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INDEPENDENT ARTICLE

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A MACHINE TO HEAR FOR THEM: ON THE VERY POSSIBILITY OF SOUND'S REPRODUCTION

Abstract

Although many writers have argued that the sound reproduction technologies invented in the late nineteenth and early twentieth century United States transformed cultural understandings of hearing, these technologies also embody prior changes in the meaning of hearing and function of the ear in nineteenth century culture. Taking as its point of departure an analysis of the ear phonautograph (a machine that traced sound vibrations on smoked glass using an excised human middle ear), this essay shows how the ear assumed a new importance in nineteenth century life, culminating in its becoming a kind of abstract model for sound reproduction technologies. Their physical form, as well as their most basic mechanical function (the vibration of a diaphragm to produce sound) resulted from the interplay among researches on sound, the training of the deaf, the new science of otology, and the institutions of science and medicine during the third quarter of the nineteenth-century. Based on this history, the essay argues for a new philosophy of sound that takes seriously the physiological, physical, and mechanical aspects of sound culture as dynamic – rather than static – elements within the history of sound.

Keywords

sound culture; ear; hearing; media technology; philosophy of communication; history of communication

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> If, at some later point, instead of doing a 'history of ideas,' one were to read the state of the cultural spirit off of the sundial of human technology, then the prehistory of the gramophone could take on an importance than might eclipse that of many a famous composer.
>
> Theodor Adorno (1990: 59)

> I would merely direct your attention to the apparatus itself, as it gave me the clue to the present form of the telephone.
>
> Alexander Graham Bell (in Snyder, 1974: 30)

Introduction

IN 1874 ALEXANDER GRAHAM BELL and Clarence Blake[1] constructed a most curious machine (figure 1). A direct ancestor of the telephone and phonograph, it consisted of an excised human ear attached by thumbscrews to a wooden chassis, which produced tracings of sound on a sheet of smoked glass when sound entered the mouthpiece. This machine, a version of the phonautograph invented by Leon Scott in 1857, was a mechanism for literally 'writing' sound – it was produced with the intent of making sound visible. Inasmuch as we can say that the ear phonautograph embodies the basic principles of other inventions that followed it, we could claim for it a minor technological significance. But here, I am interested in the ear phonautograph as a cultural artefact in the most literal sense.

How is it that a human ear came to be affixed to a machine at this time, in this way, and in this place? For Bell, the ear phonautograph was 'the clue' to the functioning of the telephone. For my purposes, it gives a clue to a more general characteristic of the machines and relationships that follow it in time: it places the human ear, *as a mechanism*, as the source and object of sound reproduction. The ear phonautograph marks a shift from models of sound reproduction based on imitations of the mouth to imitations of the ear. Through the figure of the ear phonautograph, through an archaeology of the machine and its construction, this essay follows a series of movements: the emergence of new relationships between sound and light and between hearing and seeing in nineteenth century science; the medicalization and objectification of the human ear as a knowledge problem; the delimitation of a set of functional principles based on the workings of the human ear; and finally an inversion, whereby the human ear becomes but one more instance of a more general, *tympanic* principle.

I use the word tympanic deliberately: its linguistic evolution reflects the same cultural movements I describe below. It begins as a description of a specific location in human and animal bodies: the tympanic bone and tympanic membrane

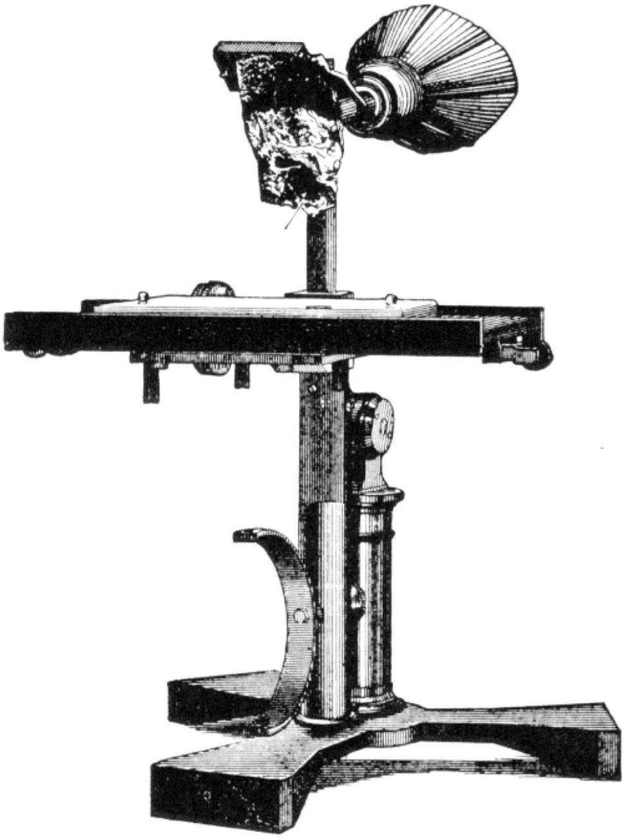

Figure 1 Bell and Blake's Ear Phonautograph. Source: Charles H. Dibner Library, National Museum of American History.

make up the ear drum – the tympanum. By 1851, this location becomes an operation. It is possible to speak of a 'tympanic apparatus' the purpose of which is to 'receive the sonorous vibrations from the air and to transmit them to the membranous wall of the labyrinth'. By the end of the century, tympanic also refers to the function of a telephone's diaphragm, or anything else resembling a drum (*Oxford English Dictionary*, s.v.: 'tympaic'; 'tympanum').[2] Following the etymology, the word moves from connoting a region, to a functional description of the region, to a pure function.

Thus, to speak of a set of sound reproduction technologies as tympanic is to understand them as all functionally related, as sharing a set of common operational and philosophical principles, and most importantly, as embodiments and intensifications of tendencies that were already existent elsewhere in the culture. What began as a theory of hearing became an operational principle of hearing machines. The very workings of the telephone, phonograph, and related technologies were thus an outgrowth of changes in practical understandings of hearing and scientific and medical approaches to the human ear in the mid nineteenth century. To examine the tympanic character of sound reproduction is to begin unearthing its social and cultural roots. It is also to reframe a set of philosophical problems surrounding historical and cultural accounts of sound reproduction.

From sources to mechanisms: what is sound reproduction?

It is fashionable among writers on sound communication, sound technologies, and music to note that sound culture has been under-examined in the current scholarly fervor to mark out and explore visual culture: we're told that hearing has been wrongly labelled as the poor country cousin of cosmopolitan vision in media studies (and now cultural studies as well). Listening is, we are told, the neglected sense, a novel sense for analysis: this claim appears with great regularity from relatively early writings on sound technologies right on down to the present day (see, for instance, Cantrill and Allport, 1935; Arnheim, 1936; Eisler and Adorno 1947; Ong, 1967, 1982; Truax, 1984; Altman, 1992; Douglas, 1999). One can hardly blame visuality scholars for their focus on the culture of light: it is, after all, their chosen object of study.[3] What is interesting is the strange consensus sound culture scholars have reached over the decades concerning the nature of hearing. Finding its most fully articulated form in Walter Ong's (1967) *Presence of the Word* but underscoring analyses backwards to Cantrill and Arnheim and forward to Susan Douglas' latest book on radio, explanations of sound culture begin with appeals to the physiological, psychological, and phenomenological characteristics of listening.

In contrast to these appeals to irreducible differences between hearing and seeing, most sound culture scholars – even those who never fully digested the poisoned fruit from the tree called 'social construction' – realize that the very notion of 'culture' implies the possibility of change over space and time. Like their visual culture counterparts, many sound culture scholars have addressed the mass media and modernity as major themes in their work. As a result, we now have some fine social, cultural, and industrial histories of the telephone, phonograph, and radio (e.g., Czitrom, 1982; Douglas, 1987, 1999; Marvin, 1988; Martin, 1991; Fischer, 1992; McChesney, 1994; Smulyan, 1994; Chanan, 1995; Hilmes, 1997; Kenney, forthcoming). Yet these histories either take the very existence of sound reproduction as their point of departure (the usual move in cultural histories), or they point to the possibility of sound reproduction as an historical rupture, where sound culture is irrevocably transformed (Kern, 1983; Attali, 1985). As a result, both approaches, while teaching us much about the history of sound and its reproduction, do not offer much more than a technical account of the fundamental possibility of sound reproduction.

These two tendencies in sound culture scholarship are related: more exactly, a theoretical and historical account of sound culture that takes as its philosophical basis the physiological differences between seeing and hearing will most likely offer a similarly inert theory of technology because it upholds an *a priori*, fixed notion of the boundary between nature (e.g., the characteristics of hearing, the physics of sound and the workings of machines) and culture (e.g., social and cultural practices of hearing). As Michael Taussig suggests in his introduction to *Mimesis and Alterity* (1993: xix), the shortcoming of social construction as a philosophical stance is the incredibly static view of nature that it presumes. This is not to suggest that we ignore biological or physical facts. On the contrary, it is to recommend that we attend to them even more seriously. Even the most technical history is simultaneously a social and cultural history: the tympanic mechanism, at the very functional core of sound reproduction technology, offers us insight into the social and cultural core of sound's reproducibility.

This simple thesis also requires a reconsideration of how we define sound reproduction. A number of writers have offered definitions of technologically reproduced sound based on its separation from a 'source.' Pierre Schaeffer, the composer who pioneered *musique concrète,* offered a phenomenological definition: 'acousmatic' sounds are sounds that one hears without seeing their source (Chanan, 1995: 12). John Corbett extends the line of thought by using an explicitly psychoanalytic framework to talk about reproduced sound in terms of visual lack: 'it is the lack of the visual, endemic to recorded sound, that initiates desire in relation to the popular music object' (1994: 37). Barry Truax and R. Murray Schafer, meanwhile, refer to the

> split between an original sound and its electroacoustic reproduction as 'schizophonia' – use of the Greek 'schizo,' meaning split or separation, emphasizes the difference in context which characterizes electroacoustic manipulation. Schafer points to the word as being 'nervous' and makes a comparison to the psychological aberration of schizophrenia.
>
> (Truax 1984: 120; see also Shaefer, 1969)

All of these definitions oppose the reproduction of sound in some sense to the faculty of vision, and take as its primary characteristic the separation of a sound from a source (thereby incidentally suggesting that the apparatus for reproduction is not itself part of that source). Additionally, both Corbett and Truax suggest that a certain form of sensory disorientation is fundamental to the experience of sound reproduction, and this suggestion is based on a set of assumptions concerning the relationship of presence and absence in communication.

John Durham Peters has elegantly and thoroughly critiqued the philosophical presumption of the primacy of face-to-face communication on which this curious theoretical edifice rests, and I will not rehearse his argument here (see

Peters, 1994 and 1999). This is because the more significant point is that for a theory and history of sound's reproducibility, we don't need final or fundamental answers to questions about the relationships between hearing and seeing, between technological reproduction and sensory orientation, between original and copy, and between presence and absence in communication: we can simply leave these questions open for the time being. While Pierre Schaeffer and others offer a functional though flawed definition of technologically reproduced sound, a decisive conceptual definition is not required to found a social theory of sound and its reproducibility. In fact, it may serve a confusing function inasmuch as the absence of a word for reproduced sound, such as 'acousmatic', may in fact be central to the social organization of reproduced sound, and not simply an analytical oversight on the part of the entire culture.

Instead, it is enough for the moment to note a functional and structural 'family resemblance' (borrowed loosely from Wittgenstein, 1958: 32) among the modern sound reproduction technologies. This move shifts critical attention from a consideration of the relationship among sounds (such as original/copy) to the means by which a relationship among sounds is made possible – and brackets the logic of presence and absence. It shifts critical attention from contemplating the existence of reproduced sound to prior questions concerning the process of sound reproduction.

Sound reproduction need not be defined through a negative relation to the eye and vision (and its attendant economy of lack), but it does bear a unique and positive relationship to the ear and hearing. In a word, it is tympanic. As an organizing principle, the ear comes to map not only the process of reception (we hear technologically reproduced sound), but functions more curiously as a map of the process of sound reproduction itself. These constructs of the ear and hearing are not simply or necessarily the audition that Walter Ong describes in his account of the psychodynamics of orality (1982, 30–72). Tympanic technologies depend on an abstraction of and from the middle ear as a mechanism for registering the existence of sound.

This focus on the tympanic is central to understanding what is specific to the technologies we commonly refer to as reproducing sound. People have always manipulated sound; speech and music are already techniques for the production and reproduction of sound. The novelty of sound reproduction technologies is also not to be found in the advent of sound's technological manipulation: musical instruments existed before recorded history; acoustic amplification and hearing devices such as the ear trumpet are recorded as far back as ancient Greece (Bennion, 1994: 3–9).[4] The technologies that have been shaped into sound media are distinguished by the character of their reproductive quality. They are not simply understood to imitate sound but were themselves understood by their inventors and early users as an imitation of the process of hearing. Not only were the modern sound media *for* the ear, they were *of* the ear. Their history is tied to the history of the tympanic function itself, and the articulation of the tympanic function to a whole set of practices of hearing and reproducing sound (and here I am using articulation in the sense suggested by Hall, 1986 and Grossberg, 1992: the form of a cultural connection).

Like the words to describe them, tympanic sound reproduction technologies – at the most basic, structural level – are best understood as the *result* of a proliferation of a particular set of practices and practical understandings concerning sound and the ear, and not the *cause*. This is not to say that new sound technologies had no impact on the nature of sound or hearing; rather, it is to say that they were embedded in social and cultural currents that they themselves did not create. The cultural history of sound's reproduction begins long before the invention of sound reproduction technologies (whether the act of invention is construed narrowly as the work of individuals or broadly as the work of entire cultures). While this may appear to be an obvious claim, histories of sound have not yet fully accounted for it. My project here is to demonstrate that the growth of the tympanic machines represents – and is an effect of – a reorganization of these cultural constructs of the ear and hearing, rather than a singular point of origin for new constructs. This can be demonstrated historically: as the ear phonautograph shows, we can see this set of beliefs and practices literally inscribed in some of the technological predecessors of today's sound media. Thus, I turn now to a consideration of the function Bell and Blake sought to render in its purest form through the ear phonautograph.

Sound appears

Leon Scott's phonautograph (figure 2), upon which the ear phonautograph was based, produces a visual representation of sound – called a phonautogram – by partially imitating the processes of the human ear. Like the ear, this machine channels sounds through a conic funnel to vibrate a small, thin membrane. This membrane, called a diaphragm, is attached to a stylus (a needle or other instrument for writing). The diaphragm vibrates the stylus, which then makes tracings on a cylinder. Different sounds provide different vibrations, resulting in different patterns. Scott experimented with both synthetic diaphragms and also animal membranes, though it was widely assumed that his own machine was modelled on the action of the membrane and small bones of the human ear (Berliner, 1888: 4). This imitation of the ear was not lost on other inventors. Bell and Blake's 1874 phonautograph takes this metaphor literally: they used a human ear instead of a synthetic diaphragm in their quest to get ever closer to the processes of the human ear itself. Hence the name of their peculiar machine – ear phonautograph.

In a single moment, shortly before the advent of the modern sound media, researches on sound, the training of the deaf, the new science of otology, and the institutions of nineteenth century science and medicine all collided. The ear phonautograph is the shape of their entanglement after the collision. The machine

Figure 2 Leon Scott's Phonautograph. Source: Division of Mechanisms, National Museum of American History.

itself, and its own history, are thus tied to several related yet distinct fields of inquiry and practice.

Bell's interest in the ear phonautograph came from two directions at once. Bell had been following various Europeans' experiments with sound and sound reproduction – especially the work of Helmholtz. Leon Scott's work on the phonautograph was a significant part of this field. The ear phonautograph, among other things, would teach Bell that a combination of complex sound vibrations could be transmitted through a single point and represented visually. The ear phonautograph accomplished this with a very thin membrane acting on heavy bones, thus inspiring Bell to simplify his model of the telephone, allowing a simple membrane to vibrate a relatively heavy piece of iron. This is the significance usually accorded the ear phonautograph when it is even mentioned in histories of the telephone (Bruce, 1973: 121; Bell, 1878: 22; Gorman, n.d.).

Perhaps more importantly, the phonautograph presented a possible new solution to a pedagogical problem for Bell: teaching the deaf and mute to speak. Alexander Graham Bell had been a major advocate in the Americas for visible speech, a method of elocution designed by his father Melville Bell. Visible speech was an attempt at a purely phonetic alphabet: 'invariable marks for every appreciable variety of vocal and articulate sound . . . with a natural analogy and consistency that would explain to the eye their organic relations' (Melville Bell, quoted in Bruce, 1973: 19). Following his father's lead, Alexander Graham Bell had demonstrated the use of visible speech to train the deaf and mute to speak. Bell had met with some limited success with this method, but visible speech did nothing to teach the deaf to modulate their voices like hearing people. Since this was Bell's ultimate goal, he began to seek alternatives. The phonautograph presented itself as one such alternative because it rendered speech visible, not through a representation of positions of the mouth, but through a representation of the waveforms produced by speech (Bell, 1878: 20).

> My original skepticism concerning possible speech reading had one good result; it led me to devise an apparatus that might help children . . . a machine to hear for them, a machine that would render visible to the eyes of the deaf the vibrations of the air that affect our ears as sound.
>
> (A.G. Bell, in Snyder, 1974: 30)

The device would allow deaf people to *see* the sounds they were making with their voices, and could thereby modulate the sounds they made until they matched the tracings of vowels or consonants spoken by a hearing person. Bell's descriptive locution suggests an even more significant role for the machine – as a *supplement* to the human auditory faculty. 'A machine to hear for them' suggests not amplifying hearing, as through an ear-trumpet or similar device, but rather *delegating* hearing. In other words, Bell's planned practical application of the phonautograph, though it would never come to fruition, implies a programme for the use the phonautograph's mechanical descendents by people who were not deaf.

For his pedagogical purposes, Bell also experimented with the 'Manometric Flame', a machine consisting of a membrane diaphragm stretched over a hole in a gas pipe, surrounded by four mirrors. Sound would vibrate the diaphragm, which would in turn vary the gas pressure, which would alter the shape and height of the flame, an effect emphasized by the mirrors. The phonautograph and the Manometric Flame, as well as Bell's whole conceptual schema for his pedagogical approach, all rely on a basic abstract principle: treating sound as an effect or an event that can be represented through visible phenomena. The advantage of the phonautograph, and the reason that Bell pursued it further, was simply that it presented a durable visual record of the sound (Snyder, 1974: 11).

Although this pedagogical method was never fully developed, the possibility of visible sound appears repeatedly in accounts of the telephone, phonograph, and radio (and later, film sound).[5] It is something of an obsession, starting with the phonautograph itself. Leon Scott called the phonautograph an 'apparatus for the self-registering vibrations of sound' (quoted in Levin, 1990: 36). He sought to produce a 'natural stenography' which would smash the distinction between orality and literacy because sound could literally write itself – hearing and speaking would become equivalent to reading and writing.[6] Of course, Scott's plan was riddled with its own logical inconsistencies, since he was simply suggesting a different kind of writing rather than the abolition of writing itself.

Sound-writing would bear an indexical relation to speech, rather than the abstract and arbitrary relation to speech that typography was said to have.[7] In this way, Scott's plan was simply to have the phonautograph replace one form of phonetic writing with another. Despite Scott's misrecognition of his own innovation, the promise of sound writing remained seductive to nineteenth century thinkers. Bell's more modest – yet equally unsettling – programme for the phonautograph still led him to comment on its tracings in his 1877 speech to the Society of Telegraph Engineers, and the publication of that speech provides diagrams of different sounds as recorded by the phonautograph.

Bell's plans for the phonautograph have to be understood in the larger context of his opposition to deaf culture as such. In an odd way, Bell's approach to deafness parallels Scott's universalist aspirations for the phonautograph – the eradication of linguistic differences. While Bell married a deaf woman and considered himself a friend of the deaf and a committed teacher, deaf historians see him in a very different light. Bell developed an enduring interest in eugenics, which led him to advocate the full integration of deaf people into mainstream American culture – he was opposed to the 'formation of a deaf variety of the human race.' Concurrent with those beliefs was his stand against deaf people marrying one another and having children of their own. Bell understood deafness, fundamentally, as a human disability to be overcome, as opposed to a condition of life. Edwin Miner Gallaudet, on the other hand, was an advocate of deaf-specific institutions and culture, such as the teaching of sign language. To this day, the Bell-Gallaudet division exists in approaches to deaf culture and deaf pedagogy. As a result, Bell appears as a villain in deaf cultural histories at this point, since he is seen – correctly – as seeking to eradicate deaf culture altogether (Baynton 1993).[8]

When scrutinized alongside Scott's more grandiose hopes of a universal language, Bell's seemingly 'practical' goal of teaching the deaf to speak loses some of its apparent simplicity. Behind his practical task lay a very particular notion of language, speech, and what it means to be human. Ironically, the result is not the erasure of deafness and hearing loss but rather its fetishization: sound reproduction arose, in part, from an attempt to give the deaf speech; it arose, in part, from an attempt to 'solve' or at least contain the cultural problem of deafness.

While for Bell the production of 'phonautograms' was tied to an immediate goal of training people to speak, others were less sure of what to do with them. When Emile Berliner provided an illustration of sound-writing in his address introducing the gramophone, he did so with only a more general gesture to 'scientific research'.[9] This uncertainty is transformed back into a suggestion of pedagogical possibilities and an appeal to aesthetics in an 1895 pamphlet accompanying gramophones for sale by a Philadelphia firm. The pamphlet declared that the 'voice may be analyzed by studying the beautiful record curves which they show in phonautograms printed from original record plates'. The visual representation of sound is a recurring theme in radio as well – ranging from Marconi's use of a Morse telegraph's register to record dots and dashes on a strip of paper to corporate and military efforts to visually record radio signals (Berliner, 1888: 17; Berliner Gramophone Company, n.d.; General Electric, n.d.).

Even 30 years after the gramophone company's ill fated sales pitch, Theodor Adorno would still be speculating on the potential of physically reading a gramophone record. Not only did Adorno believe that through the phonograph recorded music approached its true character as writing, but that eventually people could be trained to read acoustic grooves as a musician could read a score (see Adorno, 1990). This history continues down to the present, where iconic visual representations of sound play an important part in multitracking, sound mixing and other forms of sound manipulation. This suggests a certain kind of modern synaesthesia, one opposed to the absolute break between orality and literacy – and the concomitant privileging of vision that is said to occur – that appears to underwrite many cultural theories of modernity and modernization. Put simply, these now forgotten 'visual' technologies subject visual phenomena to the orderings of sound (Ong, 1982: 135–138). In this schema, the phonautograph is not simply the submission of the aural to the logic of the visual, or just as simply the opposite; it is the result of practices that assign visibility and objecthood to sound, and specifically to the perception of sound. It is itself such a practice.

In an entirely different context, Andrew Goodwin has made a similar point regarding music video and theories of visuality. He argues that the distinctive visual character of music video is not a new, postmodern form of image making, but simply the organization of images according to aural codes or conventions (1992: 50–56 and 60–68).[10] Goodwin's point is also relevant to a technology that emerged over a century before music video: Scott's discourse on the phonautograph suggests that this kind of synaesthesia – of mixing codes and perceptible material – is a constitutive feature of the technological reproduction of sound and image.

But the phonautograph was more than simply a matter of blending aural and visual logics. Philosophies of sound prior to the nineteenth century usually dealt with sound through a particular, idealized instance such as speech or music. Some philosophers took music – and specifically musical pitch – as an idealized theoretical instance of sound. Works of grammar and logic, on the other hand, distinguished between significant and insignificant sounds by calling all significant sounds 'vox' – voice (Burnett, 1991: 48–49; Gouk, 1991: 96). Scott, both in his writings and in the phonautograph itself, treats speech as simply one particular instance of sound, rather than its ideal type, and thereby effects an inversion of the general and the specific in the philosophy of sound: where sound was once an aspect of speech or music, now speech and music could be limited instances of sound. For its part, sound becomes a more general phenomenon through its simultaneous construction in technology, technique and knowledge. Scott and the phonautograph are likely not the first instance of this inversion; but it is a striking instance, and the logic present in the phonautograph is a hallmark of a modern configuration of aurality. Thus, tympanic sound reproduction technologies do not simply 'objectify' previously unobjectified sound; to the contrary, sound's objectification is a precondition of their existence. This objectification of sound is itself related to the objectification of hearing, since the latter is the faculty by which the former is perceived. If sound is to be understood more and more as an effect which can be measured or registered, then hearing must be one site at which effects are registered; it must itself be objectified.

Otology and social ontology

Phonautographs suggest a certain set of hearing and seeing practices related to sound; but the human ear affixed to the ear phonautograph's chassis offers insight into the institutional and social fields that fed the growth of tympanic sound reproduction technologies in general. In his early experiments with the phonautograph, Bell was struck by its structural similarity to the human ear, and sought to better imitate that ear function. When he conveyed this idea to his friend Clarence Blake, a Boston otologist,[11] Blake suggested using an actual human ear for the machine. Blake had studied hearing and perception, and taught Bell the workings of the human ear. Taking advantage of his connections with the Harvard medical school, Blake procured two ears, which were then each affixed to a machine – one for Bell and one for himself – and the ear phonautograph was born. Years later, Bell would reflect on those experiments as 'one of the most joyous scientific experiences of a lifetime' (Bruce, 1973: 112).

Blake's texts concerning the ear phonautograph explain its construction in painstaking detail. The conventions of nineteenth century technological discourse (as manifested in semi-popular journals such as *Scientific American* and *Electrical World* as well as the medical journals for which Blake wrote) provide for detailed explanations of the construction and function of any technical apparatus, such that readers could both gain a practical understanding of the device under consideration and have the necessary knowledge to build it themselves. In this respect, the ear phonautograph is remarkable in its typicality: Blake wrote as if there was nothing unusual about procuring a human ear and nailing it to some wood.

> In preparing the ear for use as a phonautograph, the roof of the cavity of the middle ear is first cut away; through this opening a narrow-bladed knife may be introduced to divide the tendon on the tensor tympani muscle and the articulation of the incus with the stapes. By means of a hair-saw a section of the middle ear is then made from before backward through the divided articulation. The section removes the inner wall of the middle ear cavity with the portion of the bone containing the internal ear and exposes the inner surface of the drum membrane, with the malleus and incus attached. {. . .}

> In using a preparation of the ear as a phonautograph, a stylus made of a single fibre of wheat-straw is glued to the descending part of the small bones, parallel to the long axis of the bond. With this, tracings may be made upon a plate of smoked glass, sliding upon a glass bed at a right angle to the line of excision of the drum membrane, and moved by clock work or a falling weight, as in the apparatus mentioned by Professor Bell.
>
> (1878: 5–7)

Certainly, modern medicine has depended on the acquisition of bodies for medical examination, experimentation and pedagogy. But the strangeness of carrying around a machine consisting in part of a human ear was not lost on its inventors. As was Bell's practice, he spent the summer of 1874 with his parents in Brantford, Scotland. Bell brought his machine with him, and word quickly got around the town that he had a machine with a dog's ear or a pig's ear affixed to it. One biographer speculates that Bell himself propagated these rumours in order to prevent gossip about a human ear (Snyder, 1974: 13).

Blake's more casual attitude toward the ears in the phonautograph likely came from his professional milieu; in this way, Blake's work marks another set of changes in nineteenth century understandings of hearing. When Blake set off to Vienna for graduate study in otology in 1865, there were perhaps four people in the United States that had more than a passing acquaintance with diseases of the ear. While there were works on ear medicine available in English in the US, there was no specialized training available in otology in the US, even after the rush to medical specialization following the civil war. The state of ear medicine was generally regarded as inferior to almost every other form of medicine. The author of an British manual on aural surgery (*c.* 1843) felt compelled to defend his choice of object:

> We daily hear and read, and it has been reiterated from mouth to mouth, and copied from work to work, that the treatment of such affections {of the ear} is an opprobrium to the healing art. . . . Now notwithstanding the injudicious treatment by quacks and nostrummongers, the neglect of patients, and – as in many instances we know it is – the total abandonment of all treatment by the general practitioner, still, were the statistics of all diseases carefully collected, it would be found that there were among them as many curable cases of affection of the ear as there are among the severer maladies of the eye, or among diseases of the chest, the brain, the liver, or any other organ. Up to a very recent period, from well-educated men in this country either considering it beneath their station or acquirements to treat so insignificant an organ specially, or not finding in the direct cultivation of aural surgery a sufficient renumeration for their time and talents, this branch of the healing art remained in the state in which ophthalmic surgery was half a century ago.
>
> (Wilde, 1853: 60–61)

As in philosophy, so it was in surgery: the eye enjoyed greater status and prestige than the ear.[12] Blake himself reports a similar conversation with the visiting surgeon where he worked shortly before his departure for Vienna (Snyder, 1973: 4). Otologists understood their field's lag behind other field in terms of the difficulty of the most basic empirical research:

> The organ of hearing, the ear, is probably the most complicated organ of the {five something} sense. It is not placed on the face like those of sight and smell and taste. Its most delicate and important parts lie deeply hidden behind the hardest bone of the body at the base of the skull.
>
> (handwritten notes in Bacon, 1898)

It is widely agreed upon that advances in knowledge of the ear in general and otology in specific were related directly to advances in methods of dissection. Georg Békésy and Walter Rosenblinth's seminal history of auditory research categorized the history of hearing research into five periods based on techniques of empirical observation: a first period of pure speculation based on the absence of observation; a second period in which observation of the ear was based upon the shattering of the temporal bone; a third period in which a forceps and a file were used in anatomical investigations; a fourth period in which auditory physiology was linked most directly with microscopic observation, and a fifth period (contemporary at the time of the article's appearance) based on the use of a dental burr, experiments with living animals, and recording of electrical effects (1948: 727–728). While this characterization of historical change is still quite technologically deterministic, it does underscore the importance of dissection in both medical knowledge of the ear and histories of that knowledge: the understanding of the ear was closely tied to the instruments allowing access to ears.

Like other doctors, Blake understood the growth of medicine less in institutional terms and more in scientific terms: like his contemporaries and those who followed, he had a strong investment in dissection. He translated an atlas of the osseous anatomy of the human ear into English in 1874. The manual is significant both in its application of photography to the study of hearing and for its aestheticization of dissection. It is an early example of the application of photography – which had been gaining importance in medical and anatomical pedagogy more generally – to the ear for pedagogical purposes. Once again, audition and visibility are interconnected. The operational understanding of the phonautograph is itself dependent on an operational understanding of the human ear. The phonautograph's task of rendering sound visible was a logical result of medicine's quest to render the process of acoustic perception itself visible. Dissection was central to this process, since the ear otherwise remained hidden from medical vision and medical knowledge.

Blake's notes suggest appreciation of dissection both as a skill central to the procurement of knowledge and even as a somewhat aestheticized practice:

> the specimen represented in this Plate was prepared in the same manner as that of Plate V, and a portion of the walls of the semicircular canals of the vestibule and cochlea were then removed by careful use of the file; *a work requiring considerable caution*, as the labyrinth walls, in all parts fragile, are especially liable to break when even a small portion has been removed. The specimens represented in Plates V, VI, and VII, *bear especial evidence to the patience and mechanical skill of the author*. The bony ridges on the under surface of the osseous spiral lamina are particularly well shown in this Plate, forming as it were a series of braces for the support of the spiral lamina.
> (Blake in Rüdinger, 1878: 18; emphasis added)

Blake's text simultaneously aestheticizes the extracted ear and the act of cutting it out of a corpse's head. The text's fascination with technique rests alongside its fascination with the ear as a technology, as a mechanism. In this way, the use of a human ear in the phonautograph is symptomatic of a more standard professional disposition. In Vienna, Blake studied with Adam Politzer, who would later become the first professor of otology at the University of Vienna. Blake worked as his assistant in the clinic as well as the laboratory. Politzer was also the first to use the human ear in obtaining tracings of the membrana tympani's vibrations; when Blake proposed the use of an actual human ear in the phonautograph, he knew it could be done (Snyder, 1974: 5, 12; Helmholtz, 1873; Bruhl and Politzer, 1903).[13] The use of human ears in experiments was thus intimately tied to the development of a mechanical understanding of the ear – an ear that had to be physically extracted and abstracted from a human body. The ear could become part of the phonautograph in part because it was already being treated as a mechanism to be understood through mechanical means.[14]

Along with Politzer, Blake's other major intellectual influence was Hermann Helmholtz. While Politzer's object of study was the vibrations of the ear in living subjects, Helmholtz was interested in the physical vibration of the membrane and the ossicles in the human ear. Blake's synthesis of their thought thus rendered the ear as a functional mechanism within the body, but one that could be extracted and examined independently of the rest of that body.

Although this discussion of mechanical theories of hearing offers some insight into notions of hearing within the medical field at the time, medicine was also a social practice, and not simply a field of ideas. The facts of medicine's institutional history recasts dissection not as a technical issue, but as an eminently political issue. As Paul Starr has argued, the creation of professional organizations, the growth in size and prestige of medical schools and hospitals – as well as medical practitioners' increasing prestige – and the unification of the industry through the reorganization of the AMA and the standardization of licensing all played a part in the institutional growth of medicine – and specializations like otology with it (1982: 93–144). Blake's European education would allow him to return to Boston and take part in this larger process. He eventually became

Harvard's first professor of otology and would play a part in the promotion and advancement of the field as a whole. When he returned to the US in 1869, he also worked at the Massachusetts Eye and Ear Infirmary. While the establishment's name suggests work on otology, it was really a clinic of ophthalmology that had only reluctantly branched out into otology, largely because patients with afflictions of the ear were in the habit of going to ophthalmology clinics to seek help. Over the next few years, Blake turned the Infirmary's Aural Clinic into a centre for research as well as treatment (Snyder, 1974: 4–5). Understandings of the ear were thus closely tied to the institutions (as well as the technologies) that allowed access to the human ear. In addition to the development of facilities and funding for education and research in otology, corpses were required for education and research. Dissection played an important part in medical education, even as the growth of the profession allowed for more rationalized access to corpses. Although I have been unable to discover where exactly Blake acquired the ears for his two ear phonautographs, the possible sources of the ears are worth considering for a moment.

Dissection and anatomy have been central parts of medical education since the late eighteenth century. As in England (where medicine was more developed throughout most of the nineteenth century), early American medicine required many more bodies than it could get through legal means. Executed criminals were a common legal source of bodies for dissection, but through the better part of the nineteenth century, grave robbing was the most common means of acquiring bodies for medical students and researchers. In some cases, the students themselves were the grave robbers. Needless to say, this did little to enhance medicine's public reputation. Historians Ruth Richardson (1987) and Susan Shultz (1993) have both documented numerous instances of crowds descending on medical schools in response to discovering an empty grave.

Over the course of the nineteenth century, anatomy acts were becoming the solution for medical schools in need of bodies. By providing a plentiful and legal source of corpses for dissection, they were designed to curb grave robbing, enhance the public image of medicine, and in almost every case, assure middle class and upper class citizens that they would no longer have to worry about being disinterred. Most American anatomy acts were modelled on the British Anatomy Act of 1832, which offered to medicine any corpse that would otherwise have to be buried by the British state: people dying in workhouses or who would otherwise receive a parish funeral. In the US, since workhouses were not as widely institutionalized, this simply meant that unclaimed corpses or the bodies of people whose families could not otherwise afford a funeral were now offered up to medical science. Ruth Richardson understands the act as a form of class warfare on the poor:

> The Anatomy Act was in reality an advance clause of the New Poor Law. Its easy passage was an important political moment, permitting the

> recognition that – using the right strategies – legislation which openly turned its back on the old paternalism, and antagonized the poor as a class, could be passed with little opposition. It paved the way for the systematic dismantling of older and more humanitarian methods of perceiving and dealing with poverty.
>
> (Richardson, 1987: 266)

Although the American anatomy acts were enacted state by state over the course of almost 75 years, and although class warfare was fought somewhat differently in the United States, there is still one key similarity between the British and American acts: both made the bodies of the poor the raw material for medical knowledge (on the passage of the Anatomy Acts in the US, see Shultz, 1993: 78–94; Edwards, 1955: 18–20). Prior to the acts, people from all classes could fear grave robbers for several days after a burial: it was a textbook case of Ulrich Beck's (1994) argument that risk does not necessarily correspond with social class. The Anatomical Acts compensated for this, by connecting medicine with the state based enterprise of burying the poor. These acts shifted the burden of medical knowledge entirely onto the poor. Although no Anatomical Act could guarantee a sufficient supply of bodies (and therefore the Acts did not entirely stamp out grave robbing), they did provide a steady supply of bodies (Richardson, 1987: 207–210; Shultz, 1993: 90–94).

Since Blake acquired his bodies for study from the Harvard medical school, he was likely a beneficiary of Massachusetts Anatomical Act, which in 1831 was the first such act in the United States. Thus, the construction of the ear phonautograph – as an event – is most likely made possible by a very particular set of class relationships. The expropriation of the bodies of the poor as a kind of fixed capital for the production of knowledge is illustrated nowhere better than in the history of an ear attached to a machine. The bodies of the working poor and the destitute – and their expropriation – are thus inscribed in the very tympanic mechanism behind sound reproduction.[15] Charles Snyder casts the donors of the ears in Bell and Blake's experiments as the 'true heroes' of the research. The part played by these people was almost certainly involuntary, and their lesson is less about heroism and scientific progress than about the social relations on which science and technology depended for their very existence.

Thus, in speaking of the objectification of hearing, we are really speaking of a set of related processes: the growth and institutionalization of a new field of medicine and its attendant knowledges, pedagogies, and procedures, institutions and professional networks; advances in medical and anatomical research that allowed for greater attention to the physical ear – specifically, its isolation as a process of perception and field of knowledge; and the social distribution of the bodies of the dead and class-based organization of death and illness, on which these institutions depended for their particular character.

The ear on the phonautograph did not simply emerge from an abyss of ignorance to become an object and an instrument of knowledge; it had to be put there. Not only did the presence of the ear on the phonautograph depend on practical understandings of the human ear as a mechanism, but it also depended upon the pedagogies and institutions of human dissection, which themselves relied on the class structure of nineteenth century American society.

Of diaphragms and diagrams

Having established the intellectual, cultural and social threads coming together in the ear phonautograph's creation, I want turn to its significance in the history of reproduced sound. If it marks a particular kind of objectification of the ear and hearing, the phonautograph (and especially the ear phonautograph) also embodies a break between understandings of sound reproduction. The earlier understanding treated sound as a fundamentally complex phenomenon to be reproduced by a source; the new understanding of sound treated it as an *effect* which could be reproduced simply by reproducing a process leading to that effect. On mental maps of the body, this represented a shift to privileging the ear in the reproduction of sound, rather than the mouth (the transformed status of the mouth and voice is a topic I explore elsewhere).

Early accounts of telephony and phonography are full of historical narratives that attempt to connect then-contemporary inventions with earlier attempts to preserve or imitate sound (even the simplest instruction books for early telephones and phonographs would often have a historical narrative attached as a preface). According to these tales, which demonstrate little formal variation (although credit is meted out differently depending on the author's favourite inventor), earlier inventors sought to freeze or contain sound itself, or to construct 'automata' – models of the human tongue, larynx, mouth and teeth to imitate speech that imitated the processes by which sound is produced. Later inventors, such as Bell, Edison and Marconi are credited with the innovation of switching from machines modelled on the production of sound through speech or music to machines based on the production of sound at the perceptual end – the middle ear's transformation of vibrations into perceptible sound.

Attempts to reproduce sound through automata have a fairly long history, but all automata were based on the principle that sound could be reproduced through constructing machines that would imitate the process of sound production, whether it be speech or music that was the goal. More importantly, automata were not purely sound machines – the term refers to a whole class of 'automatic' machines. In 1738, James de Vaucanson, a famous eighteenth century inventor, built a flute player that controlled a real flute with automatic lips and fingers, a tabor and tambourine player built on a similar principle, and an artificial duck that was capable of 'eating, drinking, macerating the Food, and voiding

Excrements, pluming her Wings, picking her Feathers, and performing several Operations in Imitation of a living Duck' (Ord-Hume, 1973: 18, 25). Henri Maillardet's Musical Lady, built in early in the nineteenth century, worked on a similar principle, using levers to control its piano playing fingers, reeds to draw air into its chest to simulate breathing; and a clock in its head to switch it on and off automatically (19).

Bell and other inventors had an acute interest in this history. The quote immediately below, from John Bulwer, *Philosophicus* (1648) appears in Bell's files. It was likely of interest because it hints toward the long duration of a history of reproduced sound, while at the same time marking the difference between earlier attempts and the work of Bell and his contemporaries:

> Frier *Bacons* brazen Head, and that Statue framed by *Albertus Magnus* which spake to *Thomas Quine*, and which he mistaking for a magic device brake, was certainly nothing else but Mathematical Inventions framed in *imitation* of the *motions of speech* performed by the Instruments in and about the Mouth. As for that leaden Pipe which *Baptista* Porta in his *magia naturali* speaks of as effectual to this purpose; or that of *Walchius* who things it possible intirely to preserve the voyce or any words spoken in a hollow Trunke or Pipe, and that this Pipe being rightly opened, the Words will come out of it in the same order wherein they were spoken, they have not as substantial a way for such a Discovery.
>
> (J. B. Gordon to A. G. Bell, 6 February 1886)

Although nineteenth century inventors sought to establish themselves as within a centuries old historical stream, for them the phonautograph was significant because it embodied a switch from the mouth to the ear in efforts to understand, control and reproduce sound. Even Bell lived this switch. His account of early experiments with an imitation of the mouth is instructive.

He tells a story of childhood experiments in which he and his brother set out to construct a speaking automaton:

> Stimulated by my father, my brother Melville and I attempted to construct an Automaton Speaking Machine of our own. We divided up the work between us, his special part consisting of the larynx and vocal chords to be operated by the wind chest of a parlor organ; while I undertook the mouth and tongue.
>
> (Bell, n.d.: 17)[16]

For his part, Bell attempted to copy 'Nature herself,' using a cast made from an actual human skull as his point of departure. Their goal was an 'exact copy of the vocal organs' (Bell, n.d.: 19). Although Bell describes the physical makeup of the machine at great length, his treatment of its function is most revealing:

> We could not wait for the completion of the tongue: we could not wait for the arrival of the organ bellows. My brother simply fastened his tin larynx to my gutta percha mouth, and blew through the windpipe provided.
>
> At once the character of the sound was changed. It no longer resembled a reed musical instrument, but a human voice. Vowel quality too could be detected, and it really seemed as though someone were singing the vowel 'ah'.
>
> I then closed and opened the rubber lips a number of times in succession while my brother blew through the windpipe. The machine at once responded by uttering the syllables 'Ma-ma-ma-ma' &c, quite clearly and distinctly. By using only two syllables and prolonging the second we obtained a quite startling reproduction of the word 'Mamma', pronounced in the British fashion with the accent on the second syllable.
>
> Well of course boys will be boys and we determined to try the effect on our neighbors.
>
> My fathers' house in Edinburgh was one of a number of houses and flats that opened upon a common stair. We took the apparatus and made it *yell!* My brother put the windpipe into his mouth and blew for all he was worth, while I manipulated the lips. Soon the stairway resounded with the most agonizing cries of 'Mamma – mamma – mamma'. It really sounded like a little child in great distress calling for his mother.
>
> Presently a door opened upstairs and we heard a lady exclaim, 'my goodness, what's the matter with that baby?!'.
>
> This was all that was necessary to complete our happiness: delighted with our success we stole quietly back into my father's house and gently shut the door, leaving the poor lady to make a fruitless search for the now silent child. I do not think the speaking machine progressed very far beyond this point; but it had undoubtedly been successful in realizing my father's great desire that through its means his boys would become thoroughly familiar with the actual instrument of speech, and the functions of the various vocal organs.
>
> (Bell, n.d.: 21–22, emphasis in original)

Bell's description of his own adventures provides a rich text: here the 'human voice' becomes a purely reproducible mechanical function – the copying of nature by science and more importantly technology and technique; scientific ingenuity mystifies a woman who searches for a crying baby, and most importantly, for our purposes, the reproduction of the human voice is accomplished through the mechanical reconstruction of the human mouth.

Other writers, such as Michael Taussig (1993: 212–225), have considered automata as culturally continuous with later mimetic sound technologies. Based on his reading of Horkheimer and Adorno, Taussig sees the controlled organization of mechanical mimesis itself as symptomatic of modernity. Reproduction is bureaucratized, organized and made the province of science and technology. Yet Taussig and others who observe this mimetic quality and move on will miss an important distinction. Taussig's account freely moves between the phonograph and automata; between machines that imitate sound and machines that imitate the production of sound. But his account leaves out an important historical difference.

The automaton and the diaphragm effect the imitation of sound through two totally different processes. Automata imitate sound by imitating the vocal organs and movements of the human body, and thereby produce speech or music through an imitation of the process of speech or music-making. Diaphragm-machines imitate the process of hearing in order to produce an effect of sound. These two different technologies of sound reproduction are symptomatic of two entirely different practical understandings of sound and its reproduction. The first privileges speech and the human voice; it takes particular instances of sound production and attempts to recreate them. The second treats hearing and sound as general problems and is oriented toward the human ear. Rather than producing specific types of sound, diaphragm-machines focus on the reproduction of sound as such. Once again, Leon Scott's inversion of the general and specific in theories of sound proves crucial. Speech and music become specific instances of sound, which is itself a reproducible effect. The new sound reproduction technologies were all based on the principle of the diaphragm, and they were hailed as revolutionary on this basis. As one corporate history from 1900 put it,

> Faber {who constructed an elaborate automaton} and his predecessors were on the wrong track in attempting to solve the problem of sound reproduction in this manner, on its physical side. Faber sought a cause; Edison saw an effect, and said, 'The Thing is there, it has but to be found'. Faber started from the *source* of the sound, and built a mechanism, reproducing the causes of the vibrations that made articulate speech. It remained for Edison to start from the vibrations; to obtain the mechanical *effects* of such vibrations; to record them on a pliable material and then to reproduce them.
>
> Faber copied the movements of the vocal organs, Edison studied a vibrating diaphragm, and reproduced the action of the ear drum when acted upon by the vibration caused by the vocal organs.
>
> (National Phonograph Company, 1900: 13–14)

Apart from misattributing a long line of experimentation wholly to Thomas Edison, this account is fairly representative of late nineteenth century understandings of what was new in the phonograph and the telephone; it is also more or less correct in understanding the nature of the technological innovations later embodied by the telephone and phonograph. Their common ancestor, the phonautograph, marks a shift in abstract understandings of the nature of mimetic sound among scientists and inventors. It represents a different understanding of the nature and the function of the ear. Even Bell himself understood this to be the essential lesson of the ear phonautograph (and why he credits this machine with giving him 'the clue to the present form of the telephone' in early speeches on telephony (Snyder, 1973: 30)).

Even the most apparently transparent historical accounts, such as these fairly plain corporate and autobiographical documents, can be read as both accounts of events and philosophies of history. Histories provide both narrative accounts of events and statements of relationships among those events. Thus it is not so much a matter of reading corporate or other histories for their baseline assumptions, facts and distortions, but rather simply treating such histories as themselves documents of the past, as parts of an historical formation. Thus, one needn't read these histories for a deeper structure or a hidden meaning: the organization of reality which they document appears on their very surfaces (White, 1978: 27–51; Foucault, 1981: 10; Deleuze, 1988: 15).

One of the clearest elaborations of the diaphragm thesis appears in the writings and speeches of Emile Berliner, who is credited for inventing the gramophone in 1888 (figure 3). The gramophone differed significantly in mechanics

Figure 3 Berliner's Gramophone. Source: Division of Mechanisms, National Museum of American History.

from earlier phonographs and graphophones: it looked and worked much more like a 20th century phonograph. Instead of a rotating cylinder on a vertical spindle, the recording surface was a flat disc that rotated on a horizontal plate. Berliner was careful to construct a distinct genealogy for his invention, based on this notion of the imitation of the ear, and specifically around machines that used vibrating diaphragms. This was both for scientific and economic reasons. From a scientific point of view, Berliner's account is a reasonable and somewhat representative interpretation of the history of sound reproduction apparatus from the mid 19th century on. But this account also served an entrepreneurial function for Berliner. By tracing his lineage back through Charles Cros and others, Berliner would be able to argue that he was not infringing on Edison or Bell's patents on sound recording apparatus. Essentially, this genealogy sought to prove that Berliner had in fact invented a completely new machine. While Berliner's account may have sought to distinguish and locate his work in the web of nineteenth century innovation, its central thread – the diaphragm and the imitation of human hearing processes – demonstrates something else entirely. The characteristics of the modern sound media that later authors would label revolutionary were themselves embedded in the flow of nineteenth century ideas and practices.

Berliner's genealogy begins with Charles Bourseil's 1854 proposal that two diaphragms vibrating in sympathy could reproduce speech over telegraphic distances. By 1859, a Frankfurt teacher named Philip Reis had constructed an apparatus based on Bourseil's suggestions. Now known as the Reis telephone, this machine did effectively transmit some variability of sound (such as the cadences and rhythms of speech) – as if to *mime* the reproduction of speech – but it did not effectively reproduce articulate (which is to say understandable) speech. Scott began his work on the phonautograph in France two years earlier, and his apparatus is generally credited with rendering sound visible; Berliner, along with the general current of opinion at the time, casts it as a direct predecessor of the phonograph. In fact, he draws a direct link between the phonautograph and Frenchman Charles Cros' ideas for storing and reproducing sound. Yet Berliner takes the imitation of the human ear quite literally in his account. Commenting on Bourseil's plan, Berliner critiques him and later Bell for *insufficiently* imitating the human ear:

> He evidently desired extreme flexibility {in the diaphragm}, and diaphragms constructed on that principle proved fatal to the efforts of many subsequent experimenters, even at first to Mr. Bell, who like Bourseil, borrowed the idea from the flexible *tympanum membrani* of the human ear, and who overlooked the important modifications which the vibrations undergo, before reaching the auditory nerve, by the series of muscular hinges in which the various bony accessories of the ear are mounted, and which act as elastic dampers against the *tympanum membrani*.
>
> (Berliner, 1888: 2, emphasis in original)[17]

The failures of earlier attempts to reproduce sound – attempts that were clearly modelled on the human process of audition – appear here as inaccurate reproductions by their own criteria. For Berliner, more ear was needed to reproduce sound.

Yet, despite his protests to the contrary, the diaphragm is the one common denominator of the technologies Berliner considers. Helmholtz and König's acoustical experiments, for instance, appear in Berliner's narrative as detours from the teleology toward sound reproduction.[18] Helmholtz understood speech sounds as complex combinations of individual tones, so that 'the perusal of their work left a serious doubt in many a student whether there was not something in articulate speech, and its audibility by the human ear, beyond the grasp of the *mechanical* mind of man' (4; see also Helmholtz, 1895).[19] Likewise, Faber's automaton (constructed in about 1860) appears as an interesting but unnecessary detour in this technological history.

The importance of the telephone, for Berliner, was not that it finally transmitted understandable speech over a distance, but that it was a relatively simple apparatus (in contradistinction to Faber's automaton) based on the vibration of a diaphragm. Charles Cros' phonograph, which applied some of the telephone's principles to the phonautograph to suggest a method for storing and reproducing sound, is the final stop in Berliner's narrative before he turns to his own invention (Berliner, 1888: 4).[20]

Even early advertisements understood the significance of diaphragms. A Columbia Phonograph Company pamphlet (1895) described the functioning of the graphophone in four essential parts:

1 The diaphragm, which vibrates in the same way as the human ear drum in response to the air waves made by any sound.
2 The needle, which is attached to the diaphragm, and engraves an impression as the result of the vibration on.
3 The cylinder.
4 The arrangement for making the cylinder revolve evenly.

Even in this most basic characterization, the diaphragm and its vibrations are the central functional element of the graphophone, with the other parts of the machine either regulating or channelling that vibration. The figure of the ear is at the centre of the machine. Very quickly, this metonymy of the machine was mapped back onto the ear itself.

A working phonograph or telephone, so it was thought, could possibly compensate for or even fix a nonfunctional human ear. The 1890s saw many attempts to use the phonograph and telephone as cures for or at least solutions to deafness. An article in the *New York Times* from the same year as the Columbia circular had a Dr. Leech proposing to use the phonograph to 'massage' the ossicles in the ears of the deaf: 'the principle of treatment employed is the massage, or mechanical stimulation, and consequent reawakening of the sound-conducting apparatus of the ear by means of vibrating force {of the phonograph}' ('New Remedy for Deafness', *New York Times* 23 May 1892, n.p.; see also 'Miracle of the Phonograph', *New York Times* 12 October 1895, n.p.; and 'Possibilities of the Phonograph', *New York Times*, 13 December 1891, n.p.).

Perhaps the most striking example of this phenomenon was J. C. Chester, 'the human telephone', a man who wired himself up with a complete telephone assembly (including battery) and marched to Washington, DC to patent himself (figure 4). 'He has found by many experiments that the dulled nerves of the ear

Figure 4 The Human Telephone. Source: Division of Medical Sciences, National Museum of American History.

are quickened by these powerful electric appliances and that he does hear'. In addition to an earpiece and mouthpiece for an interlocutor, Chester had outfitted his own end with a mouthpiece and an earpiece with a special wire connected directly to his teeth, so that the signal could approach his ear from two directions at once.

> A gentleman meeting this walking telephone upon the road is offered the transmitter and receiver that hang upon the hook. The gentleman places one to the ear and talks through the other, sound being much assisted by the receiver in his ear. When he replies, he speaks through a tin horn connecting with the wires and trusts to the carrying effect of the telephone. In this way he can converse over a space of several feet as easily as any other man, the painful ear-splitting being avoided.
>
> (Eldgride, 1897)

The actual effectiveness of these apparatus is questionable; it is true that new kinds of hearing aids followed the advent of tympanic machines (especially based on principles of amplification). While these apparatus might be of some assistance to the hard of hearing by focusing sound and channelling it toward a single point (through the use of the receiver in the telephone or an ear-tube for the phonograph), they were of no use as cures for deafness. All the same, these early sound technologies were at once supplements to, imitations of, and replacements for the human ear.

This logic of supplementation suggests a further implication of cultural attitudes about hearing, deafness, and states in-between. Put simply, it puts the hearing body in analogical relief against the social body: sound reproduction came to be represented not only as a solution to the physical fact of deafness or hardness of hearing, but more importantly to the social fact of unaided hearing. As I argue elsewhere, sound reproduction requires a notion of hearing in need of supplementation. In that sense, the treatment of the deaf became a model for the treatment of the hearing.

Conclusion: recasting the very possibility of sound reproduction

In each of these cases – Berliner's account, the narratives presented by Bell, Edison and those around them, and everyday representations of the new sound technologies – we can say with some certainty that the ears have it. The key element, the defining function, in these early versions of sound reproduction technologies is the diaphragm – a simple mechanical principle, a principle that connects ear to machine through analogy, imitation, or thumbscrews. This construct of the ear as a function that can be abstracted from the human body, transposed across social contexts, produced, proliferated and mutated through technique and technology, suggests that the ear (and specifically the diaphragm) does not simply come to be a representation of sound reproduction in this period; the ear – its tympanic character – becomes the diagram of sonic reproducibility. The ear, as a mechanism, becomes a way of organizing a whole set of sounds and sonic functions; it is an informal principle by which a practice is organized (Deleuze, 1988: 34; Foucault, 1977: 205).

As a diagram, this construct of the ear-as-mechanism cuts across social relationships and social contexts; it becomes a method for organizing people, force, matter, and ideas. Yet it is *not* a 'deep structure' in Levi-Strauss' sense of enduring structural relations lying dormant beneath a society that are then carried out through social activity. The ear-as-mechanism is also not an 'ideal type' derived through analysis of a normative structure by which to consider a range of multiple and differing practices.[21] The diagram is simply the informal principles of function, relation and combination at work in a given practice, event, or context. To speak of the ear-as-mechanism as the diagram of reproducible sound; to speak of a tympanic diagram, is to understand a socially produced set of abstracted functions, themselves gradually changing over time and always manifested differently, that together organized the function of sound media from before their birth. While in its formal characteristics, each sound reproduction technology exhibits a 'family resemblance' to the others, all of their abstracted functions are both produced by and part of an ever changing diagram. Thus, the status of the ear and the tympanic itself changes over time.

Thinking through the history of the tympanic function offers a way out of triumphalist and ultimately tautological histories and theories of sound reproduction that presume its contemporary form (i.e., sound reproduction technologies as we now know them) in their definition of the analytical problem; it moves away from presuming and then attempting to adjudicate among different relationships among different sounds (original/copy; reality/representation) to a consideration of the social, cultural, and technical mechanisms that open up the question of those relationships in the first place. But this is also precisely the reason for *not* positing the ear and its tympanic function as a stable and timeless 'deep structure' of sound reproduction. To do so would be to suggest that the 'prehistory' (to use Adorno's term) of the telephone, phonograph, microphone, and radio entirely determines their subsequent social and cultural significance – and that would be silly. While sound reproduction technologies did not drop out of the sky to create a new sense of the human ear or transform the fact and function of hearing, they certainly would undergo their own transformations as they grew more socially and institutionally established, as they were shaped into media. As the technologies were gradually organized into media systems with their own distinctive industrial and cultural practices – as they became sound recording, telephony, and radio as we know them today – they could in a sense take on a life of their own (see Bijker 1995 for one possible theory of technological agency that does not fall into technological determinism). The same is true with the tympanic diagram: it begins as an imitation of the human ear, but very quickly the human ear would become but one instance of a more general tympanic function – a function that could begin proliferating through American culture by virtue of its embeddedness in the institutions of science, culture and commerce. The tympanic diagram would also, in a sense, take on a life of its own.

Once the telephone and phonograph were invented, Bell and others would quickly turn away from literal imitations of the human ear, since, for instance, the telephone's diaphragm needed to be heavier than the tympanic membrane because it was used to vibrate iron, not bone. Nevertheless, as late as 1878, Bell, Watson, Blake and others were still experimenting with human ears, this time with an ear telephone. Blake wrote that 'I have been able to carry on conversation without difficulty over a line something more than six hundred feet in length, the ear telephone being used only as the receiving instrument.' Yet already in 1878 the human middle ear was becoming a weak instance of the tympanic function. Thomas Watson wrote to Blake saying that he and Bell had also tried a tympanic membrane among a number of different diaphragms for the telephone: 'They all worked, even the real ear telephone, which was, however, the poorest of the lot' (Blake, 1878: 7; Snyder, 1974: 21).

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Notes

1. Throughout this essay, though I invoke the names of famous individuals, I do not want to give the impression that this is a 'great man' history. On the contrary, following Pierre Bourdieu (1988: 2–3, 21–35), I want to consider Bell, Blake, and others as 'epistemic individuals': their actions are not so much matters of personal biography as they are instances and particular locations of social activity. Thus, the goal is not to establish the merits or characteristics of particular individuals but rather to use documents they produced as evidence of activity in a particular social milieu.
2. 'Tympanum' has a considerably longer history, but the adjectival form is significant here because it indicates that the term has come to have some mobility.

'Tympanum' also refers to an architectural form, the recessed part of a pediment, often adorned with sculpture.

3 One could easily take issue with the ways in which some scholars have slipped from asserting 'the primacy of the visual' to essentially treating the aural as irrelevant, asocial and ahistorical. It will be enough for present purposes to note that many visuality scholars commit the same errors concerning aurality as sound culture scholars, only with greater brevity.

4 Elisabeth Bennion (1994) has found multiple references to the principles of ear and speaking trumpets in ancient texts: as a hearing aid in the *Illiad*, as a means for amplifying the voice used by Alexander the Great to assemble groups of hunters, and as a principle for transmitting sound over distances and in specific directions.

5 The two predominant techniques for early film sound – sound on disc and sound on film – are also tympanic. Sound on disc was essentially based on a modified version of the gramophone; sound on film used light pulses in a manner analogous to the telephone's use of magnetism. For a discussion of the working of these technologies see (Neale, 1985: 71–76).

6 Levin cites Scott in support of his thesis that just as early cinema was heralded as a transparent reproduction of images that would supercede national languages, the prehistory of sound recording articulated an 'analogous discourse of democratization and univocal, natural signs.'

7 And, as Derrida (1976) and others have noted, to treat writing as simply a representation of speech is to efface its own social character.

8 Baynton makes the interesting argument that oralist positions (those arguing against the use of sign language) were in part rooted in scientific racism. He quotes one oralist as writing 'savage races have a code of signs by which they can communicate with each other. Surely we have reached a stage in the world's history when we can lay aside the tools of savagery' (100). See also Gannon (1981: 75–79), Bruce (1973: 409–412); and Jeffries (1995: 32, 81). Jeffries provides a nice critique of the category of disability, especially as it is applied to deafness. He argues convincingly that deafness is not, strictly speaking, a linguistic disability – especially since sign language is a perfectly adequate form of verbal communication.

9 Arnold Pacey's (1983: 78–96) discussion of 'virtuosity values' is apropos here. Pacey argues that scientific and technical research often seeks technological innovation for its own sake, rather than toward a specific end. Thus, even though Berliner had no idea what to do with phonautograms (though he was likely familiar with Bell's plans for them), he could herald their existence with the hope that a use would later be found.

10 Admittedly, Goodwin's argument is somewhat different than mine here. Most significantly, music video does not depend on an iconic or corresponding relation between image and sound. On the contrary, cutting appears to be off the beat. Similarly, writers such as Christopher Small (1977) have argued that the visibility of a music score subjects music to a visual logic: it is only possible to notate certain aspects of music. While this is certainly true, a musical score

represents instructions for a musical performance; a phonautogram (and its descendants) has an iconic relationship to the sonorial aspect of music—it is a trace of the sounds.

11 Otology is the branch of medicine dealing with the ear and its disorders. Today, medical consumers usually experience it in conjunction with the related fields of rhinology and laryngology as Ear, Nose and Throat medicine, or otorhinolaryngology.

12 For a full discussion of the status of vision in modern thought, see Jay (1993) and Levin (1989). Both books chart a shift in modern ideas about visuality, from its valorization in Cartesian and empiricist thought to its critique in post-Nietzschean continental thought (Heidegger, Gadamer, Habermas, Foucault, Derrida). While Jay suggests that the critique of ocularcentrism could profitably lead to a kind of ocular-eccentrism, Levin specifically suggests that we are experiencing a switch from vision centred theories of knowledge to hearing centred ones (based on dialogue). Although a general discussion of theories of knowledge is beyond the present project, is it worth noting that Levin's phenomenology of listening is exactly the one Derrida (1976) claims is at the very centre of modern thought all along.

13 Brühl and Politzer's book is both an anatomical and diagnostic manual, containing illustrations from Politzer's collection. It is a testimony to the significance of Politzer's collection of models and bones in the development of European otology. Its translation and mass dissemination in the United States is also indicative of the greater degree of institutionalization and professionalization of otology in the US by the turn of the century, and also medicine in general.

14 Inventions such as the auriscope were also part of this transformation in knowledge of the ear. Invented by John Brunton in 1862, the auriscope used a speculum to open up the ear cavity and then focused a light from a candle or a lamp through a funnel and then reflected on a mirror. Later improvements included a magnifying lens. The auriscope allowed doctors a much clearer view of partients ears and aided in diagnosis (Bennion, 1979: 99–101).

15 These relations are worth considering in light of Marx's comments on the surplus population:

> If the surplus-labouring population is a necessary product of accumulation or of the development of wealth on a capitalist basis, this surplus-production becomes, conversely, the lever of capitalistic accumulation, nay, a condition of existence of the capitalist mode of production. It forms a disposable industrial reserve army, that belongs to capital quite as absolutely as if the latter had bred it at its own cast. Independently of the limits of the actual increase of population, it creates, for the changing needs of the self-expansion of capital, a mass of human material always ready for exploitation.
>
> (1967: 592)

Marx may have been speaking of a reserve army of labourers, used to satisfy needs for temporary increases in production, or as a level against working class struggles for better working conditions; but here the 'human material' is appropriated at its most literal level.

16 This project itself was inspired by a visit to Sir Charles Wheatstone, where Bell and his brother first saw a reproduction of a speaking automaton built by Baron De Kemplen in the eighteenth century. Bell recounts his fascination with hearing it speak a few words. Wheatstone lent the elder Bell the instructions, which were the basis for the machine described here. See also Bell (1910: 7–8).

17 The phrase '*tympanum membrani*' is probably an erroneous locution on Berliner's part, though it could have been in common use at the time.

18 Interestingly enough, König's manometric flame was also based on the diaphragm principle, though it is not commonly thought of as a predecessor of other sound reproduction technologies.

19 Helmholtz is interesting in his own right, since his work represented a far reaching attempt to fuse the sciences of physical and psychological acoustics with the technique and aesthetics of music.

20 It's also worth noting that Bell too understood the relationship between this diaphragm principle, telephony, and sound recording. Bruce (1973: 252) recounts Bell's response to learning of Edison's invention:

> It is a most astonishing thing to me that I could possibly have let this slip though my fingers when I consider how my thoughts have been directed to this subject for so many years past.

Like some of the telephone claimants, he passed easily from the feeling that he should have thought of it to the conviction that in principle he had. In his telephone lecture he had remarked that if some implement could be made to follow the curves of a phonautograph tracing, it would reproduce the sound that had made the tracing.

> And yet in spite of this the thought never occurred to me to indent a substance and from the indentation to reproduce sound.

Although Bell's lamentations are those of a wishful entrepreneur, it is certainly the case that through the principles of the phonautograph, he and many others (most notably Cros) had grasped the principle of the phonograph before it was actually invented.

21 See Foucault (1981: 8–9) for his comparison of his own work with Weber's.

References

(1891) 'Possibilities of the Phonograph', *New York Times* 13 December. Clipping in the Hearing Folder, Medical Sciences Division, National Museum of American History, Smithsonian Institution.

(1892) 'New Remedy for Deafness: Dr. Leech Believes That The Phonograph Will

Cause a Cure', *The New York Times* 23 May. Clipping in the Hearing Folder, Medical Sciences Division, National Museum of American History, Smithsonian Institution.

(1895) 'Miracle of the Phonograph: Edison's Invention Applied to the Scientific Cure of Deafness', *New York Times* 12 October, Clipping in the Hearing Folder, Medical Sciences Division, National Museum of American History, Smithsonian Institution.

Adorno, Theodor (1990) 'The Form of the Phonograph Record', trans. Thomas Y. Levin, *October* 55.

Altman, Rick (ed.) (1992) *Sound Theory, Sound Practice*, New York: Routledge.

Arnheim, Rudolf (1936) *Radio*, trans. Margaret Ludwig and Herbert Read, London: Faber and Faber.

Attali, Jacques (1985) *Noise: The Political Economy of Music*, trans. Brian Massumi. Minneapolis: University of Minnesota Press.

Bacon, Gorham (1898) *A Manual of Otology*, with an introductory chapter by Clarence John Blake, New York: Lea Brothers and Co. The text cited come from hand-written notes (probably for or from an introductory lecture) in the cover of a copy housed in the main library of the University of Illinois.

Baynton, Douglas C. (1993) '"Savages and Deaf-Mutes": Evolutionary Theory and the Campaign Against Sign Language in the Nineteenth Century', in John Vickery Van Cleve (ed.) *Deaf History Unveiled: Interpretations from the New Scholarship*, Washington, D.C.: Gallaudet University Press.

Beck, Ulrich (1992) *Risk Society: Towards a New Modernity*, trans. Mark Ritter. Newbury Park: Sage.

Bell, Alexander Graham (1878) 'The Telephone: A Lecture Entitled Researches in Electric Telephony by Professor Alexander Graham Bell, Delivered Before the Society of Telegraph Engineers, October 31st, 1877', New York: Society of Telegraph Engineers, 1878. Available through the Charles H. Dibner Library, National Museum of American History, Smithsonian Institution.

Bell, Alexander Graham (n.d.) 'Prehistoric Telephone Days', Alexander Graham Bell Collection, Archives Division, Library of Congress, Box 385, speech file of the same title.

Bell, Alexander Graham, (1910) 'Early Telephony' address Before the Telephone Society of Washington (3 February). Alexander Graham Bell Collection, Archives Division, Library of Congress, Box 383, speech file of the same name.

Bennion, Elisabeth (1979) *Antique Medical Instruments*, Berkeley: University of California Press.

Bennion, Elisabeth (1994) *Antique Hearing Devices*, London: Vernier Press.

Berliner Gramophone Company, Philadelphia Division (n.d.) 'The Gramophone'. Emile Berliner Collection, Library of Congress, Recorded Sound Reading Room, Scrap Book 2.

Berliner, Emile (1888) 'The Gramophone: Etching the Human Voice'. Paper read before the Franklin Institute (16 May), Emile Berliner Collection, Recorded Sound Reading Room, Library of Congress (unsorted papers).

Bijker, Wiebe (1995) *Of Bicycles, Bakelites and Bulbs: Toward a theory of Sociotechnical Change*, Cambridge: MIT Press.

Blake, Clarence (1878) 'Sound and the Telephone', read Before the British Society of Telegraph Engineers (8 May). Available from the Charles H. Dibner Library, National Museum of American History, Smithsonian Institution.

Blake, Clarence (1878) 'The Use of the Membrana Tympani as a Phonautograph and Logograph'. Archives of Opthamology and Otology.

Bourdieu, Pierre (1988) *Homo Academicus*, trans. Peter Collier, Stanford: Stanford University Press.

Bruce, Robert V. (1973) *Bell: Alexander Graham Bell and the Conquest of Solitude*, Boston: Little, Brown and Co.

Brühl, Gustav and Adam Politzer (1903) *Atlas and Epitome of Otology*, trans. and ed. S. MacCuen Smith, Philadelphia: W. B. Saunders and Co.

Burnett, Charles (1991) 'Sound and its Perception in the Middle Ages', in Charles Burnett, Michael Fend, and Penelope Gouk (eds.) *The Second Sense: Studies in Hearing and Musical Judgement From Antiquity to the Seventeenth Century*, London: The Warburg Institute.

Cantrill, Hadley and Allport Gordon (1935) *The Psychology of Radio*, New York: Harper and Brothers Publishers.

Chanan, Michael (1995) *Repeated Takes: A Short History of Recording and Its Effects on Music*, New York: Verso.

Columbia Phonograph Company (1895) *The Latest and Best Talking Machines: The Perfected Graphophone with Clockwork or Electric Motor*, Washington, DC: Columbia Phonograph Co.

Corbett, John (1994) *Extended Play: Sounding Off: From John Cage to Dr. Funkenstein*, Durham: Duke University Press.

Czitrom, Daniel (1982) *Media and the American Mind: From Morse to McLuhan*, Chapel Hill: University of North Carolina Press.

Deleuze, Gilles (1988) *Foucault*, trans. Sean Hand. Minneapolis: University of Minnesota Press.

Derrida, Jacques (1976) *Of Grammatology*, trans. Gayatri Chakravorty Spivak, Baltimore: the Johns Hopkins University Press.

Douglas, Susan (1987) *Inventing American Broadcasting, 1899–1922*, Baltimore: The Johns Hopkins University Press.

Douglas, Susan (1999) *Listening In: Radio and the American Imagination From Amos 'n Andy to Wolfman Jack and Howard Stern*, New York: Random House.

Edwards, Linden F. (1955) *The History of Human Dissection*, Fort Wayne, TX: Fort Wayne and Allen County Public Libraries.

Eisler, Hanns and Theodor Adorno (1947) *Composing for the Films*, New York: Oxford University Press.

Eldridge, Grant (1897) 'The Human Telephone', *Buffalo (N.Y.) Times*, 24 January. Clipping in the Hearing Folder, Medical Sciences Division, National Museum of American History, Smithsonian Institution.

Fischer, Claude S. (1992) *America Calling: A Social History of the Telephone to 1940*, Berkeley: University of California Press.

Foucault, Michel (1981) 'Questions of Method: An Interview with Michel Foucault', *Ideology and Consciousness* 8.

Gannon, Jack R. (1981) *Deaf Heritage: A Narrative History of Deaf America,* Silver Spring, MD: National Association of the Deaf.

General Electric Company (n.d.) 'Radio Signals Recorded by the General Electric Visual and Photograph Recorder', George H.Clark Radioana Collection, National Museum of American History, Smithsonian Institution, Series 93, Box 389.

Goodwin, Andrew (1992) *Dancing in the Distraction Factory: Music Television and Popular Culture*, Minneapolis: University of Minnesota Press.

Gorden, J. C. (1886) to Bell A. G. 6 February, copied verbatim from original – John Bulwer, *Philosophicus* (1648) – Alexander Graham Bell Collection, Archives Division, Library of Congress, Box 256, Folder: Subject, Phonograph, Miscellany.

Gorman, Mike (1994) 'Bell's Path to the Telephone', {http: //jefferson.village.virginia.edu/albell/homepage.html} (last accessed 18 November 1999).

Gouk, Penelope (1991) 'Some English Theories of Hearing in the Seventeenth Century: Before and After Descartes', in Charles Burnett, Michael Fend and Penelope Gouk (eds.) *The Second Sense: Studies in Hearing and Musical Judgement From Antiquity to the Seventeenth Century*, London: The Warburg Institute.

Grossberg, Lawrence (1992) *We Gotta Get Out of This Place: Popular Conservatism and Postmodern Culture*, New York: Routledge.

Hall, Stuart (1986) 'On Postmodernism and Articulation: An Interview with Stuart Hall'. *Journal of Communication Inquiry* 10(2).

Helmholtz, Hermann (1873) *The Mechanism of the Ossicles of the Ear and the Membrana Tympani*, trans. Albert H. Buck and Normand Smith. New York: William Wood and Co.

Helmholtz, Hermann (1895) *On the Sensations of Tone as a Physiological Basis for the Theory of Music* (3rd Edition), trans. Alexander Ellis, New York: Longmans, Green and Co.

Hilmes, Michele (1997) *Radio Voices: American Broadcasting 1922–1952*, Minneapolis: University of Minnesota Press.

Jay, Martin (1993) *Downcast Eyes: The Denigration of Vision in 20th Century French Thought*, Berkeley: University of California Press.

Jeffries, Lennard (1995) *Enforcing Normalcy: Disability, Deafness and the Body*, New York: Verso.

Kenney, William (forthcoming) *Recorded Music in American Life 1890–1945*, New York: Oxford University Press.

Kern, Stephen (1983) *The Culture of Time and Space 1800–1918*, Cambridge: Harvard University Press.

Levin, David Michael (1989) *The Listening Self: Personal Growth, Social Change, and the Closure of Metaphysics*, New York: Routledge.

Levin, Thomas Y. (1990) 'For the Record: Adorno on Music in the Age of its Technological Reproducibility', *October* 55.

Martin, Michèle (1991) *'Hello, Central?': Gender, Technology, and Culture in the Formation of Telephone Systems*, Montreal: McGill-Queen's University Press.

Marvin, Carolyn (1988) *When Old Technologies Were New: Thinking About Electrical Communication in the Late Nineteenth Century*, New York: Oxford University Press.

Marx, Karl (1967) *Capital: A Critique of Political Economy, Volume I—the Process of Capitalist Production*, trans. Samuel Moore and Edward Aveling, edited by Frederick Engels, New York: International Publishers.

McChesney, Robert (1994) *Telecommunications, Mass Media, and Democracy: The Battle for Control of US Broadcasting, 1928–1935*, New York: Oxford University Press.

National Phonograph Company (1900) *The Phonograph and How to Use It, Being a short history of its invention and development containing also directions helpful hints and plain talks as to its care and use, etc*, New Jersey: The National Phonograph Company. Available in the Library of the National Museum of American History, Smithsonian Institution.

Neale, Stephen (1985) *Cinema and Technology: Image, Sound, Colour*, Bloomington: Indiana University Press.

Ong, Walter (1967) *The Presence of the Word: Some Prolegomena for Cultural and Religious History*, New Haven: Yale University Press.

Ong, Walter (1982) *Orality and Literacy: The Technologizing of the Word,* New York: Routledge.

Ord-Hume, Arthur W. J. G. (1973) *Clockwork Music: An Illustrated History of Mechanical Musical Instruments From the Musical Box to the Pianola, From Automaton Lady Virginal Players to Orchestrion*, New York: Crown Publishers.

Pacey, Arnold (1983) *The Culture of Technology*, Cambridge: MIT Press.

Peters, John Durham (1994) 'The Gaps of Which Communication is Made', *Critical Studies in Mass Communication* 11(2) 117–140.

Peters, John Durham (1999) *Speaking into the Air: A History of the Idea of Communication*, Chicago: University of Chicago Press.

Richardson, Ruth (1987) *Death, Dissection and the Destitute*, New York: Routledge and Kegan Paul.

Rüdinger, N. (1874) *Rüdinger Atlas of the Osseous Anatomy of the Human Ear*, Comprising a Portion of the Atlas of the Human Ear, trans. and with notes and an additional plate by Clarence Blake, Boston: A. Williams and Co.

Schafer, R. Murray (1969) *The New Soundscape*, Vienna: Universal Edition.

Shultz, Suzanne (1993) *Body Snatching: The Robbing of Graves for the Education of Physicians*, Jefferson, NC: MacFarland Publishers.

Small, Christopher (1977) *Music-Society-Education*, London: John Calder.

Smulyan, Susan (1994) *Selling Radio: The Commercialization of American Broadcasting 1920–1934*, Washington, DC: Smithsonian Institution Press.

Snyder, Charles (1974) 'Clarence John Blake and Alexander Graham Bell: Otology and the Telephone', *The Annals of Otology, Rhinology and Laryngology* Supplement 13, 83(4) Part 2.

Starr, Paul (1982) *The Social Transformation of American Medicine*, New York: Basic Books.

Taussig, Michael (1993) *Mimesis and Alterity: A Particular History of the Senses*, New York: Routledge.

Truax, Barry (1984) *Acoustic Communication*, Norwood, NJ: Ablex Publishing.

White, Hayden (1978) *Tropics of Discourse: Essays in Cultural Criticism*, Baltimore: The Johns Hopkins University Press.

Wilde, William R. (1853) *Practical Observations on Aural Surgery and the Nature and Treatment of Diseases of the Ear With Illustrations*, Philadelphia: Blanchard and Lea.

Wittgenstein, Ludwig (1958) *Philosophical Investigations*, New York: MacMillan.