John Durham Peters

HELMHOLTZ, EDISON, AND SOUND HISTORY

To know what eyes see today and ears hear today one would have to explain what brought Helmholtz to Chicago to shake Edison's hand before all his other colleagues.—FRIEDRICH A. KITTLER, *Grammophon, Film, Typewriter*

The Messiah, said Walter Benjamin, comes in inconspicuous ways. Thomas Alva Edison's tinfoil phonograph, a rather unprepossessing instrument, divides history into two halves, a before and an after. Prior to 1877, all sounds died. Indeed, dissipation is the very essence of sound as we know it: if sounds did not die, no music or speech would be possible. Hegel even made the fading of the voice a philosophical principle, a distinguishing mark of human temporality and finitude.[1] The phonograph, however, redeemed sound waves from the curse of transience. It achieved, in Edison's words, "the captivity of all manner of soundwaves heretofore designated as 'fugitive.'"[2] To be sure, the storage and playback of sound was an old dream, comically expressed in Baron Münchausen's frozen trumpet that, when it thawed, emitted the tones that winter had trapped inside. A less cryogenic dream of acoustic storage is found, of course, in writing itself, which Plato's *Phaedrus* treats as a kind of phonegraphy, a recording of voices. The notion that writing captured human voices and *kleos*—acoustic renown—was widespread in ancient Greece, an oral culture in which silent reading had little "raison d'être."[3] Plato's anxieties about writing's catching and throwing of voices recur in late-nineteenth-century commentary about phonographic inscription: both are held to simulate live presence, distort face-to-face dialogue, compulsively repeat themselves, and relate promiscuously with audiences.[4] Both sound recording and alphabetic writing lifted old limits that held voices in check—distance, dissipation, and discretion. A captured voice forfeits its body, mortality, and authorial control. With the ability to record, amplify, and transmit sound by machines, the voice apparently lost its finitude.

Of all technological and sensory transformations of electronic media, those pertaining to sound are perhaps the most radical. From time immemorial drawings and paintings have portrayed moments in time, but sound recording requires duration, a fourth dimension that the painted surface can only imply. To store sound events requires a sort of inscription that traces time in its serial flow.[5] Like the eye, their much more studied colleague, the voice and ear have fairly recently in our species history become subject to transmission, recording, and amplification. The disembodiment of ear and voice is as important a story about our times as the hypertrophy of the eye.

This disembodiment, however, did not begin abruptly with new phonographic instruments in the late nineteenth century. When Marshall McLuhan called media the extensions of the human nervous system, he thought he was simply offering a smart metaphor.[6] He did not seem aware of a long tradition of physiological investigation that understands the human nervous system as precisely an extension of media. The phonograph was only one of many mechanisms fabricated in the 1850s through 1880s as artificial portals to the human (or sometimes animal) nervous system, many of them derived from the telegraph. The electrical telegraph was the seedbed for the invention of graphic recording instruments in the nineteenth century. It not only enabled the compression of time and space and gave elites a means to manage distant properties and populations, as James Carey demonstrates,[7] but also inspired new arts of neurophysiological mimicry. Its automatic writing on spooled paper, dissociation of eye, ear, voice, and hand, and fine measurement of temporal intervals inspired around mid-century a variety of devices for registering minute physiological changes, such

as Ludwig's kymograph (blood pressure), the myograph (muscle fatigue), and Marey's sphygmograph (pulse).[8] In addition, there are important efforts to record sound well before Edison in the 1850s through 1870s, such as Léon Scott de Martinville's phonautograph and Charles Cros's paléophone.[9] Recent research has traced the origins of twentieth-century media to diverse forms of nineteenth-century culture, but medical measurement devices designed to represent temporal processes are just as important a source for our entertainment machines today. Film, telephony, phonography, television, and human-computer interfaces are in diverse ways psychotechnical practices that derive from study—and simulation—of the human sense organs. Media are all fruits of the graphic method; they are "applied physiology," as Nietzsche defined aesthetics.

To understand the origins, subsequent trajectory, and larger cultural significance of the recorded voice and assisted hearing, we should look not only to Edison, who, as the inventor of duplex telegraphy, the phonograph, kinetoscope, and electric lightbulb (a technology crucial for the future of radio, with its vacuum tubes), not to mention his near misses in inventing the typewriter, microphone, and telephone, presides over the founding era of analog media, but also to the science of the sense organs that emerged a generation before Edison, and whose greatest representative was Hermann von Helmholtz (1821–1894). Perhaps the last great universal genius of science, Helmholtz—physicist, physiologist of the eye and ear, aesthetician, and epistemologist, among many other interests and accomplishments—played a key role in the externalization and instrumentalization of the senses, which forms a crucial but largely forgotten backdrop for modern media. Timothy Lenoir notes: "Helmholtz conceived of the nervous system as a telegraph—and not just for purposes of popular presentation. He viewed its appendages—sensory organs—as media apparatus" and adapted "a number of interrelated technical devices employed in telegraphy to the measurement of small intervals of time and the graphic recording of temporal events in sensory physiology."[10] McLuhan was right to link media and physiology, but he settled too quickly for poetic montage instead of historical research. To fathom the voice in the age of its technical reproducibility, one must appreciate the ways that it was already externalized before it was mechanized. Helmholtz is perhaps the best representative of externalization, as Edison is of mechanization.

The American inventor/entrepreneur and the German scientist share much, starting with a fascination for the telegraph, the seedbed of nineteenth-century media instruments. For Helmholtz the telegraph was a model of the nervous system and wellspring of instrumentation; for Edison, it was an early source of livelihood because he worked as an itinerant telegraphist in his youth. Edison proposed to his wife by signing Morse code into the palm of her hand, and his son and daughter were nicknamed Dash and Dot. Both Edison and Helmholtz occupied positions of institutional power: Helmholtz as director of the Institute of Physics at the University of Berlin from 1871 and of the Physikalisch-Technische Reichsanstalt in Charlottenburg from 1887 to his death in 1894; and Edison as director of his laboratories and factories. Both had learned the lesson of minute quantities, care for what Edison called "attention to many seemingly unimportant and minor details."[11] Both sorted through an immense variety of raw and cooked materials with near infinite patience, Edison supposedly having tested 6,200 different substances for the filament in his electric light. Both Helmholtz and Edison understood the isomorphism of the ear and eye. As Edison says of the origins of film: "In the year 1887, the idea occurred to me that it was possible to devise an instrument which should do for the eye what the phonograph does for the ear, and that by a combination of the two, all motion and sound could be recorded and reproduced simultaneously."[12] There are important differences as well: Edison was an empiric, Helmholtz an experimentalist; Edison cared about effects and applications, Helmholtz cared about theory. Edison recounts of the telegraph: "The best explanation I ever got was from an old Scotch line repairer who said that if you had a dog like a dachshund long enough to reach from Edinburgh to London, if you pulled his tail in Edinburgh he would bark in London. I could understand that. But it was hard to get at what it was that went through the dog or over the wire."[13] Helmholtz, in contrast, understood—and measured—exactly what went through the dog: one worked in an academic tradition of integrative science, the other in a vernacular tradition of mechanical invention. Still, Edison cared enough about theory to read and annotate the 1875 translation of Helmholtz's *On the Sensations of Tone*; he also built and tested Helmholtz resonators. Both are clearly two of the characteristic "geniuses," if this word can still be used, of the nineteenth century, and here I intend to use them as representatives of

different moments in the history of sound recording rather than to tell a tight tale of influence.

Helmholtz

Later-nineteenth-century science and engineering constantly explored the large differences made by minute quantities: catalysts in chemical reactions, vitamins, trace elements (such as thallium), by-products of coal tar, phonograph grooves, radio signals, radioactivity, and electricity above all. Helmholtz was no exception. His pioneering work on reaction times, on blind spots and afterimages, and the effects of equal tempering on the development and destiny of Western music, for instance, all revealed the profound importance of small differences that had hardly been noticed before. Take, for example, his early research on the transmission speed of impulses in the sciatic nerves of frogs. Helmholtz had learned from his teacher, the physiologist Johannes Müller, that "the difference in the sensations due to various senses, does not depend upon the actions which excite them, but upon the various nervous arrangements which receive them."[14] Müller pushed the Kantian problematic of the all-coloring powers of apperception in a new physiological direction. Helmholtz went further: "Kant's question about the fundamental conditions of possibility of all knowledge is reformulated by Helmholtz into a question of experimental physiology about the conditions of spatial perception."[15] In an 1850 letter to his father, he wrote: "The reason why the time-span of [nervous] propagation seems so terribly small is that we just cannot perceive any faster than our nervous system works; for that reason, the time-spans that it uses for its operations are imperceptibly small to us."[16] The Kantian limits of pure reason are here measured and quantified. Just as the blind spot is filled in so that the eye cannot perceive its own junction with the optic nerve, so the structural inevitability of failure in introspection and self-knowledge lies in the fact that we cannot observe the slight delay it takes for our nerves to send their signals. There is no bootstrapping out of the nervous circuit. The soul's access to itself and to its body, in other words, always occurs across a gap. With Müller the a priori became physiological; with Helmholtz the qualitative structure of the sense organs became quantitative. William James states the consequences of Helmholtz's measurements of nervous propagation with characteristic eloquence: "The phrase 'quick as thought' had from time immemorial signified all that was wonderful and elusive of determination in the line of speed; and the way in which Science laid her doomful hand upon this mystery reminded people of the day when Franklin first *eripuit coelo fulmen*, foreshadowing the reign of a newer and colder race of gods."[17]

For this newer and colder race of gods led by Helmholtz, *aesthetics* assumed its ancient Greek tie to sensation (*aisthêsis*). Painting was subsumed by optics, music by acoustics. Beauty, and its emotional and cognitive overflows, became subject to physics, physiology, and psychology. To be sure, Helmholtz always retained a certain gracious modesty in the face of great artistic achievements, as he did of the more complex regions of mental life: although his method clearly was reductionistic, he did not claim to explain more than he could, even if the logic of his work reached more radically in the colder directions James indicated.

Hemholtz's two great contributions to the physiology of the eye and ear were his three-volume *Handbuch der physiologischen Optik* (1856–1867) and *Von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (1863; fourth edition, 1877). The latter, on which I focus here, makes a number of fascinating contributions to musical theory; in spots Helmholtz sounds like Hegel in understanding dissonance as the condition of reconciliation; like Adorno on part-whole relationships in musical form; or even like Schönberg on the trend to dissolution of the tonal system. In the musical arguments of the book, Helmholtz states that the voice (and not the piano) is the preeminent musical instrument because it is all but infinitely fine in its tuning, having no fixed notes as do pianos, organs, and the open strings on a violin, all of which necessitate minor distortions in tempering. Modern ears, trained to hear the notes of the equally tempered piano, are largely corrupted because the piano and organ have taught us to accept notes as in tune that actually are as much as one fifth of a semitone off their true pitch. The voice is the tutor in natural tempering, the source of the minute quantities that make such gigantic qualitative differences. Helmholtz offers a kind of natural history of the voice, one that recognizes both its physical and its cultural basis.

The senses, most especially the ear and eye, were for Helmholtz apparatuses of measurement whose actions were not only qualitative but reducible to quantitative effects: "The organs of sense do indeed give us information about external effects produced on them, but convey those effects to our consciousness in a totally different form, so that the character of a sensuous perception depends not so much on the properties of the object perceived as on those of the organ by which we receive the information."[18] Seeing and hearing are structurally parallel: the hue, intensity, and saturation of colors are respectively like the pitch, volume, and tone quality (*Klangfarbe*) of sounds. An afterimage is to an image as harmony is to melody.[19] And yet the two organs are also different. The eye is synthetic; the ear, in contrast, has an astonishing analytic aptitude, a morphological gift. A single wave form can be heard by the ear as a stack of overlapping harmonics. "This analysis of compound into simple pendular vibrations is an astonishing property of the ear."[20] The eye, in contrast, never grasps elementary sensations, say, of color: all perception is admixture for the eye: "The eye has no sense of harmony in the same meaning as the ear. There is no music to the eye."[21] The eye and ear also have acutely different time sensitivities. The ear can distinguish, even if it cannot count, at least 132 beats per second, whereas the maximum for the eye, Helmholtz suggests, is 24 images per second, a number with an uncanny relevance for the eventual flicker rate of the movies.[22] The eye excels in grasping the all-at-onceness of space, but the ear perceives only a small portion of the sound ocean in which we swim because the ear canal, like a looking glass for the eye, narrows the field of sensation.[23]

Helmholtz's chief contribution in musical acoustics was to show that the infinitely diverse tone qualities of voices, musical instruments, and of all sounds derive from upper partials (*Obertone*). Pitch is a function of the frequency of sound waves, as volume is of amplitude, but tone quality owes to wave form, more specifically to the series of upper partials that a compound wave carries. The particular timbre of a musical instrument is not due to anything more mysterious than its upper partials. So, too, with much of human speech. Even vowels, the heart of speech and singing, are marked by a particular pitch for Helmholtz and a characteristic series of upper partials. (Helmholtz coined what is called "the fixed-pitch theory of vowels.") All sounds become, in principle, synthesizable. "It is quite indifferent whether they [sounds] are generated by the vibrating strings of a piano or violin, the vocal chords of the human larynx, the metal tongues of the harmonium, the reeds of the clarinet, oboe, and bassoon, the trembling lips of the trumpeter, or the air cut by a sharp edge in organ pipes and flutes."[24] Vowels can be aped by instruments and machines—by vowel bottles, pianos, and electrified tuning forks, and eventually, of course, by the phonograph and telephone.[25] Helmholtz levels all modalities and is indifferent to bodily origins: sound is sound is sound. What matters is the wave form and not the source (although, in practice, some sources are extremely hard to mimic, the voice above all). Ear and voice are in principle detached from a mortal body—immortal organs capable of diverse coupling with (and as) machines.

Central to Helmholtz's reductionistic method was the creative use of instruments both in experiment and as analogies. We have already seen the architectonic role of the telegraph: Lenoir states that "telegraphic devices were not only important as means for representation and experiment; telegraphy embodied a system of signification that was central to Helmholtz's views about mental representations and their relationship to the world."[26] But other devices encouraged his habit of conceiving the eye and ear as instruments, perhaps most notably his invention of the ophthalmoscope and resonators. The latter were specially shaped glass bottles tuned to pick precise pitches out of the air. They not only demonstrated the existence of upper partials but also trained the ear to recognize them. At first he covered one end of the bottle with a pigskin membrane that could register sonic vibrations visually by patterns in the sand placed upon it, quite in the manner of Chladni figures (self-inscribing sound pictures). Then, fitting the pointy end with wax and inserting it in the ear canal, "the observer's own tympanic membrane has been made to replace the former artificial membrane," the advantage of this design being that the resonator is brought into "direct connection with the auditory nerves themselves."[27] Once equipped with these resonators, the ear not only readily identifies upper partials in music, but the isle turns out to be full of noises: "The proper tone of the resonator may even be somehow heard cropping up in the whistling of the wind, the rattling of carriage wheels, the splashing of water."[28] Everything becomes, potentially, a voice! In Helmholtz's universe, all bodies are oscillating: the periodic oscillators produce sound, and the irregular ones produce noise. Even the eardrum, like all elastic bodies, is a resonator with its own pitch (around 2,640 to 3,168 vibrations per second), a range in which the human voice is particularly rich

in upper partials. This sonic revelation is the fruit of instruments every bit as unprepossessing as the phonograph (a glass resonator stuck in the ear canal with wax) and of a clever substitution (a nervous membrane for an artificial one). According to Helmholtz, these resonators formed the very conditions of possibility of his acoustical studies.[29]

Von den Tonempfindungen is an illustrated catalog of mid-nineteenth century instruments. An index of Helmholtz's centrality in the social network of his time is his ready access to the very best scientific and musical instruments, including pianos by Steinway and Bausch and a Guadanini violin, as well as to musicians. He even measured the fingering of the foremost violinist of his era, Joseph Joachim, and found intuitive adjustments to produce natural as opposed to equal tempering.[30] But instruments are not only toys but also things with which to think with and command. As James, the founder of the first German-style psychological laboratory in the United States, noted of psychophysics, "every new problem requires some new electrical or mechanical disposition of apparatus."[31] For Helmholtz, the resonator educates the ear; but the resonator was already modeled on the ear—indeed, it is quite literally a hearing aid. His metaphorizing of the ear as instrument invites the instrumentalization of the ear.

Helmholtz's resonance theory of hearing is a fine example of the nervous system as an analogic extension of media. Helmholtz understood hearing as sympathetic vibration of elastic appendages attached to nerve endings. As his resonator substitutes a pigskin for an eardrum, so Helmholtz takes the ear as a gigantic piano, with strings tied not to tuning pegs on a sounding board but to nerves. Hearing turns out to be a particularly delicate operation that involves the magic of small quantities: the ear must "transform a motion of great amplitude and little force, such as impinges on the eardrum, into a motion of small amplitude and great force . . . to be communicated to the fluid in the labyrinth."[32] (The eardrum's movements, as we now know, are as small as the diameter of a hydrogen molecule.) The ear hears by sympathetic vibration, just as the strings of a piano with the damping pedal lifted will resonate, selectively, to the sounds that strike them. "Now suppose that we were able to connect every string of a piano with a nervous fibre in such a manner that this fibre would be excited and experience a sensation every time the string vibrated."[33] For Helmholtz, this is no mere flight of fancy. There are 4,500 or so outer arches in the cochlea, which gives us nearly 600 for each of the seven or so octaves that are musically usable (the young human ear can discern up to eleven octaves). Each sound in the universe sympathetically vibrates with one or more of these, which are placed "orderly beside each other, like the keys of a piano."[34] (He notes that combinations of sympathetically vibrating strings may be necessary to account for the full differentiation of a musically trained ear.) All sound, speech, and music, then, plays on our inner piano, a contraption of vibrating strings and nervous tissue in conjunction. Helmholtz belonged to his age in the project of mating mechanism and organism. For the romantics of an earlier generation, a Herder or Pestalozzi, everyone had a clavichord in the ear, an instrument of inwardness on which our thoughts were played. For Helmholtz, every person has a piano in the ear as a measuring instrument for the motions produced by periodically oscillating bodies.[35]

Although not without its critics (including James),[36] Helmholtz's theory of hearing remained dominant until the mid-twentieth century with Georg von Bekesy's Nobel Prize–winning work. The theory nicely catches Helmholtz's overall ambitions: "Physiologically it should be observed that the present assumption [of a sympathetically vibrating inner piano of sorts] reduces sensations which differ qualitatively according to pitch and quality of tone, to a difference in the nerve fibres which are excited."[37] Voilà! In one lucid stroke we find quality converted into quantity, sounds into sensations, art into physiology. He joins a piano key, a tuning fork, and the inner ear's most sensitive bone. Thus Helmholtz philosophizes with a hammer.

One gets dizzy trying to keep track of what is the model and what is the copy in the engineering and science of the sense organs, and, as we will see in Edison, sometimes the aim is precisely to mix them: "Psychotechnics connects [*verschaltet*] psychology and media technology under the condition that every psychical apparatus is also a technical one and vice versa."[38] Two years before his successful telephone call to Watson in 1876, Alexander Graham Bell tried to build a harmonic telephone based on Helmholtz's model of the ear, "a sort of piano-sized musical box-comb with between 3000 and 5000 tines to replicate the hair-like organs of Corti within the human ear." Bell kept these experiments under wraps for fear of ridicule, "especially by those unacquainted with Helmholtz's experiments"[39] (which he apparently read in French translation). Bell does not just envision

the ear as a piano but builds a piano *as* an ear. Metaphors leap off of pages—and out of ears—into machines. Bell took to a monstrous extreme the logic in Helmholtz's analogies: the ear as an acoustic apparatus that could be reconstructed outside the body. Helmholtz, with the physiologists and psychophysicists of his day, rewrote the sound producing or receiving parts of human body as a collection of instruments: the voice is a musical instrument, a reed pipe or woodwind; the throat is organ pipe, the vocal chords are membranous tongues; the eardrum is a resonator. Helmholtz's practice shows that metaphors, like media themselves, are time machines and matter replicators, able to reconfigure bodies and transport them across space and time.

Helmholtz may have stimulated the dream of building apparatuses that deviate from bodily bounds, but he also focused on a new kind of finitude in our sense organs. Never before had the lacks of the ear been so clearly revealed: its limited range of audibility, its microscopic (rather than panoramic) focus on the universe of sound, and the extremely fine quanta beyond which its sensitivities could not pass. Helmholtz repeatedly shows the routine fallibility of ordinary sensation, and a consequence of his work underscores the imperfections of the sense organs, the thresholds of perception (what Fechner called "just noticeable differences"), afterimages, optical illusions, the production of combinatorial tones, etc. Just as revealing the small intervals of nervous transmission helped make mind measurable, so analogies of the sense organs as artificial instruments and of artificial instruments as sense organs revealed, as we shall see in Edison, not only finitude lost but finitude regained. The new models of boundless hearing reacted backward on the ear, showing it to be a flawed instrument.

Edison

Edison's work continued along the lines Helmholtz had drawn for the ear and voice except for the stunning breakthrough of the capture of time in phonography. He was a rather astute commentator on the cultural significance of the phonograph except for one crucial blind spot: its eventual destiny as the centerpiece of a popular music industry. The first symphony recorded, for instance, was in 1914 (Beethoven's Fifth), almost forty years after the phonograph.[40]

Edison's original aim was the recording of voices, not the playing of music; conservation, not repetition; stenography, not entertainment. The need behind the phonograph lay in, again, the telegraph: to make a repeater that would store words without the labor of the human hand or errors of human attention. What started as an aid to transmission ended as a technique of recording. The aim to transcend distance led to the transcendence of time. As one 1896 phonograph enthusiast announced a trifle too prematurely: "Death has lost some of its sting since we are able to forever retain the voices of the dead."[41] Recording, after all, is transmission in reverse, and the phonograph reveals this reversibility—not the least of its achievements. To transmit, one must record the data in some form. Perhaps the key facts in the philosophy of the phonograph are, first, the reversibility of transmission and recording and, second, the reversibility of mouth and ear. These may be the same thing.

The cultural consequences of Edison's innovations in sound recording were diverse. First, as with Helmholtz, the phonograph's voices inaugurate a new era of blurred bodies, an interhuman blending of bees, dogs, angels, and humans. On first hearing the phonograph Edison is said to have said: "I was never so taken aback in my life." The phonograph took him back in time and history, to the mimetically rich conditions of childhood, animals, and primitivism.[42] Recording the children's song "Mary Had a Little Lamb," he foreshadowed the indefinite repeatability of advertising jingles. The phonograph made time itself a ventriloquist. An 1878 piece on "the papa of the phonograph" reported this gem: "'A dog came along here the other day and barked in the mouthpiece,' said Edison, 'and the voice was admirably reproduced. We have hung up that sheet yonder, and now we can make him bark any time. That dog, perchance, may die and pass away to dog-heaven,' added he in a bloodcurdling voice and an impressive wave of the hand, 'but we've got them—all that is vocal survives.'"[43] Edison thus acts like a backward Cerberus, a man controlling the afterlife of a dog. The phonograph opens infra- and ultrahuman realms of sound: "Vibrations above the highest rate audible to the ear can be recorded on the phonograph and then reproduced by lowering the pitch [i.e., slowing the playback speed], until we actually hear the record of those inaudible pulsations."[44] Time axis manipulation allows eavesdropping on the speech and song of bees, dogs, and angels. No more do sonic dissipation and sensory thresholds delimit the range of possible experience. Like the microphone, which took its name from the microscope, the phonograph made "very faint sounds" accessible. As stated by Théodore DuMoncel, "Even a fly's scream, especially at the moment of death, is said by Mr. Hughes [inventor of the microphone] to be audible."[45]

Second, as with Helmholtz, the mimicry of the human vocal and hearing apparatus led to the confusion of originals and doubles. The rhetoric around early sound recording was often unclear about what kind of copy was made—an imitation, a Doppelgänger, or a copy. Edison thought the recording left no remainder once compared to the real: "The phonograph is the acid test of a voice, for it catches and reproduces the voice just as it is; in fact, it is nothing more nor less than a re-creation of the voice."[46] Intentional confusion of the voice and the machine reached a climax in the "tone tests" that were used to market Edison diamond disc phonographs and recordings in the United States from around 1915 to 1925. In over four thousand tests given to theatrical audiences that may have included two million, Edison's company teased listeners with the indiscernibility of the live and recorded voice.[47] As Edison explains, "the singer stands beside the phonograph and sings with a record he or she has previously made. Suddenly the singer stops, but the song goes on, and the audience cannot tell the difference except by noting that the singer's lips are closed."[48] The tests sought to permanently cross the two apparatuses. One 1915 ad from the beginning of the campaign humbly announced: "This New Edison was nature itself. It was the artist in all but form."[49] Despite the rhetoric, the "form" (mortal body) of the artist was not the only noticeable difference; some "live" singers admitted to coloring their voices to resemble the more metallic sounds of the phonograph (that is, as Helmholtz would remind us, to suppress certain upper partials). Obviously, human-machine mimesis is mutual. Like Helmholtz, Edison's tone tests sought to erase the difference between bodies and apparatus as sound sources. This doubling, of course, ultimately failed: mortality is too hard to match. "Speech, has become, as it were, immortal," said *Scientific American* in 1877 of Edison's contraption;[50] but ghosts dwell in the "as it were." Claims of interchangeability yield body doubles. Time travel is always matter replication, as all readers of science fiction or Stephen Hawking know, and the new bodies made are always slightly weird.

Third, sound media sought to argue that absence is as good as presence. "Live" human presence could be an impediment. A key episode is recounted in a letter Charles Batchelor wrote to the editor of the *English Mechanic* on 3 January 1878: "So accurately are the words repeated by the machine that a gentleman who was present at the exhibition would not believe that the sounds were made by it. He insisted that it was a ventriloqual performance, and would not be convinced that it was not until Mr. Edison retired into another room while the instrument was worked by someone else."[51] The proof of successful communication is obtained, curiously enough, by sending a human being into another room. As in the Turing test, the body is hidden so that the machine can fool you. Acoustic media are machines for transporting bodies from room to room—or banishing them.

In a late memoir, Edison's rival Alexander Graham Bell recalls his father's lectures in Edinburgh in the early 1860s on Universal Alphabetics, a system for representing vocal sounds by graphic marks. Before the phonograph and telephone, the aim was to reproduce sounds across gaps of time and distance. Young Alexander, acting as his father's assistant, would leave the lecture hall, and "volunteers were called to the platform, where they uttered the most weird and uncanny noises, while my father studied their mouths and attempted to express in symbols the actions of the vocal organs he had observed." On returning, Alexander would read his father's graphemes and produce the sound to the surprise and applause of the audience. A special triumph occurred when young Bell was able to produce a sound "correctly at the very first trial, without ever having heard the sound at all."[52] This is the primal scene of the supercession of presence by programming. The original is indifferent for a convincing performance. No interiority is needed for successful communication. We are in the realm of effects—of pragmatism, the philosophy fit for what Kittler calls the discourse network of 1900.[53] Bell thus found the Holy Grail of modern media: a code that can pass as an adequate substitute for the original. The ambition from Helmholtz to Edison, from Bell to Turing, has been to make communication channels immune to the troublesome fact of bodily presence.[54] It too has always failed—but only in the most inconspicuous ways.

The preferability of absence to presence pervades Edison's first essay on the phonograph. He brags that his assistants can transcribe "without the loss of a word, one or more columns of a newspaper

article unfamiliar to them, and which were spoken into the apparatus when they were not present."[55] He further asserts that the phonograph generates sound waves in all their "original characteristics at will, without the presence or consent of the original source, and after the lapse of any period of time" (530). Here again, the old limits of distance, death, discretion avail not: "The phonograph letters may be dictated at home, or in the office of a friend, the *presence* of a stenographer *not being required*" (532). He even suggests that a telephone plus phonograph would remove the potentials for misunderstandings in face-to-face discussions: "Men would find it more advantageous to actually separate a half-mile or so in order to discuss important business matters, than to discuss them verbally" (535). Since the sound quality of the early phonograph was often terrible, the question was how to evoke the original without direct access to it. This is the classic problem in telecommunications of sending signals that carry information the receiver does not already possess, a problem that Claude Shannon was to formalize in 1948 with his mathematical theory of communication. His aim, again, was to produce a copy able to eliminate the need to be there.

Finally, the instrumentalization of the voice and ear retroactively imposed a disability onto the human being. The perfection of humanoid instruments invited the handicapping of our bodily organs. What had once been normal ears and voices are now revealed in all their deficiency. Edison, as is well known, had a hearing loss, and even boasted "I am a phonograph," because his high-frequency deafness helped him filter the same sounds in which the phonograph was also lacking. In his actively cultivated personal mythology,[56] Edison's deafness was not a mark of shame but a proof of authenticity. The text for a 1913 ad states: "'I hear through my teeth,' said he [Edison], 'and through my skull. Ordinarily I merely place my head against the phonograph. But if there is some faint sound that I don't quite catch this way, I bite my teeth into the wood, and then I get it good and strong."[57] Here again is the oral primitivism of the phonograph: listening as mastication. If the ear doesn't work, use the mouth. Indeed, there is a perverse logic in Edison's chomping on the machine, because the phonograph (as opposed to the gramophone, which is ROM or read-only) also achieved the reversibility of mouth and ear, of recording and playback.

Human imperfection helped to sell the phonograph. Edward Johnson, an early Edison salesman, describes his adventures on the road wowing the natives with the uncanny little machine. Although he sings badly, he sings into the phonograph when he fails to get a volunteer from the audience: "The effect when they hear me singing is stupendous, but when they hear the Phonograph reproducing my song with all its *im*perfections they endanger the walls with clamor I then tell them they have negative proof that it will reproduce song—the whole thing proving the happiest possible exhibition of the work of the instrument."[58] New prosthetics make us gods, as Freud famously argued, but also into cripples by revealing what we previously missed.[59] What the phonograph offers, indeed, is negative proof.

William James, who knew Helmholtz's work backward and forward, gave perhaps the best insights on the disabilities that Helmholtz, Edison, and company impose on us. As a physiologically trained physician like Helmholtz, James saw in himself and his patients the dissolution of old forms of human sensation and embodiment amid late-nineteenth-century media instruments. But in these changes he saw an occasion not for despair but for reinvention. The great psychophysicist and mystic Fechner taught not the sad or stoic dissolution of our bodies into machines, thought James, but the possibility of "an altogether different plan of life": "Our animal organization comes from our inferiority. Our need of moving to and fro, of stretching our limbs and bending our bodies, shows only our defect. What are our legs but crutches, by means of which, with restless efforts, we go hunting after the things we have not inside of ourselves. But the earth is no such cripple; why should she who already possesses within herself the things we so painfully pursue, have limbs analogous to ours? Shall she mimic a small part of herself?"[60]

Disability (in this case, motoric disability) thus becomes part of the general human condition. James is far superior to the cultural pessimists who worry that machines that expand or mimic our senses will make us inhuman,[61] because he knows, like Saint Augustine, that humans have never been anything but creatures stuck amid artificial bodies and organs. James's descriptions of psychopathology in his massive *Principles of Psychology* (1890) constitute a catalog of the varieties of embodied experience in a media age: aphasia (the ability to hear but not speak, like radio listeners); agraphia (the ability to write but not read, like blind typists); cutaneous anaesthesias (the ability to see and hear but not feel, like the

spectators in sound cinema or television). James states: "One of the most constant symptoms in persons suffering from hysteric disease in its extreme forms consists in alterations of the natural sensibility of various parts and organs of the body."[62] Then we are all, by James's definition, hysterics. Quite like what Deleuze and Guattari do with schizophrenia, the psychopathologies of his day provide James with descriptions of media-induced alterations of various organs and bodies.

Conclusion

McLuhan remarked that the content of a new medium was a previous one. The car, he said, was first known as a horseless carriage. Likewise, the telephone was a speaking telegraph, the radio a wireless telegraph. A new medium's most important effects work backward, not on the future. Thus Edison was taken aback. Media progressively reveal bodily imperfections. Humanity is what is left behind when all media have been stripped out of our bodies and souls. The uniquely human is established in a subtractive process: it is defined by what media machines cannot copy. The telephone made us all deaf to distant voices; the phonograph to past voices. Writing would make everyone forgetful, worried Socrates in the *Phaedrus*. The camera made our eyes forgetful to past sights. Artificial intelligence shifted the location of unique humanity to skin, handwriting, beauty, and birth: all the things that Turing took care to exclude from his game. Immortalizing media are mortalizing media. They not only make voices and other organs immortal, they also retroactively reveal the lacks of all our built-in instruments.

To understand the ways that media inscribe themselves on our bodies, we need a philosophy of history that recognizes the production of a "new already." New emergences reveal what was always there—but was never there *before*. Thus the fundamental principle of the phonograph for Edison was "the gathering up and retaining of sounds hitherto fugitive, and their reproduction at will."[63] The phonograph discovered a brand-new "hitherto." Before the phonograph, no sound had the option not to be fugitive. A historical rupture in the nature of sound arises that, in turn, rewrites its entire history. Charles Sanders Peirce, the single man of science in the nineteenth century who might rival Helmholtz as a polymath, contemplated an archaeology of vanished voices: "Give science only a hundred more centuries of increase in geometrical progression, and she may be expected to find that the sound waves of Aristotle's voice have somehow recorded themselves."[64] Like Charles Babbage, who claimed that "the air we breathe is the never-failing historian of the sentiments we have uttered,"[65] Peirce dreams the analog dream of ever-smaller tracings reverberating forever in an airborne archive. But not only does Peirce contemplate the retrieval of departed voices from the air, he imagines the past being transformed by the future in such a way that the passage of time makes infinitesimal tracings more—and not less—accessible. He understands that new media give us sense organs to perceive old things that were never, and always, there before. "Apparemment, c'est le phonographe qui fait prendre conscience à l'homme de sa voix" [Apparently, it was the phonograph that made people conscious of their voices].[66] Perriault is almost right: before sound recording, Helmholtz and his resonators and tuning forks made us aware of the voice, as echoes and laryngitis did from time immemorial.

The lesson of media history as philosophy of history is the retroactive redescription of the previous standard as limited. Finitude consists of media's leftovers, what they have not yet copied, or more precisely, what they reveal in their attempts at mimicry. In sum, the phonograph and its fellow devices of sound recording liberated the voice from its finitude, because voices can now live forever, travel far, and fall under the command of many besides their "owners." But acoustic media of recording, transmission, and amplification also revealed the grain of the voice, its lacks, breath and whispers—its mortality, in short—to a degree unprecedented in history. The phonograph, like many other media, is a memento mori, a source of the dour wisdom that the closer we approximate to the gods, the more our disabilities are made manifest.

As new media proliferate, all of which must adapt to hands, eyes, ears, mouths, mind, and bodily fatigue, we can expect an ongoing rediscovery of past amenities. Current cosmological theory speaks of a "chronology protection conjecture": the notion that the inventors of a time machine could never travel to an era historically prior to the invention of the machine, because time travel did not exist before the invention of the machine (and lest the travelers accidentally invalidate the very basis of their invention).[67] As far as I can tell, media history has no such protected chronology: new media, as vehicles that carry our senses and bodies across the space-time continuum, introduce us to old modes of experience that we never recognized we had before and therefore seem new. Media thus bear the messianic power, in Benjamin's special sense of that word, to forever alter the past.

Notes

I would like to thank Clark Farmer, Lisa Gitelman, Jim Lastra, Allison McCracken, Lauren Rabinovitz, Cornelius Reiber, Mark Sandberg, Ingo Titze, Katie Trumpener, and Steve Wurtzler for suggestions and sources. The Lilian Voudouris Music Library of Greece was a crucial resource. Much of my research was enabled by a Special Projects in the Arts and Humanities grant from the University of Iowa. An earlier version of this essay was published as "Helmholtz und Edison: Zur Endlichkeit der Stimme," trans. Antje Pfannkuchen, in *Swischen Rauschen und Offenbarung: Zur kulturellen und Medien-geschichte der Stimme*, ed. Friedrich A. Kittler, Thomas Macho, and Sigrid Weigel (Berlin: Akademie Verlag, 2002), 291–312.

1 Josef Simon, *Das Problem der Sprache bei Hegel* (Stuttgart: Kohlhammer, 1966).
2 Thomas A. Edison, "The Phonograph and Its Future," *North American Review* 126 (1878): 530.
3 Jesper Svenbro, *Phrasikleia: Anthropologie de la lecture en Grèce ancienne* (Paris: Éditions la Découverte, 1988), 183.
4 John Durham Peters, *Speaking into the Air: A History of the Idea of Communication* (Chicago: University of Chicago Press, 1999), 36–51, 160–64.
5 Friedrich A. Kittler, *Grammophon, Film, Typewriter* (Berlin: Brinkmann und Bose, 1986).
6 Marshall McLuhan, *Understanding Media: The Extensions of Man* (New York: McGraw-Hill, 1964).
7 James W. Carey, *Communication as Culture: Essays on Media and Society* (Boston: Unwin Hyman, 1989), chapter 8.
8 Thomas L. Hankins and Robert J. Silverman, *Instruments and the Imagination* (Princeton: Princeton University Press, 1995), 113–47.
9 Jacques Perriault, "Une autre genèse du phonographe," in *Mémoires de l'ombre et du son: Une archéologie de l'audio-visuel* (Paris: Flammerion, 1981), 121, 160.
10 Timothy Lenoir, "Helmholtz and the Materialities of Communication," *Osiris* 9 (1994): 185–86.

11 Edison, "The Phonograph and Its Future," 528.
12 *The Diary and Sundry Observations of Thomas Alva Edison*, ed. Dogobert D. Runes (New York: Greenwood Press, 1968), 84.
13 Ibid., 216.
14 Hermann von Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, translated from the fourth German edition by Alexander J. Ellis (1877; New York: Dover, 1954), 148.
15 Quoted in Timothy Lenoir, "Helmholtz, Müller, und die Erziehung der Sinne," in *Johannes Müller und die Philosophie*, ed. Michael Hagner and Bettina Wahrig-Schmidt (Berlin: Akademie-Verlag, 1998), 208.
16 Ibid., 217.
17 William James, *The Principles of Psychology* (1890; New York: Dover, 1950), 1: 85–86.
18 Hermann von Helmholtz, "Goethe's Scientific Researches," in *Science and Culture: Popular and Philosophical Essays by Hermann von Helmholtz*, ed. David Cahan (1853; Chicago: University of Chicago Press, 1995), 13.
19 Helmholtz, *On the Sensations of Tone*, 364.
20 Ibid., 128.
21 Ibid., 64–65; Hermann von Helmholtz, "On the Physiological Causes of Harmony in Music," in *Science and Culture*, 74.
22 Helmholtz, *On the Sensations of Tone*, 173.
23 Ibid., 26–29.
24 Helmholtz, "On the Physiological Causes of Harmony in Music," 40.
25 Helmholtz, *On the Sensations of Tone*, 123ff. Alexander Ellis, Helmholtz's English translator, includes an extended appendix in the 1885 edition on the relevance of the Edison phonograph for the study of vowel sounds (538–43).
26 Lenoir, "Helmholtz and the Materialities of Communication," 206–7. For a key passage using the telegraph as an analogy for Hemholtz's theory of the sense organs, see *On the Sensations of Tone*, 149.
27 Helmholtz, *On the Sensations of Tone*, 43–44.
28 Ibid., 44.
29 Ibid.
30 Ibid., 325.
31 James, *Principles of Psychology*, 1: 88.
32 Helmholtz, *On the Sensations of Tone*, 133.
33 Ibid., 129.
34 Helmholtz, "On the Physiological Causes of Harmony in Music," 60.
35 Wolfgang Scherer, "Die Stimme und das Clavichord: Medientechnische Bedingungen der musikalischen Empfindsamkeit im 18. Jahrhundert," in *Zwischen Rauschen und Offenbarung: Zur Kultur- und Mediengeschichte der Stimme*, ed. Friedrich Kittler, Thomas Macho, and Sigrid Weigel (Berlin: Akademie Verlag, 2002), 288.
36 James, *Principles of Psychology*, 2: 170.

37 Helmholtz, *On the Sensations of Tone*, 148.
38 Kittler, *Grammophon, Film, Typewriter*, 238.
39 Brian Winston, *Media Technology and Society: A History from the Telegraph to the Internet* (London: Routledge, 1998), 38.
40 Jacques Attali, *Bruits: Essai sur l'économie politique de la musique* (Paris: Presses universitaires de France, 1977), 201.
41 "Voices of the Dead," *Phonoscope* 1 (1896): 1.
42 Michael Taussig, *Mimesis and Alterity: A Particular History of the Senses* (New York: Routledge, 1992), 211–14.
43 William Croffut, "The Papa of the Phonograph: An Afternoon with Edison, the Inventor of the Talking Machines," in *The Papers of Thomas A. Edison*, ed. Robert A. Rosenberg (1878; Baltimore: Johns Hopkins University Press, 1998), 4: 218.
44 Edison, "The Perfected Phonograph," 642.
45 Théodore DuMoncel, *The Telephone, the Microphone, and the Phonograph* (New York: Harper and Brothers, 1879), 145–46.
46 *The Diary and Sundry Observations of Thomas Alva Edison*, 83.
47 Thompson, "Machines, Music, and the Quest for Fidelity," 153.
48 *The Diary and Sundry Observations of Thomas Alva Edison*, 83.
49 Steve Wurtzler, "The Social Construction of Technological Change: American Mass Media and the Advent of Electricity" (Ph.D. diss., University of Iowa, 2001), 35.
50 "A Wonderful Invention—Speech Capable of Indefinite Repetition from Automatic Records," *Scientific American* (17 November 1877): 304.
51 *The Papers of Thomas A. Edison*, 7.
52 Alexander Graham Bell, "Prehistoric Telephone Days," *National Geographic* 41, no. 3 (1922): 228–29.
53 Friedrich A. Kittler, *Aufschreibesysteme, 1800/1900*, rev. ed. (Munich: Wilhelm Fink, 1995).
54 Alan M. Turing, "Computing Machinery and Intelligence," *Mind* 59 (1950): 433–60. See also Peters, *Speaking into the Air*, 233–41.
55 Edison, "The Phonograph and its Future," 528–29.
56 Portia Dadley, "The Garden of Edison: Invention and the American Imagination," in *Cultural Babbage: Technology, Time and Invention*, ed. Francis Spufford and Jenny Uglow (London: Faber, 1996), 81–98.
57 Wurtzler, "The Social Construction of Technological Change," 37.
58 *The Papers of Thomas A. Edison*, 4: 44.
59 Sigmund Freud, *Civilization and Its Discontents*, trans. Joan Riviere (1930; New York: Norton, 1961).
60 William James, *A Pluralistic Universe* (New York: Longman, Green, and Co., 1909), 158–59.
61 For example, see Günter Stern (later known as Günter Anders), "Spuk und Radio," *Anbruch* 2 (1930): 65–66.
62 James, *Principles of Psychology*, 1: 202.

63 Edison, "The Phonograph and Its Future," 527.
64 Charles Sanders Peirce, *Collected Papers*, ed. Charles Hartshorne and Paul Weiss (Cambridge: Harvard University Press, 1931–1958), 5: 543.
65 Charles Babbage, *The Ninth Bridgewater Treatise*, 2nd ed. (1838), in *The Works of Charles Babbage*, ed. Martin Campbell-Kelly (London: William Pickering, 1989), 9: 36.
66 Perriault, *Mémoires de l'ombre et du son*, 192.
67 Michael White and John Gribben, *Stephen Hawking: A Life in Science*, 2nd ed. (London: Penguin, 1998), 296–98.

Lisa Gitelman

MEDIA, MATERIALITY, AND THE MEASURE OF THE DIGITAL; OR, THE CASE OF SHEET MUSIC AND THE PROBLEM OF PIANO ROLLS

> The notion of property starts, I suppose, from confirmed possession of a tangible object and consists in the right to exclude others from interference with the more or less free doing with it as one wills. But in copyright property has reached a more abstract expression. The right to exclude is not directed to an object in possession or owned, but is *in vacuo*, so to speak.
> —JUSTICE HOLMES, *White-Smith v. Apollo*

Media tend to be very slippery historical subjects, at least because media—so often portentously "the" media—of any generation tend to become naturalized; they start to seem inevitable and then transparent, or transparent and then inevitable. Much has been written, for example, regarding the identity of communication and transportation before the advent of the telegraph. The electric telegraph, we are told, decisively severed the age-old connection between point-to-point communication and point-to-point travel. Much has