Varèse *in vitro*: On Attention, Aurality, and the Laboratory

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1.

In his 1936 lecture on "New Instruments and New Music," Edgard Varèse insisted:

> "There should be at least one laboratory in the world where the fundamental facts of music could be investigated under conditions reasonably conducive to success. The interest in music is so widespread and intense, its appeal so intimate and poignant, and its significance for mankind so potent and profound, that it becomes unwise not to devote some portion of the enormous outlay for music to research in its fundamental questions." (1967:197)

Though Varèse was quoting this entire paragraph from a 1928 popular-science monograph by John Redfield, former physics lecturer at Columbia University, the composer made the sentiment and argument very much his own in other writings and interviews from the period.[1] Yet some uncertainties remain as to the laboratory's value for Varèse. Did his vision of music as an "art-science" stem simply from infatuation with scientific authority? What were the specific "conditions reasonably conducive to" a laboratory's success? In what would this "success" consist?

I would like to suggest in this essay that we can begin to appreciate Varèse's flirtation with laboratory research by considering the situation on three levels: first, the peculiar societal function and position of the laboratory, which has been suggestively addressed within the field of science studies by Bruno Latour (1983); second, the special forms of aural attentive observation a laboratory can facilitate; and third, the aesthetic possibilities afforded by stimulating the latter modes of attention in the contexts of musical composition. In exploring these various levels, I will consider aspects of Varèse's laboratory listening in a sequence of related scenes and scenarios: the composer's attempts in the late 1920s through the mid-1930s to gain access to a research laboratory; some particular conditions and instruments of the ersatz "lab" Varèse inhabited in his Manhattan apartment from 1925 on; and, finally, a brief passage from the 1923 chamber piece,

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Laboratories, and the scenes of attentive observation that often inhabit them, are valuable resources because they are technologies for transforming interests. According to Latour, to whom this claim owes a great deal, laboratories can enable a transformation of people's interests because they are designed to translate the uncontrollable and often unobservable things of the outside world into things easily manipulable by individuals inside a lab; such individuals can easily learn a limited set of skills in order to bring observed objects into measured and calibrated relations with one another. While nothing cognitively or technologically mysterious need unfold inside a laboratory for this to happen, the overall effect is of a lever shifting the observational capabilities of otherwise constrained individuals from a weak point to a relatively strong point, so that unruly objects can be brought under sustained attention in the lab. Once sustained attention has been nurtured within that protected interior space, this situation can then be inverted in order to re-translate knowledge constructed in the lab back out into the world. What results from this arrangement is the "short circuit established between many groups usually uninterested by what happens inside laboratory walls and laboratories usually isolated and insulated from such attention and passion." Ultimately, argues Latour, "the very difference between the 'inside' and the 'outside' . . . is precisely what laboratories are built to destabilize or undo" (1983:142–43).

If the laboratory function sketched here results in a certain destabilization of distance or of the "inside"/"outside" distinction, we will also find that the modes of attentive observation often at play in this environment coincide more generally with a simultaneous shrinking and expanding of experience. It is that specific paradox—the capacity to perceive immensity in domains of intimate intensity and thereby to unsettle a given sense of scale in the world—which constitutes the form of attention I claim is present in each of the scenarios explored here. It is also a characteristic facet we find Varèse exploring in his rather distinctive aurality (by which I mean, in analogy with "visuality," a loose family of discourses, knowledge, and experiences of hearing and the ear). Yet, while I find it valuable in this context to seek a degree of narrative continuity through an abstract model of attention, I would caution that it is not tenable to ascribe an overriding transhistorical regulative function to any one particular concept of attention.[2] Attention is no less multifarious as a historical notion than it is as a mode of engagement with the world. Indeed, the very multiplicity of attentional modes becomes highly significant in the context of listening to Varèse's music, as we will find at the end of this essay.

In the partial narrative I present of Varèse's abortive communications

with, first, the research labs of Bell Telephone Systems and, a few years later, the studios of the National Broadcasting Corporation, we will see how these institutions promised just the kind of neutralization of distance Latour saw in the social technology of the modern lab. Even if Varèse failed or refused to align his own aesthetic and material interests with the interests of those institutions, I suggest that we can still see the habits and values of sustained attention at work in the composer's own private practices of observation. Moreover, we need not see this effort as entirely wasted. Rather, we can take the characteristic image of Varèse enacting a peculiarly "scientific" attention at home as a goad to complicate our own listening to his music. What we discover in considering the practices of attention familiar to Varèse is that, for all the leverage afforded by laboratory-like observation, attention remains a profoundly fragile disposition, one rooted in the contingency and finitude of the physiological body. Having situated Varèse's domestic empiricism provisionally in the context of broader problematics of attention, including those raised indirectly by one of Varèse's scientific heroes, physiologist Hermann von Helmholtz, we might hope to intuit better how such topographies of scientific attention, with all its vulnerabilties, could have expanded the compositional strategies available to Varèse.

2.

In 1929, soon after Varèse had begun to correspond with Harvey Fletcher, the Acoustical Research Director at Bell Telephone Laboratories, Fletcher published an influential book entitled *Speech and Hearing*, which surveyed research conducted at Bell in the previous fifteen years. The book's introduction, written by H. D. Arnold, director of Bell's Research Laboratories, immediately conveys a sense of the profound changes such research wrought in aural experiences of scale and distance. Arnold opens by evoking an epiphanic attention to the "marvelous mechanism" of audition, toward which humans had previously "come to feel, if not contempt, at least indifference." In the relative state of nature Arnold saw before the advent of telephone and radio, we had been able to "trace the sound to its source to hear its perfect form, for that is the method we have used from childhood in investigating the sounds of our immediate neighborhood." Arnold appears half-consciously to equate a child's intuitive sense of real physical distance with the same originary sense possessed by the whole species in the days before mass communication technologies. With the development of such technologies, though, not only does the organic experience of distance between a sound and its origin evaporate, but, Arnold suggests, the privileged

position of the acoustic origin is no longer assured:

> Now with one broad sweep the barriers of space and time are gone and all the world becomes our vocal neighborhood. No longer can we transport ourselves to the origin of a sound and thus become convinced that we are hearing it aright, for that origin may be thousands of miles away or may have vanished years before; and so we must establish a new method to measure the accuracy of the copy which reaches our ears. (Fletcher 1929:xi)

If such rhetoric was representative of the feeling at Bell Labs in the late 1920s, it is not difficult to imagine that its expansive confidence could only have strengthened Varèse's resolve to join ranks with the researchers at Bell before other composers had the chance. One pictures him reading such a text all agog.

Yet Arnold's globalizing rhetoric need not distract us from the labs' day-to-day work, which consisted of a series of carefully observed, minute acts of measurement. These were undertaken on the assumption that our ears are, after all, "only machines to translate air waves into a form suited to stimulate the auditory nerve; and as machines we may measure and describe them in the same terms that apply to devices we ourselves construct" (xi-xii). Arnold continued:

> Some important factors relating to the process of hearing we can, however, determine by measuring the least changes in sound which can be detected under a variety of conditions of pitch, loudness, and accompanying noise. Thus we may obtain a quantitative means of comparing individuals in this respect, and establish a standard of average hearing. (xii)

In Emily Thompson's recent study of early twentieth-century architectural acoustics, the historian describes how comparative measurements, like those Arnold mentions, were carried out in similar work Fletcher had directed at Western Electric in 1923 using an "audiometer." The Fordist rhythms of such research emerge in the image of one test subject after another donning headphones, attentively listening to a sequence of pure tones of gradually increasing intensity, and signalling to researchers when the tones first became audible (Thompson 2004:146–47). "While the basic parameters of the limits of human hearing had been known before," Thompson writes,

> the large-scale precision testing made possible by the new audiometer endowed [the subjects' response] curve with a statistical relevance that it had not previously possessed. The experience of being tested additionally became a new element of aural culture for increasing numbers of people over the course of the decade. (147–48)[3]

Nothing in Varèse's own rhetoric suggests sympathy to a research culture that founded its work on the goal of establishing what Arnold called "a standard of average hearing." We might be left to wonder what would compel a composer, who still prided himself on having been a model for the genius eponym in *Jean-Christophe,* Romain Rolland's 1912 *Bildungsroman,*[4] to seek a position at an industrial institution like Bell Labs where the horrifyingly sterile prospect of "forty-eight normal ears" could undermine the authority of solitary, subjective listening.[5] Still, my intent in dwelling on Fletcher's research methods is not only to evoke the potentially incongruous image of a composer entering into a factory-like research atmosphere that would efface his place of distinction. What is also worth appreciating is how Varèse, famously and perhaps uniquely fascinated with the alternating vastnesses and microscopicisms of modern science, found himself knocking on the door of an institution that managed to disrupt the "natural" scale of things in two distinct ways. The first was simply in appearing to create the sort of "vocal neighborhood" to which any communications enterprise must aspire. The second disruption was a result of Bell's capitalizing on the transformative leverage Latour ascribes to the modern lab. The translation of unmeasurable "ear" into measurable "machine," followed by the creation and extension back outwards of *new* machines based on the initial measurements—for example, telephones—exemplifies the way in which labs can both claim a privileged societal position and neutralize their distance from the world. Once ears were understood to be machines and it was understood that machines could be produced and manipulated only in Bell Labs, the interests of those dependent on communication technologies would come to be dependent on the interests of those working the levers at Bell.

Varèse need not have explicitly approved of the underlying market orientation in this view of things, although, notably, he did remark to a friend in 1930 that he was "abandoning music" to "become a businessman" because "music does not interest anybody today." "I will offer my services to a large enterprise," he said. "With my acquaintances, in mathematics and in physics, I will succeed" (Carpentier 1967:26).[6] In any case, the transformative potential of the laboratory had multiple implications of great interest to the composer-businessman. One was that a lab could be exploited to create new technologies and instruments that could renew compositional materials and thereby embody the translation of others' interests into one's own technical language. It is almost too easy to intuit how Varèse would have found himself sympathetic to Bell's goal of developing "better and more precise instruments" (Fletcher 1929:v). In the same 1936 lecture quoted earlier, Varèse wrote,

> The new musical apparatus I envisage, able to emit sounds of any number of frequencies, will extend the limits of the lowest and highest registers, hence new organizations of the vertical resultants: chords, their arrangements, their spacings—that is, their oxygenation. Not only will the harmonic possibilities of the overtones be revealed in all their splendor, but the use of certain interferences created by the partials will represent an appreciable contribution. The never-before-thought-of use of the inferior resultants and of the differential and additional sounds may also be expected. An entirely new magic of sound! (1967:197–98)

Another implication of the laboratory, more broadly speaking, was that the naïve understanding of music as an abstraction symbolized in notation could be translated into something felt, perhaps just as naïvely, to be closer to the physical reality of sound. Both themes, the development of instruments and the revalution of compositional material into raw acoustic resonance, informed Varèse's correspondence with laboratory directors, as we will see. Something else, however, first stood in the way of capitalizing on these advantages, namely a debilitating disciplinary specialization that appeared to preclude productive communication between musicians and other skilled professionals.

Varèse's suspicions about this problem were loudly confirmed in Redfield's *Music: A Science and an Art* (1928). Redfield's book linked otherwise unremarkable statements to the effect that music consists not merely of "lame and halting hieroglyphics" but of "thousands of Lilliputian musical forces acting every instant with the rapidity of thought on every air particle in the musical field" (5–6) with the firm conviction that multiple individuals must contribute to musical production: "the composer, the instrument maker, and the intepretative [sic] musician" (1). For Redfield, the actualization of sound's raw materiality was not just a physical phenomenon but also a unique product of the social relations behind musical production: "Not until all three [individuals] have been brought into intimate collaboration, and the air between the instrument and the listener's ear is disturbed by the actual playing of the instrument, is music produced" (1).

Redfield's insistence that collaboration was the only means toward real and immediate contact with sound reveals the great extent to which a crude but undeniable division of labor was seen to be complicit in clouding the image of music's true substance. The problem, according to the physicist, was that musicians refused to acknowledge this arrangement and were therefore unable first to remove themselves from the detrimental specialization that confined them and then to hear sound for what it was. In one of two lengthy chapters on "The Musical Laboratory" and "The Laboratory Study of Music," Redfield drew an unfavorable comparison between musicians

and "other manufacturers," noting that

> as compared with other manufacturers, the musician assumes a very surprising attitude. Other manufacturers find it advantageous to study their raw material. If something is wrong with their finished product, they know that the fault must lie either with their manufacturing processes or with the material they are using; and they can not be sure the fault is with their processes until they are certain it is not in their raw material . . . Not so, our musician manufacturer . . . He thinks it quite unnecessary to know anything about the raw material he uses . . . To be sure, things sometimes turn out badly, but it never occurs to him that there is anything to be gained by a study of sound. (1928:105–06)

In a 1955 interview, Varèse echoed Redfield by affirming that a composer, "if he wants to obtain the results which his conception demands, should not forget that his raw material is sound" and that he "should understand not only the mechanism and the possibilities of different sound machines [machines sonores] that make his music live; but he should also familiarize himself with the laws of acoustics" (Charbonnier 1970:71).[7] Elsewhere, Varèse had complained that "by its education, the human ear has been disciplined or trained to produce an abstraction" from immediate acoustic phenomena (Varèse 1930:127–28).[8] What Varèse imagined, then, was a kind of listening that could reach back past status-quo disciplining of perception to create a new kind of aural discipline, unfettered by specialized training.

Like Varèse, Redfield believed the constraints of specialization could be mitigated by creating a laboratory that was more accessible to musicians who lacked, but sought, technical knowledge. With evident faith in the redemptive potential of collaboration similar to Redfield's, Varèse addressed the issue of specialization in a long and passionate 1936 letter to Edward J. Nally, who was then the president of Radio Corporation of America. (RCA was the parent company of NBC, where Varèse was seeking an advisorial position.) "Specialization," Varèse wrote,

> while deepening a person's knowledge of one's subject, too often tends to limit, not only his knowledge but his sympathies and imagination to his special subject. In broadcasting and the sound-film, the music adviser, with his specialized knowledge of the *Art* of music, has probably never before turned his thoughts to the basic *Sound*-principles of his art; and the scientist has probably, heretofore, thought of the esthetics of music as remote from his particular sphere of sound. Now these two specialists are brought together with a common goal in view, and must learn to speak a common language which does not yet exist. (Edgard Varèse Collection, Paul Sacher Foundation)

The letter clarifies that Varèse's resistance to specialization did not demand a radical end to fragmentary disciplines, but instead inclined toward a type of individualism or particularism that would orient the "synthetic imagination," as Varèse said, toward intersubjective communication both in new educational settings and also in new laboratory spaces. The very arrangement of collaboration Varèse envisioned would presumably have promoted verbal exchange—and literally learning "to speak a common language"—as a means toward glimpsing beyond "the backyard" of traditionally isolated composerly production (Paul Sacher Foundation).

We can make this out again in his first fellowship application letter to Henry Allen Moe at the Guggenheim Foundation in September, 1932. The project description was framed in terms of a collaboration with technician, René Bertrand, with whom Varèse had developed a friendship and working relationship in the 1910s. Varèse wished "to present [his] ideas to technicians from different organizations in order to proceed with these verifications and also to convince them of the necessity of a close collaboration between the composer and the scientist" (Varèse 1983:67). In a follow-up letter a few months later, Varèse was more focused, listing specific technical goals, which included the production of "pure fundamentals," manipulation of harmonic spectra, experimentation with combining Bertrand's "Dynaphones" into a new compound instrument, and production of instruments with increased frequency range and intensity. "The practical result of our work," Varèse assured Moe, "will be a new instrument which will be adequate to the needs both of the creative musicians and of the musicologist" (Paul Sacher Foundation).

When Varèse asked Fletcher to write in support of the fellowship, Fletcher agreed, replying that he saw "a great need for some institution to set up an organization for doing the type of work which you outlined in your [Guggenheim] application and where the workers could proceed with the investigation in an uninterrupted fashion" (Paul Sacher Foundation). Yet in Varèse's next letter to Fletcher of December 1, 1932, the composer, perhaps realizing that the Guggenheim Foundation would reject his application, inquired whether it would be possible to work with someone at Bell or any another company known to Fletcher, as Varèse wished to offer his "regular collaboration" (Varèse 1983:67–68).[9] Fletcher's subsequent letter of December 15 bluntly rejected Varese's offer on the grounds it lacked commercial application: "It is very questionable even in normal times [that is, beyond the depths of the Depression] of these companies employing someone of your abilities . . . I doubt whether your venture of this sort would ever pay in the commercial sense, but I am sure some very great contributions would be made to the musical art" (Paul Sacher Foundation).

From the tone of these letters, it is evident that Varèse failed to give either Bell Labs or NBC a good reason to be interested in his work. At NBC, for example, the consensus among executives and engineers was that his research would not benefit the company, since Varèse tended to confuse economic limitations for technical ones. (Varèse recommended that NBC develop a technique for broadcasting over a wider frequency to preserve sound fidelity, not realizing that such a method was impracticable because of the prohibitive cost of bandwidth.) And his musical taste was, well, a turn-off. One executive wrote a memo in January, 1937, expressing what is now probably unsurprising but was evidently not a foregone conclusion to Varèse at the time:

> No one is impressed with him or his ideas. They feel that he is radical and extreme in his thoughts on music and sound reproduction, and for several years has been considered a bit eccentric. Those who know him agree with [O. R.] Hanson [NBC's Chief Engineer], that he does not have anything we could use. (Paul Sacher Foundation)

In all fairness, the laboratories Varèse coveted were neither simply scientific ventures, nor simply business ventures, nor simply aesthetic ventures, but tended to sit at a precarious intersection of all three domains. The trick was to position oneself in such a way that one seemed to have an eye on each of the three (or more) roads leading to the laboratory door—a nearly impossible proposition. Perhaps this explains why it was that Varèse never really got the knack of it and always came out seeming a bit out of place.

Whatever the reasons for his failed business propositions, one thing remained clear and urgent for Varèse: composers, at least, would profit from a space, indeed an actual place, where acoustic materials were no longer perceived as floating around willy-nilly in the world at large, or in that awkward netherworld between compositional aspirations and disappointing realizations at the hands of fallible performers. In the laboratory space, the very scale of sound would be variable, so that not only could instrumental capabilities be extended, but sounds could be repeated and sustained freely, with minimal exertion and with license to make mistakes, technical, compositional, perceptual. In spite of research methods we saw in Fletcher's work, repetition need not always come down to a case of Fordism, of reducing the supposed authenticity of an original object or experience to an empty series of exchangeables. In reproducing or sustaining a sound indefinitely with keenly focused attention, it is not only that one might gradually begin to pick out the unobserved through a constantly renewed set of comparisons, but also that the peculiarity of the frame of observation itself would alter its

everyday objects in such a way that they could come, as if for the first time, to have value.

An opportunity to explore in more detail the sort of attention Varèse was evidently able to practice on a daily basis arises in the next section of this essay, as we turn to the specific scene of Varèse's workspace and consider one of his arcane laboratory instruments, the siren, which had attracted Varèse's attention since at least the 1910s.

3.

Varèse's efforts to collaborate with a laboratory physicist on acoustical research and gain access to a well-funded lab were, of course, rewarded to a degree in the 1950s.[10] By that time, though, Varèse had long since been forced to compensate for unforthcoming institutional support by developing his own somewhat isolated domestic "laboratory," as Bell Labs technicians Max Mathews and Newman Guttman called it after visiting Varèse's home in 1959.[11] In exploring some topographical detail of the Varèse apartment, my initial aim is to draw out certain structural similarities between the setting of Varèse's private attentiveness and the forms of institutionally sanctioned attention we have already seen. Through, first, a detailed observation of the scene by the writer Anäis Nin, one of the Varèses' close friends, and, second, an account of the siren in Helmholtz's work, we can infer a great deal about the modes of attentive observation available to the composer. We again find not only a neutralization or destabilization of distance in multiple registers but also that distinctive simultaneity of narrowing and expanding perception that typifies one form of attention.

Nin's recollection of her frequent visits to the Varèse home in the 1940s gives us a vivid sense of locality. As Latour has emphasized the unmysterious quality of most lab settings, it is little surprise to find the setting for Varèse home laboratory low-key and bourgeois, with a hint of the old downtown charm:

> Edgar and Louise Varèse live on Sullivan Street, near Bleecker Street. Their house is built of red bricks. The back of it gives onto a series of gardens belonging to houses of the same style and period. It looks European. The neighborhood is Italian. At number 188 I walk down a few steps and push a red door. Inside I ring two doorbells, one for Varèse's studio, which is on the level with the garden, and the other for the floor above, where the living room, dining room, and kitchen take on a green tint from the trees in the back yard.

And yet, Nin shows us, the scale of the setting is all out of proportion with the scale of the perceptual activity taking place there. Varèse "looks too big for the small house in the Village. The sounds he plays shake the old walls." Most pertinent, though, is the way in which Nin's prose funnels successively inward, textually enacting the very experience of absorption ascribed to the composer and his visitor:

> When he takes you down the narrow turning stairway to his studio, it is a cave of sounds, coming from tapes, recordings, gongs . . . He wants one possessed, absorbed into its oceanic waves and rhythms. Varèse demonstrates a new bell, a new object capable of giving forth a new tonality, new nuance. He is in love with his materials, with an indefatigable curiosity. In his room one becomes another instrument, a container, a giant ear, enclosed in his flights into sound. (1969:61–62)[12]

Varèse's visitor brings out a carefully structured relationship between multiple resonant enclosures. A labyrinthine downward path toward the locus of the sounding bodies arrives with a distinct accent on the punctual site of a bell, whose resonance in turn re-animates the whole scene from inside out. The image of another sort of "labyrinth," the "giant ear" that asserts itself as the rude emblem of aurality, finally subsumes or substitutes for each other resonating object: ear, instrument, the cavernous studio, and the entire apartment whose walls shake precariously.[13]

My point in scrutinizing the poetics of this diary account is not to pay gratuitous homage to a quaint encounter between two authoritative modernist figures. In the ambiguous border between sound and ear—are we "containers" for sound or ourselves "enclosed" in sound?—we rediscover the undoing of the "very difference between the 'inside' and the 'outside'" transferred to an intimate scene. This situation delicately persists here despite the apartment studio's obvious relative *lack* of leverage for transforming outside interests. Beyond recommending Varèse's "indefatigable" commitment to the "materials" of his sounds, then, and beyond embedding Varèse's persona in a grossly lived aurality, Nin shows us how the Varèsian image of attention depends on the unsettling explosion of a pointed focus of perception. Yet where Arnold had earlier celebrated the effacement of acoustic origins in favor of the "copy," Varèse's engagement with his instruments works from a different relation of the old to the new. His attentive listening, generally deprived of technoscientific wonders until the 1950s, sought to coax novelty from the banal, insignificant, and arcane. Despite having little more than gongs, bells, and sirens to work with, the sounds seemed "to come from other planets" (61). I suggest that it was partly the very monotony of sustaining, repeating, restriking, and replaying that would

defamiliarize such aging objects and bring Varèse's laboratory practice into a recognizably mimetic relationship with the defamiliarizing translation Latour sees in the measured manipulation of scientific objects. Since Varèse's practice was intimately bound to specific technological and cultural artifacts, however, it will now be worthwhile "to pay closer attention to the materiality of the [artifacts] themselves and to the manner in which they are actually constitutive of the signifying scene," as science historian Timothy Lenoir puts it in an essay on Helmholtz's research (1994:205).

In 1959, Varèse wrote that, as a student, he had "studied Helmholtz, and was fascinated by his experiments with sirens described in his [*On the Sensations of Tone*]." "I went to the Marché aux Puces," Varèse recalled, "where you can find just about anything, in search of a siren, and picked up two small ones" (1967:205).[14] This object, both curious and modest, was radiant with significance in the context of Varèse's work. If the siren eventually came to specify a certain urbanicity through its association with traffic, tugboat fog-horns, and other sonic signs of the American city, this was not the only value adhering to the instrument. In a different vein, Douglas Kahn has suggested that the siren, for Varèse and other modernists (including Luigi Russolo and Henry Cowell), also represented a doubly-significant line, which inscribed both sonorous curves resembling movements through space and also the very difference between noise and tone. That is, in tracing a continuous transition through an infinity of tones, a siren's glissando might be thought to occupy, and therefore destabilize, precisely that slim, curvilinear boundary between the rational, discrete pitch space of common-practice European music and the expansive, unruly space outside of that practice, inhabited by noise, or everything that music was thought to exclude (Kahn 1999:88–91).

Such interpretations doubtless enfold a good deal of productive thinking, but I would like to take a step or two back and consider how Varèse's probable awareness of a more particular context for the siren, one that has little to do with the Varèsian glissando, could have graced this object with yet another layer of meaning for him. It is worth taking a detailed look at the role of the siren in Helmholtz's work for a couple of reasons. First, the historical episode of Helmholtz's siren research exemplifies the leverage gained by employing specific laboratory technologies to support and regulate attention. Second, one sees in *On the Sensations of Tone* the almost moral imperative attached to aural attention in acoustic research, and particularly siren research.

In Helmholtz's plan for developing a psychophysiological theory of harmony, the siren occupied a special place as an emblem for the modernization of aural perceptual models through the new physiological acous-

tics.[15] One of Helmholtz's primary projects in the 1850s and 1860s was to create greater empirical access to the phenomena that underlay contemporary knowledge of acoustics and its physiological ramifications. He exemplified some strategies for accomplishing this through his response to recent work in acoustics, where the siren had emerged as one of the instruments driving research. In the mid-1840s, two acousticians, Georg Simon Ohm and August Seebeck, had disagreed over an essential matter in acoustics.[16] Briefly put, Ohm believed that all periodic sounds, no matter what their composite wave patterns, could *in theory* be reduced through Fourier analysis to simple sinusoidal waves. But Seebeck's work with early models of the siren, like that in figure 1 and the more powerful one in figure 2, convinced him not only that the behavior of sound was more complex than Ohm's theoretical image of it had allowed, but also that this image did not seem to reflect accurately the relative intensities of harmonics above the fundamental (or, in some cases, that of the fundamental itself). Many of the sounds predicted by Ohm's theory, more remote from the fundamental tone, were not readily apprehensible to the ear.

When Helmholtz revived some basic issues from the Ohm-Seebeck dispute a decade later, he came to believe that each physicist failed to appreciate the complex relationship between the raw physiological impact of sonic sensations and the psychological mechanisms that render those sensations intelligible. *On the Sensations of Tone* rests on the assumption, not always explicitly stated, that most tone sensations are in fact repressed by a synthesizing unconscious mechanism, which behaves like a stimulus shield to deflect the shocks and superfluities of our chaotic acoustic environment.[17] Phenomena such as upper partials, beats, and combination tones were generally not consciously perceived because the dissolution of rational bundles of consistently associated sensations would have led to perceptual chaos.[18] But if the utilitarian unconscious functioned to reduce experience in some sense, a listener could still respond to those involuntary mechanisms by claiming a certain limited analytical agency, which Helmholtz specifically and repeatedly entrusted to a state of empirical attentiveness. In the final pages of the book, the physiologist reflected that

> in our usual observations on external nature our attention is so thoroughly engaged by external objects that we are entirely unpractised in taking for the subjects of conscious observation, any properties of our sensations themselves, which we do not already know as the sensible expression of some individual external object or event. (368)

Turning attention away from the semiosis of external events toward the physics of sensory-physiological events was Helmholtz's unspoken resis-

Figure 1: Rotating disk from an early, simple siren used by August Seebeck.

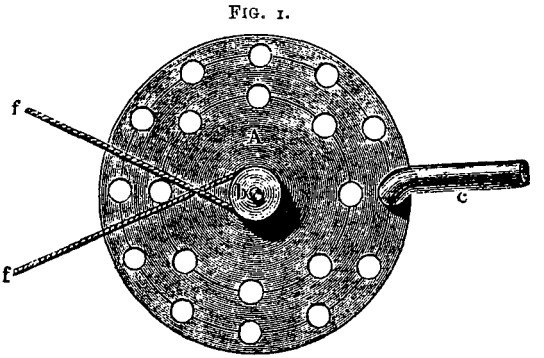
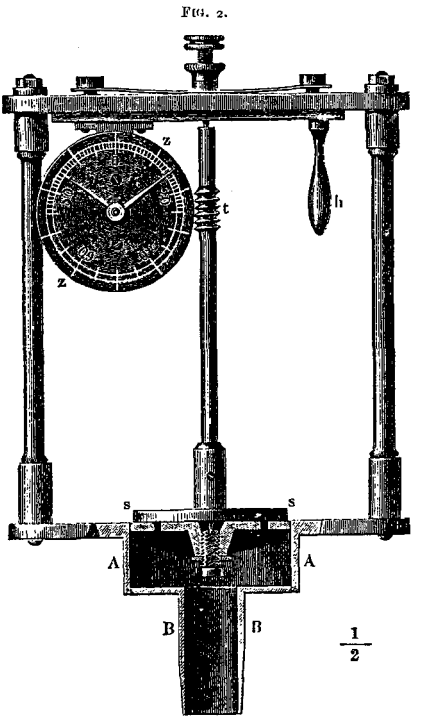
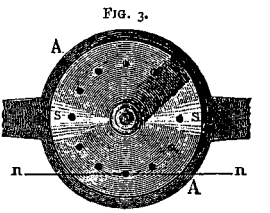


Figure 2: Views of a stronger siren used by Hermann von Helmholtz.





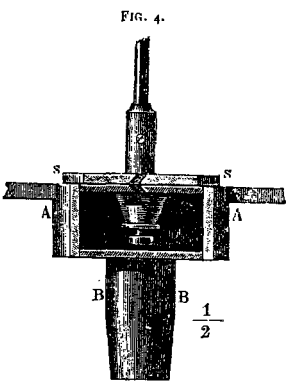


Figure 3: "Polyphonic siren" custom built for Helmholtz.

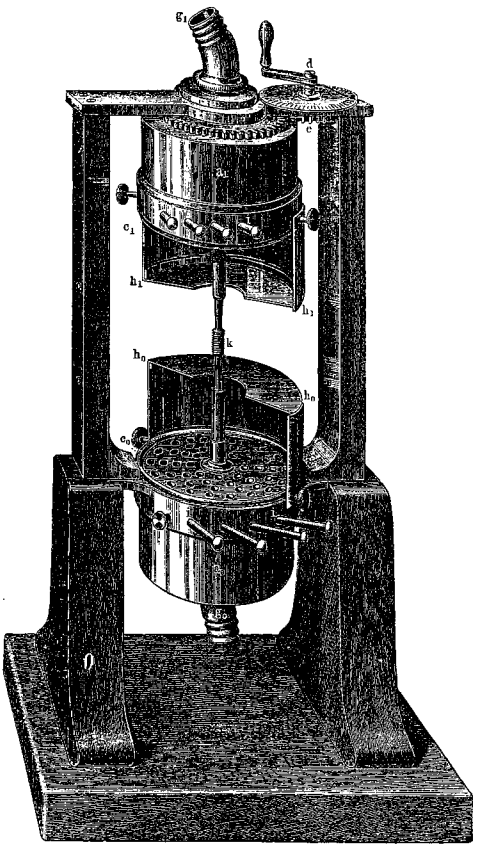
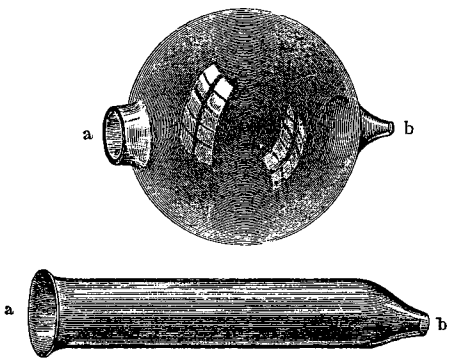


Figure 4: "Resonators" designed by Helmholtz.



tance to the means-ends trivialities of everyday life. Helmholtz, in summary, felt that Ohm's and Seebeck's difficulties (and, by extension, the insufficiency of the whole field of acoustics) resulted from an inability to appreciate that the phenomena they strained to comprehend were beyond the purview of "the conscious perception of everyday life" (368), which in fact relied upon the unconscious and uncritical consumption of external appearances. It was therefore necessary to learn new modes of listening that were themselves simultaneously aided, entailed, and regulated—in short, disciplined—by new technologies of aural attention.

The siren was one such technology. Unlike earlier instruments, scientific or musical, it could produce an indefinitely sustained tone, more regular and certainly louder than the tone of most other contemporary devices, including most pipe organs. Helmholtz described the siren tone at its most resonant as "full, strong and soft" and at times "piercing" (163). Both indefinite duration and intensity were critical, since sheer volume made it possible to observe beats and combination tones in a steady-state tone (or tones as in the "polyphonic siren" in figure 3), and to sustain the requisite attention.[19] As Helmholtz said, a propos of Seebeck's siren research, "where the experiment succeeds, it gives the best proof of the essential dependence of the result on varying activity of attention" (61). Yet if the siren represented the elimination of irregularity in the means and modes of sound production, it tended to foreground the laboring listener's perceptual fatigue.[20] One can only pay so much attention to long-enduring sensation.

Of necessity, Helmholtz was acutely conscious of potential observational fatigue, which the siren would have made especially evident. In response to the problem, he devised a modest but effective new research instrument, the so-called "resonator" (fig. 4), which aptly models the mode of aural attention Helmholtz practiced and promoted.[21] The glass or brass apparatus, which was held to the ear like a conch shell, like another "giant ear," came in many graduated sizes, each tuned to a different frequency, so that each frequency was amplified when present. Helmholtz would coat the smaller end (at b, fig. 4) with melted sealing wax, allow it to cool without entirely hardening, and then fit the wax-covered end into his ear creating an air-tight funnel for sound into the middle ear. In effect, the resonator regulated specific aural attention to even the most fragile strands within the interweaving mass of sonic events, especially higher, weaker overtones (Helmholtz 1954:43–44). If the polyphonic siren made the causes of dissonance—that is, combination tones and beats—loudly accessible to the inquisitive ear, the resonators, which could be used effectively in conjunction with the siren, gave perceptual acts a specificity and precision previously undreamed of.[22] In bringing unruly sound objects into easily manipulable,

calibrated relations with one another, and in disseminating a limited set of observational skills through popular-lecture audiences and university acoustics lecture halls, Helmholtz's sirens and resonators collapsed the distance that had separated listeners from the inaccessible aura of tone.

It is true that in Varèse's recollection of finally laying hands on his own pair of sirens, he spent more time manipulating the "marvellous parabolas and hyperbolas" they sonorously inscribed than becoming absorbed in steady-state timbre. Still, his apparently close reading of the Helmholtz text could only have imparted or strengthened a sense of the value in observing a loud, sustained tone (or tones) in order to discover renewed possibilities of sensation even in the banality of such tones. In turning now to the last scenario, a compositional one, I wish to focus on a moment in Varèse's work where the values of Helmholtzian attention play out in an unsettling manner by interrupting the flow of a very different sort of attentive engagement.

4.

The transition between the first and second movements of Varèse's *Octandre* (ex. 1) depends on a sudden shift between at least two disparate modes of engagement. In the final gestures of the first movement, as the oboe briefly recapitulates its opening *cantabile* gestures, the listener's relationship with the music seems staked on traditional expectations. Underlying the integrity of the phrasing is something like sentential repetition: statement, varied counterstatement, and fragmentary elaboration of an idea common to two preceding utterances. (What is missing, of course, is a concluding idea, a classical sense of closure.) Subphrases move to evident points of rhythmic and expressive climax; points of initiation and local closure sharply differentiate themselves. The tune itself seems to indicate its own most interesting moments. Agogically accented B♭6s, for example, locate the intensive centers of things. Deep breaths locate the ends of things, becoming the beginnings (C6) of the beginnings (B5) of new things. We might, during these utterances, feel assured that there is little ambiguity about how our attention is to align with the rhetorical codes in play. This is not to deny the complexity of the phrasing. For now, though, it is worth noticing how leisurely our encounter with the line can be, despite its expressivism: the oboe does half the work.

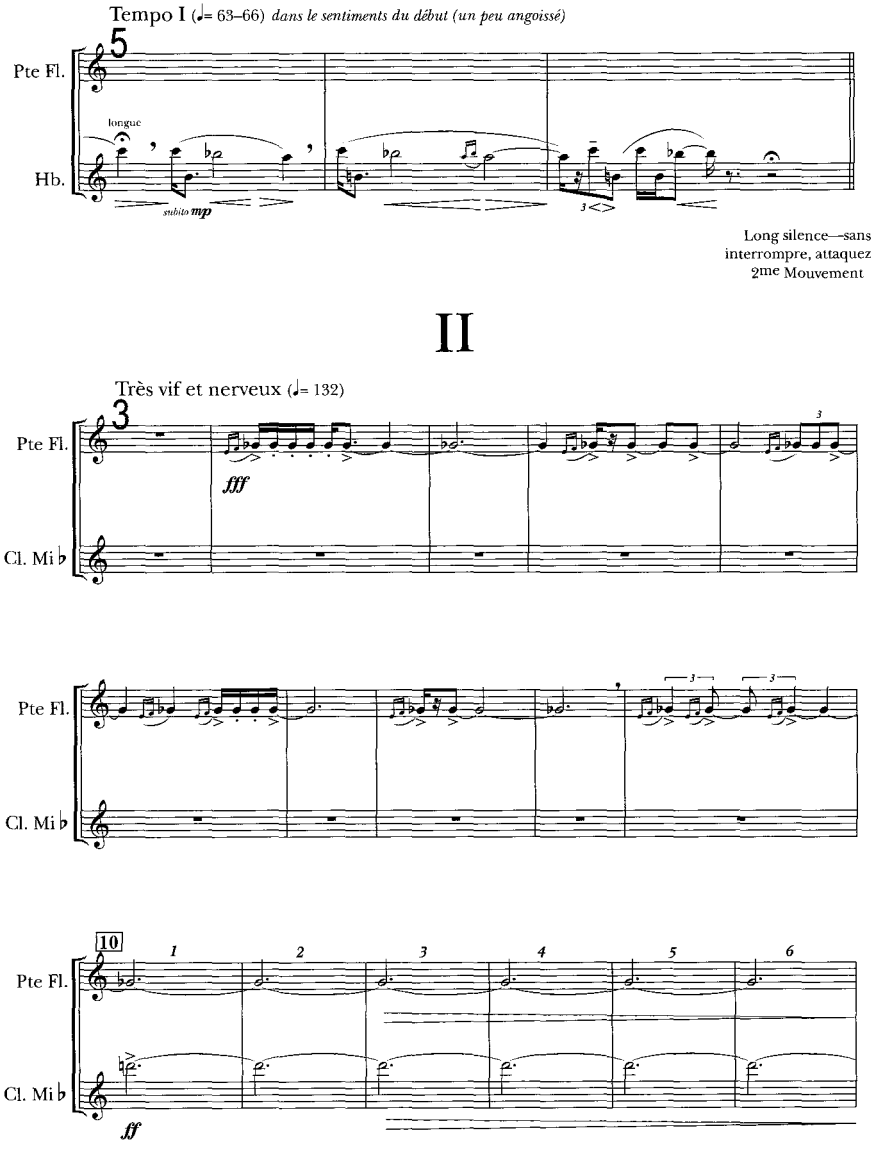
The mode of attention, of engagement and investment, which this field enables, is arguably more venerable than the one we have been exploring in the context of laboratory scenarios. In the vocal, song-like quality of the

oboe line, one might discern the passing illusion of a mutuality between a musical subjectivity beckoning from within the tones and a willing and reciprocally attentive listener. The seeming transparency of the situation recalls Rousseau in its bluffed naturalism. That is, the very singularity of the singing solo line purports, with willful naïvety, to guarantee perfect engagement between subject and object: what is uttered would be apprehended through a thin veil that separates no more than it brings together.[23] Quaintly enough for Varèse in 1923, the oboe utterances are even marked by *sentiment*, and specifically one "a bit anguished" (*un peu angoissé*). Even the caesura between movements functions on at least two levels: both on the level of *sentiment*, since the very interruption of utterance and denial of an implied continuation might have an affective, "anguished" resonance; and on a formal level, the level of form articulated by silence, which, paradoxically, is to be executed "without interruption" (*sans interrompre*). But then the situation obviously changes, as we hear how the "anguished," with its psychological implications, gives way to the "nervous" (*nerveux*), a crassly corporeal condition. At the same time, the composed and self-evident gives way to the conjured and enigmatic.

At first, frantic solo piccolo noises (mm. 1–9) render the *nerveux* expressive marking superfluous. Audible (and presumably visible) signs of nervousness accumulate as the piccolo-player executes several rapid series of fortississimo attacks in a low register and quickly becomes breathless. Rhythmic irregularity in the piccolo solo sends a distracted ear to seeking regularity *in ictus*. The sudden fortissimo entrance of the E♭ clarinet in m. 10 paralyzes the piccolo; but paralysis in the sound seems to trigger a transferal of movement from the instruments to the fully attentive ear. During mm. 10–15, my indecisive interest leaps agitatedly between G♭5 and F6. Even as attention flutters between piccolo and clarinet, we can return to an awareness of the raw sensation of a single, fused sound. That awareness might become stronger over the course of the diminuendo as the clarinet's higher partials, which are at first very harsh and tend to make F6 stand out above G♭5, soften relative to the lower fundamental. Yet, largely because the two instruments are not quite an octave but only a major seventh apart, the fusion is fairly weak. Far from fixing the object of my attention, the frozen sonority inspires a keen indecision about which simple tone to isolate. An attentive effort ends, as it must have begun, in inattention.[24] In forfeiting the sense of perceptual center to the dissipating energies of Varèse's dyad, one may intuit what art historian Jonathan Crary has called "the idea of a perception that can be both an absorption and an absence or a deferral" (1999:10).

But surely all this emphasis on the purely sustained does not say every-

Example 1: Edgar Vàrese, *Octandre* (second movement).



thing about Varèse's poetics of sound or his expectations for positive aural experience—especially when we so often find the composer making comments like this:

> The periodicity of "normal" sound puts the listener to sleep. I do not distinguish between tone and noise. If one says noise (to oppose it to musical tone) it has to do with a refusal of a psychological order: the refusal of all that turns away from purring, from "pleasing," from "lulling." (Charbonnier 1970:44)

In other words, Varèse knew that noisy attack could be a primary condition of attention. That is no doubt why the second movement of *Octandre* begins by dancing around a neurosis which Helmholtz had *written out of his book*: where Helmholtz began *On the Sensations of Tone* by dividing all sound into noise and musical tone and then proceeding to exclude noise from his subsequent writing (1954:7), Varèse made his own beginning by fixating on the inevitable breathy noise that signals the onset of a piccolo tone. Indeed, the most striking difference between Helmholtz's account of timbre and more recent ones probably lies in Helmholtz's singular attention to steady-state timbre to the repressive exclusion of "irrational" acoustic contingencies not captured by the model of the sustained attention requisite for aural Fourier analysis. But if Helmholtz's own engagement with sound found him slipping imperceptibly into contact with the already-there—deftly maneuvering his ear to alight on thin, continuous streams of this third-order combination tone or of that sixteenth partial, both of which he imagined had long been waiting to be found—Varèse confronted head-on the eventful beginnings of sounds. Varèse's invitation to attend for the first nine measures of *Octandre*'s second movement, then, appears in an extended effort to overcome that awkward and paradoxical moment of suspension in which the imperative "Listen!" is unheard because nobody is yet listening.

And yet, despite Varèse's obvious inversion or dissolution of the Helmholtzian noise-tone dichotomy, *Octandre*'s smooth dyad continues to share a significant quality with Helmholtz's sustained polyphonic siren tones in that, unlike *Octandre*'s oboe solo and the sirens' Homeric namesakes, neither was meant to beckon from afar. At least part of the effectiveness of this inter-movement transition, arguably, is that, once again, it manages a shift of scale and distance, which is not immediately perceptible, but has enormous implications for the modes of attention we devote to it. As in Nin's narrative funnel from outside in, the trajectory here seems to be from a distinctly exterior singing voice in the oboe to a dyad that presents a sensation whose location can only be found in the resonant tympanic ear, if not deeper in the aural labyrinth. I cannot think of many moments in mod-

ern music where the sense of flatness, of no distance at all, or even of negative distance, is so clearly evoked as in mm. 10–15 of this movement. And the complete eradication of distance has everything to do with the kind of sensation Helmholtz had in mind: to the extent that the human sensorium (and not external objects or their qualities) had the last word in the production of perception, the question of how far our bodies were from what was acting on them became, to a great extent, a moot point. When I attend carefully to this dyad, I cannot help but become keenly—painfully—sensitive to the interiority of the sensation, to the sense of my head vibrating and resonating, and to the feeling of becoming a "giant ear." This, I believe, is the aurality that Helmholtz's sirens and resonators pull into focus. Though it was usually clear to Helmholtz whether what we heard resided in exterior acoustic modifications of the air or in interior acoustic modifications of the ear and its associated nervous pathways, the emphasis in the last analysis was always on the inside, or at least on the inside exteriorized to the physiological gaze.

5.

After our concern with the laboratory space, the laboratory's transformative generation of interests, interest's legitimation of attention, and, finally, attention's resistance to utilitarian perception, what are we to make of this awkward exchange between Varèse and a friend in 1955, which recapitulates all of these themes in an unsettlingly inconclusive manner?

> **George Charbonnier**: When I consider the *sentiment* of nature for Jean-Jacques Rousseau, the utilitarian side of signs disappears completely. Or when I consider the *sentiment* of nature the pre-Romantics may have had. What I want to say is that *sentiment*, disengaged completely from any utilitarian consideration, contains an auditive image, a visual image.

> **Edgard Varèse**: The physicists of our epoch live in a realm very different from ours . . . they receive visual images, auditive images different from those which struck M. Jean-Jacques Rousseau, and which interest them nevertheless. For example, the images collected in the tunnels where they do experiments on supersonic or ultrasonic models. The machine sends images to the lone physicist. And it is in these images that the physicist interests himself. [*La machine propose des images au seul physicien. Et c'est à ces images que le physicien s'intéresse.*] (Charbonnier 1970:41)[25]

Why does Varèse coyly sidestep the issue of Rousseauan "*sentiment*" when it

seems that he was at one point quite willing to raise it musically (at least between himself and *Octandre*'s oboist)?

Here, as between the first two movements of *Octandre*, we slide effortlessly from the airy world of "natural" signs and sentimental empathy to the speechlessly corporeal in Varèse's fantasy of a particle physics experiment, where anonymous images seem to stare blankly back at the attentive physicist. It is intriguing to see how Varèse's oblique response to Charbonnier's question lands him back in an amniotic space inhabited by the isolated scientist, the *seul physicien*, of anomalous interest, passively "receiving" images rather than creating or even manipulating them. Sadly, by the mid-1950s, although Varèse was just then beginning to find points of entry into some labs equipped for composers, his vision of the laboratory laborer has lost something of its earlier optimistic, collaborative character.

Despite the hint of despair in the latter vision, Varèse had been justified in hoping that a laboratory would be a site of transformation where musicians could re-align the values of symbolic notations with respect to the materialities of acoustic phenomena. I have explored possible motivations for Varèse's faith in the potential of laboratory collaboration to bring attention, even in its contingency and fallibility, to bear on the transformation of compositional materials by re-scaling the registers in which aural perception unfolds. Such transformative negotiations would apparently be only mediable through close listening of the awkward kind that confronts us when we try to get something other than "static dyad" out of the second movement of *Octandre*. As we have seen, "real" or "natural" acoustic events rarely if ever reveal themselves through the kind of transparency that attentive engagement may at times promise; access to such phenomena always presupposes a specially trained sensorium heavily marked by habit and implicit knowledge. To see that the aurality of the laboratory is always bound up in a network of technologies both visible and invisible is to grasp and grant that no attentive observation is ever entirely transparent or natural.[26] Indeed, the laboratories that housed such attentive labors were nothing if not extensions of an unusually modern fantasy: railroad-like means to shift everything constantly around in relation to everything else, such that the movement is disconcertingly imperceptible. In Varese's transposition of "laboratory" techniques of listening into composition, though, these shifts of distance come to have a slightly different value. By giving us a moment's pause, such points of suspended attention as that in *Octandre*, or any number of similar events in Varèse's music, present a vital opportunity to remind ourselves both of attention's vulnerability to outside, extensive forces and also of its capacity to make intensive, musical perception our own.

Notes

This article has profited from many private conversations about Varèse and Helmholtz with a number of individuals, including Robert Brain, Christopher Hasty, Myles Jackson, David Lewin, David Pantalony, and Alexander Rehding. I am grateful to the organizers of the Columbia University Graduate Student Conference in Music Scholarship in January, 2004 for allowing me a chance to air some initial thoughts on this topic. Many thanks also to the *Current Musicology* editorial staff and Brigid Cohen for patient and critical readings and discussion of the article's various drafts. Finally, I am thankful to Dr. Felix Meyer of the Paul Sacher Foundation in Basel, Switzerland, for making the new Edgard Varèse Collection available and for permitting me to publish some excerpts from correspondence held there.

1. See, for example, Varèse (1930; 1967:198–201) and Charbonnier (1970:69–79).

2. A wealth of recent scholarship across many humanities disciplines indicates just how complex and multivalent notions of attention can be. See Crary (1999), Daston (2001), Hagner (1998), Hamacher (1998), Johnson (1995:53–70), Riley (2000), and Wheelock (1992:154–92).

3. Thompson's chapter on "Noise and Modern Culture, 1900–1933" provides fresh and compelling context for Varèse's New York (Thompson 2004:115–69).

4. In a 1939 lecture, Varèse proclaimed, "Jean Christophe, the hero of [Rolland's] novel, was a prototype of the modern composer and was modeled on different composers whom Romain Rolland knew—among others, myself" (Varèse 1967:199). (Rolland had already been writing the novel before he met Varèse in 1909.)

5. Fletcher's reference to "forty-eight normal ears" occurs specifically in the context of describing experiments to establish the lowest threshold at which gradually increasing intensity of tone becomes "sensed by the ear" as sound (1929:142).

6. In Alejo Carpentier's words, "'J'abandonne la musique, déclara Varèse. La musique n'intéresse plus personne aujourd'hui. Je deviens businessman. Ne riez pas. J'ai le sens des affaires. Je vais de ce pas offrir mes services à une grande entreprise. Avec mes connaissances, en mathémathiques et en physique, je peux réussir."

7. "Un compositeur, s'il veut obtenir les résultats que sa conception appelle, ne doit jamais oublier que son matériau brut est le son . . . Il doit comprendre non seulement le mécanisme et les possibilités des différentes machines sonores qui font vivre sa musique, mais il doit être aussi familiarisé avec les lois de l'acoustique."

8. "De par son éducation l'oreille humaine a été discipliné ou entraînée à faire abstraction de ce résultat."

9. "Pour présenter mes idées à des techniciens de différentes organisations afin de procéder à des vérifications et aussi pour leur prouver la nécessité d'une collaboration étroite entre le compositeur et l'homme de science."

10. He worked on *Déserts* in 1954 at the Club d'Essai of Radiodiffusion-Télévision Française in Paris and later touched up that piece's tape components at the Columbia-Princeton Electronic Music Center in New York. *Poème électronique* was composed in 1958 at Philips Laboratories in Eindhoven.

11. Mathews and Guttman expressed their approval of the "laboratory," however crude it may have been, in a thank-you note sent after a dinner party at the Varèse home. The note is in the Edgard Varèse Collection, Paul Sacher Foundation.

12. Nin's momentous entrance into the Varèse home-laboratory was not unique. Younger

composers, including David Lewin, have related parallel anecdotes. Lewin told me (in private conversation, April 22, 2003) that when he visited Varèse in the early 1960s, the older composer was very excited about the particular resonances produced by a certain metal rod and told his guest to hold an ear up to the instrument while Varèse struck the rod forcefully with a hammer. As young Lewin's eardrum vibrated violently in (sympathetic?) response to the quivering tube, Varèse grinned with pride and enthusiasm. I take this story to convey how Varèse located the experience and close empirical observation of complex isolated resonances not only at the center of his solitary laboratory life but even at the crux of his social interactions. It does not seem too much to imagine this otherwise casual encounter as another instance of Varèse's attempts to use even his makeshift laboratory to capture outside interest in his activities by focusing attention on objects he created in his own interior space.

13. For a unique and provocative evaluation of "aurality" and the metaphor of the "aural labyrinth" in postmodern cultural production, see Docherty (1997). Kahn (1999) also takes certain constructions of "modern aurality" as an interpretive point of departure for a range of cultural artifacts from the 1870s to the 1960s.

14. For relevant discussions of the siren, see Helmholtz (1954:11–14,161–65). It is well worth noting that one of Helmholtz's most accomplished instrument-builders, an acoustician named Rudolph Koenig, lived and worked in Paris and, from the 1860s on, constructed sirens of several models, attesting to the siren's great popularity as a research instrument at that time. According to David Pantalony, the siren remained "quite popular" in Paris after Koenig's death in 1901 (2002:87). Little surprise, then, that Varèse would have found two specimens in a Paris flea market in the first decade of the century.

15. Several recent publications on the siren in nineteenth-century research have manifested a fairly broad current interest in Helmholtz's siren experiments. For a thorough discussion of the sources and significances of Helmholtz's acoustic research instruments, see Pantalony (2002:54–117). The siren (especially in connection with *On the Sensation of Tone*) sits prominently amid wider cultural-historical arguments in Welsh (2004) and Hilgers (2004). Also see Vogel (1993).

16. Summaries of this debate can be found in Helmholtz (1954:58–63), Turner (1977), Vogel (1993), and Hilgers (2004). Vogel points out that the siren's mode of sound production in itself heralded a new conception of sound: rather than the wave form, let alone the medium of vibrating bodies, determining the quality of tone, this would now be observed to vary purely with the upper partials' vibrational periodicities, whether periodicity was imaged sinusoidally (Ohm) or otherwise (Seebeck) (Vogel 1993:263). Hilgers extends this point to argue that sirens put the theoretical notion of sound's fundamental continuity into question by contesting the dominant sinusoidal image of sound with a discretely pulsive one (i.e., a nearly isochronous series of puffs). The latter would find a more comfortable place within the systems of discrete signs (*Zeichensysteme*) Helmholtz postulated as enabling an intelligible external world, despite his ultimate validation of Ohm's law (Hilgers 2004).

17. See, for example, the discussion of difficulties in observing upper partials (Helmholtz 1954:56–67).

18. Helmholtz's notion of "unconscious inference" was apparently developed first in his work on physiological optics. Discussions of the Helmholtzian unconscious, with varying emphases, appear in Boring (1929:308–11) and more recently in Krauss (1993:133–37) and Hatfield (1993:547–51; 2002:128–31).

19. While early sirens of the 1820's through mid-century were operated manually by wind bellows and crank—but, critically, with minimal human physical exertion—later sirens of

the 1870s were often powered electromagnetically, confirming their place within a canon of modest but modern sound technologies. See Pantalony (2002:85–88).

20. The siren was not the only, nor even the most spectacular, of Helmholtz's devices for producing tones of indefinite duration in the laboratory. The "vowel synthesizer," composed of several tuning forks, which were caused to vibrate electromagnetically and tuned to each of the first several partials of a particular fundamental, was used to demonstrate the relationship between the various partials' amplitudes or intensities and the overall timbre of the full, sounding series, and was fundamental to Helmholtz's research on vowel quality. See the discussions of this instrument in Lenoir (1994) and Pantalony (2002:73–76).

21. This instrument was to become perhaps the most common feature of psychology laboratories as well as of acoustics lectures in the second half of the nineteenth century and represented a significant material extension of Helmholtz's scientific authority across the discipline of physical acoustics. See the discussions of resonators in Helmholtz's and later research in Pantalony (2002:70–73,92–109).

22. Ultimately, the aim of Helmholtz's book was to indicate the ramifications of these now-observable sensations, first in their influence on the perception of dissonance and consonance and then on the unconscious logic of European triadic harmony. The hidden structure of the upper partials, once revealed through technologically-supported perceptual vigilance, could be heard not only to cause the unpleasant disturbances of dissonance that we had for centuries sensed but failed to understand, but also to provide the rationale upon which composers proceeded to make aesthetic decisions.

23. The sentimental mutuality and empathetic structure of this attention surely recapitulates Rousseau's vision of the compassionate citizen. As Terry Eagleton has written: "The root of this civic virtue is the pity we experience for each other in the state of nature; and this pity rests on a kind of empathetic imagination, 'transporting ourselves outside ourselves' ... At the very root of social relations lies the aesthetic source of all human bonding. If bourgeois society releases its individuals into lonely autonomy, then only by such an imaginative exchange or appropriation of each other's identities can they be deeply enough united" (1990:24).

24. "G. C.: Mais si je pense au sentiment de la nature pour Jean-Jacques Rousseau, le côté utilitaire des signes disparaît complètement . . . Je veux dire que ce sentiment, dégagé de toute considération utilitaire, se contentait de l'image auditive, de l'image visuelle.

"E. V.: Les physiciens de notre époque . . . reçoivent des images visuelles, des images auditives différentes de celles qui frappaient Monsieur Jean-Jacques Rousseau, et qui cependant les intéressent autant. Par exemple, les images recueillies dans les tunnels où l'on fait des expériences sur les modèles supersoniques ou ultrasoniques. La machine propose des images au seul physicien. Et c'est à ces images que le physicien s'intéresse."

25. I am by no means the first to linger on this moment. James Tenney, in his *History of "Consonance" and "Dissonance,"* observes the F-G♭ sonority closely in illustration of the relationship between timbre and dissonance in Hermann von Helmholtz's theory of beats (1988:90–91). I thank Bob Hasegawa for referring me to this book.

Helga de la Motte-Haber intuits a very different, more unified, gambit from this modest dyad, arguing that "even if beats are intended, no dissonance is meant." She then discusses how certain "inferior resultant tones" present during the dyad's sounding are picked up as fundamentals in the music's continution. This supports her argument that Varèse's physicalist orientation is distinct from a non-relational aesthetic that would value the sounds in themselves without regard to their specific formal, compositional implications (Motte-Haber

1993:59–61).

26. To say this unqualifiedly does no justice to a great amount of recent thinking that has sought to explore the so-called "materialities of communication." But that is another study in itself. Here, I simply cite three relevant publications, each of which distinctively undertakes to re-evaluate the constitutive roles of technology in nineteenth-century listening: Timothy Lenoir's analysis of an influential acoustic research instrument of Helmholtz (1988), Jonathan Sterne's compelling history of sound and techniques of listening (2003), and John Durham Peters' exploration of Helmholtz's and Thomas Edison's reconceptualization and, quite literally, reactualization of "voice" (2004).

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