved, recasting such platitudes as "acting like a machine" and "purely mechanical behavior" (Turing, "Intelligent" 107). This, then, was the "media revolution" in which Keller took part. The old question "Can deaf people think?" resounded in the new question "Can machines think?"

Turing argued that mechanical intelligence was foreseeable because it was already "possible to make machinery to imitate any small part of man" ("Intelligent" 116–17). The translation of sound, text, and image into electrical signals had begun to provide, in Wiener's words, "a language which the machine can understand." J. C. R. Licklider suggested that the leap from sensory "extension" to "artificial intelligence" would be facilitated by the "time-and-motion analysis of technical thinking" ("Man-Computer" 76).

In Turing's account, it would be uneconomical to remake the body in its entirety if the objective were simply "thinking machinery." For human beings, however, atypical embodiment was not so lightly sanctioned. The hearing glove's allure had been the possibility of sensory substitution in the interest of maintaining communication norms. Wiener intended the glove to regulate deaf speech, beyond translating the speech of others. He hoped that it would ultimately disguise both impairment and mediation—he only intended to "lose" certain kinds of bodies.

Along with the human-technology hybrids and self-regulating machines of cybernetics, information theory emerged from the milieu of signal transmission. "Communication theory," John Pierce of AT&T insisted, "has its origins in the study of electrical communication" (24). Starting with Ralph Hartley's 1928 "Transmission of Information," information was defined by communication engineers as quantitative and *physical*. Signals transported messages, which themselves contained a limited amount of information. If this information were identified, signals could be better coded for economy and for reliable transmission through noise. "We should ignore the question of interpretation," Hartley wrote. Instead, the measure of information in a telegraph, telephone, or television signal should be "based on physical as contrasted with psychological considerations" (Hartley 535, 538).

Inspired in part by the vocoder, Claude Shannon would subsequently prove that a signal could be encoded efficiently and compressed "due to the statistical structure of the original message and due to the nature of the final destination of the information" (1). It had long been evident in the history of hearing gloves that speech information comprised a small fraction of the sound wave and that human sense organs constrained the design of signals. While digital signal processing, plus computation, would eventually enable countless media simulations, reproduction was Shannon's primary concern in "A Mathematical Theory of Communication." For the analog messages of television, radio, and telephony, Shannon maintained that perfect reproduction was impractical: "We are not interested in exact transmission when we have a continuous source, but only in transmission to within a certain tolerance" (48). Continuous messages should be efficiently coded based on a "fidelity criterion" set by engineers. Shannon offered a hypothetical example for the efficient transmission of speech and music, which would later be realized in the development of "perceptual coding" (exemplified by the MP3):

> *The structure of the ear and brain determine implicitly an evaluation, or rather a number of evaluations, appropriate in the case of speech or music transmission. There is, for example, an "intelligibility" criterion in which (x;y) is equal to the relative frequency of incorrectly interpreted words when message x(t) is received as y(t). Although we cannot give an explicit representation of (x;y) in these cases it could, in principle, be determined by sufficient experimentation. Some of its properties follow from well-known experimental results in hearing, e.g., the ear is relatively insensitive to phase and the sensitivity to amplitude and frequency is roughly logarithmic. (49)*

Media that deploy economizing "fidelity criteria" to reproduce audio/visual messages have led Friedrich Kittler to assert that "our sense perceptions are the dependent variable" in "a compromise between engineers and salespeople" (2). Yet perceptual norms, derived from population surveys or experimental trials, are in many cases the *independent* variables that determine coding procedures—which only later interact with the senses of individual listeners and observers.

For the case of discrete sources like telegraphy or computing, where the message is inherently digital, Shannon based the quantification of information—and the determination of the minimal "bits per second required to specify the particular signal"—on the statistical properties of the source. As an example, he noted that "this is already done to a limited extent in telegraphy by using the shortest channel symbol, a dot, for the most common English letter E; while the infrequent letters, Q, X, Z are represented by longer sequences of dots and dashes." The statistical approach to phenomena is inherently departicularizing, smoothing individual variety into the regularity of mass patterns. As a guide to coding and compression, and as a material-semiotic phenomenon, it results in the cutting up or shaping of *particular* signals based on probability (i.e., a short symbol for "e").

At stake in thinking about signals, then, beyond the issue of fidelity, are questions about optimization: the range of possible human "destinations" afforded by a given transmission system, the ergonomic design of human-machine interfaces, the types of messages that can be handled, the elements of those messages deemed relevant for transmission. Paying attention to the material commitments of cybernetics and information theory, and to the machinic filtering that intercedes in so much communication, reveals more about bodies than disembodiment—specifically, the phenomenal and interactional consequences of the industrial conception of language.

With thanks to George Kupczak of the AT&T *Archives and History Center, Helen Selsdon of the American Foundation for the Blind, and Deborah Douglas of the* MIT *Museum for their meticulous research assistance.*

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Notes

1 Helen Keller to Dr. Buckley, 17 June 1949, Series 1, Box 35, Folder 6, Helen Keller Archives, AFB.

2 Hubbard was also the father of Bell's wife-to-be, Mabel.

3 "Program for Visit of Miss Helen Keller: Murray Hill, Tuesday, June 14, 1949," Series 1, Box 35, Folder 6, Keller Archives, AFB.

4 For accounts of other bodily mechanizations, see Crary; Giedion; and Rabinbach.

5 Wendy Chun has recently compared electronic signals and information to the commodity form: "[C]ommodities, like information, depend on ghostly abstraction" that "transforms material things and their embedded use-values, into things that can be exchanged" (135).

6 The rate and shape of signals are material representations. On "electrical analogies" in the early twentieth century, see Care. For a telephone engineer's account of reproduced speech as a "commodity," see Fletcher.

7 For influential examples, see Liu; Manovich; and Rodowick. For a counterargument on the significance of the telephone to the long history of sound recording and audio engineering, see Sterne.

8 For more on this topic, see Bellovin.

9 According to K. W. Cattermole, telegraphy "led to the beginning of information theory," which ultimately resulted from combining the insights of telegraphy and telephony (19). The work of Alec Reeves on PCM and the subsequent contributions of Shannon and Wiener were attempts to apply the precedent of telegraphy to the coding and transmission of continuous signals.

10 *Technification* (or *technicization*) refers to machine building as well as the production of efficient techniques, the extension of technical methods to all domains of life. On this term, see Husserl.

11 As one example of recent scholarship on the materiality of electronic media, see Kirschenbaum.

12 Phonemes, in contrast to phones, are the smallest *meaningful* units in a given language.

13 Claude Shannon explicitly dismissed signification in the opening paragraphs of "A Mathematical Theory of Communication": "The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem" (379).

14 She specifically compares Wiener and Saussure in terms of their approaches to "signification" (98). See also 192. Hayles herself adheres to "constrained constructivism," which involves the copenetration of information and materiality, inscription, and incorporation. The engineering approach to construction, I argue, was similarly "constrained."

15 Kline notes that Manfred Clynes, who coined the word *cyborg*, "did not think that joining humans to machines in this manner would change the nature of being human" (340).

16 Kline distinguishes between human-machine analogies and human-machine fusion in the

history of cybernetics; the hearing glove, contrary to his analysis, at once "fused" human and machine and was constructed based upon a series of analogies to the human ear and vocal organs (331).

17 The transfer of patterns between media was understood to be a feature of communication in the century before Wiener. Nineteenth-century physicists, for instance, described waves as traveling patterns that moved across physical media. Analogical theories of human sense perception, moreover, were often premised upon touching rather than the separation of senses and world.

18 Helen Keller to Dr. Buckley, 17 June 1949, Helen Keller Papers, AFB , New York.

19 Helen Keller to Norbert Wiener, 12 Feb. 1950, Series 1, Box 89, folder 2, Keller Archive, AFB. For Wiener's later work on the "Boston Arm," a limb prosthesis that "ultimately found [its] way to a very different end-user: the industrial robot," see Serlin 49.

20 Kline depicts the popular response to the MIT glove in similarly condescending terms (338).

21 Andrew Pickering recently advised that there are "other origin stor[ies] of cybernetics" than military research (55).

22 On speech processing in the telephone system as an early leader in the field of DSP, see Milman 110–11.

23 Wiener argued that the "same sort of pruning not only comes up in speech; it also occurs with language in machines" (qtd. in Licklider, "Manner" 92).

24 Dudley correlated this highly compressed information to the phonemes of speech.

25 On the sound spectrograph, see Mills, "Deaf Jam"; on the vocoder, see "The Dead Room."

26 Wiener defined *feedback* as the "method of controlling a system by reinserting into it the results of its past performance" (*Human* 61).

27 According to Pickering, British cyberneticians in the 1960s moved away from this style of "control" and instead favored open-ended, two-way experiments with feedback.

28 Wiener specifically argued, "The whole of human social life in its normal manifestations centers about speech, and [. . .] if speech is not learned at the proper time, the whole social aspect of the individual will be aborted" (*Human* 85).

29 In addition to acoustics, harmonic analysis has been central to optics, astronomy, and other fields tied to periodic or wave phenomena. Wiener traced harmonic analysis from the musical theories of Pythagorus, through the tradition of musical notation based on time and frequency. See Wiener, "Historical Background."

30 Wiener defines control devices as those "which take our orders and pass them on to a machine in a language which the machine can understand" (*Tempter* 128).

31 In her rebuttal to the myth of the natural human, Haraway tends to universalize the figure of the cyborg.

32 Wiener's rationale: "Matters as important as this are of such great public interest that they transcend patent boundaries, and for this reason we are continuing to work on the improvement and use of this apparatus" ("Sound" 260). AT&T eventually granted him permission to work on the project.

33 Dudley's vocoder itself had been inspired by the practice of lipreading.

34 "Helen Keller Addresses Pioneers," *Western Electric News*, 12, AT&T Archives, Warren, New Jersey. Thomas Edison, who was hard of hearing, once asked Keller to describe the vibrations from a Victrola. When she asked him, in return, to invent a hearing aid, he retorted, "People say so little that is worth listening to" (Keller, *Midstream* 290).

35 Memorandum, E. B. Craft to F. B. Jewett, 16 Mar. 1926, 72–02–03–14, Frank B. Jewett Collection, AT&T Archives. Gault did not seem to be aware of Édouard-Léon Scott's earlier suggestion that the phonautograph membrane be used "to have the deaf-mute who knows how to read follow the performance of a dictation printed on a table behind the operator, at once on the lips of this last by sight and on the tympanum which vibrates by means of tactile feeling."

36 The history of feedback in the engineering context is usually attributed to the negative-feedback amplifier built by Harold Black, for the telephone company, in 1927.

37 This insight dates at least to Hermann von Helmholtz.

38 J. M. Pickett to Robert Gault, 7 Sept. 1967, Enclosure: "Speech Transmission Laboratory, Stockholm, Quarterly Progress Report January 1965," p. 15, Box 1, Folder 5, Gault Papers, Northwestern University.

39 Edward E. David built an early prototype of the vibrating apparatus.

40 Leon Levine, in conversation with the author, 8 Sept. 2009. Similarly, in 1971 Michael Noll credited Huxley with foreseeing human-machine tactile communication:

Perhaps [. . .] today's science and technology are only acting out a script written decades ago by members of the other culture. But perhaps the best visionaries in science fiction are really creative scientists and technologists who are simply far in advance of new developments in science and technology. Most certainly it would seem that the topics of computer-generated speech, real-time interactive stereoscopy, and man-machine tactile communication were all predicted forty years ago by Huxley in his "Feelies." (Noll 71–72)

41 For mention of Wiener's legacy for the dataglove, see Tan and Pentland.

42 Levine claims that Wiener in fact had very little involvement in the construction and testing of the hearing glove.

43 David Mudgett to Norbert Wiener, 1 Feb. 1950, Series 1, Box 7, Folder 111, Wiener Papers, MIT Archives.

44 Patrick G. McGowan to Norbert Wiener, Feb. 1950, Series 1, Box 7, Folder 111, Wiener Papers, MIT Archives.

45 Edison felt that his deafness afforded him a greater physical closeness to his wife, whether he was tapping out Morse code or straining to hear her speak.

46 Bell was inspired by the seventeenth-century glove of George Dalgarno.

47 Helen Keller to Norbert Wiener, 12 Feb. 1950, Series 1, Box 89, Folder 2, Keller Archive, AFB.

48 Elmer Sperry to Helen Keller, 21 Dec. 1929, Series 1, Box 84, Folder 6, Keller Archive, AFB. For more

on Sperry and cybernetics, see Mindell ch. 3.

49 Helen Keller to Norbert Wiener, 12 Feb. 1950, Series 1, Box 89, Folder 2, Keller Archive, AFB.

50 In 1960, psychologist Frank Geldard insisted that a unique "cutaneous language" ("vibratese," a form of Morse code) would be more successful than forced "hearing through the skin" (1584). For a fascinating discussion of Geldard and the ways haptic media now embody the long history of the mechanization of touch, see Parisi.

51 For this reason, Richard Powers chose the name "Helen" for the computer in his novel, *Galatea 2.2*.

52 Granville Stanley Hall, with the cooperation of otologist Clarence Blake (Bell's assistant in the development of the phonautograph), painstakingly examined Laura Bridgman at the Perkins Institute in 1879. According to his commentary, also published in *Mind*, Hall was fascinated by Bridgman's ability to interpret the intensity and frequency of musical vibrations. "If oscillations as such can be directly felt, then the most generic fact of the physical world enters consciousness immediately without passing any 'inconceivable chasm'" (156).

53 See Fuss 128, 137–38.

54 For instance, Brooks 71.

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