Music and the Transhuman Ear:
Ultrasonics, Material Bodies, and the Limits of Sensation

"We favor morphological freedom – the right to modify and enhance one's body, cognition and emotions." (Transhumanist declaration, 2012)[1]

"I am apt to think, if we knew what it was to be an angel for one hour, we should return to this world, though it were to sit on the brightest throne in it, with vastly more loathing and reluctance than we would now descend into a loathsome dungeon or sepulchre." (George Berkeley, 1732)[2]

PART I

The materialist turn

When Voyager probes 1 and 2 left the earth's orbit in 1977, the committee tasked with assembling cultural artifacts followed scientist Lewis Thomas' advice to include recordings of J. S. Bach among the many musical samples. This, it seems, was the best way to open a conversation with an unknown non-human interlocutor, wherein exchanges may be spaced hundreds of years apart. Many styles and genres were committed to the golden discs, but Thomas worried that by broadcasting Bach, the human race might be guilty of bragging to aliens: "we would be bragging, of course," he admitted in 1972, "but it is surely excusable to put the best possible face on at the beginning of such an acquaintance."[3] His statement makes telling assumptions. To take one example, the three-voice C-major fugue Glenn Gould recorded (WTC, Book II) matches humans' ability at auditory streaming, which, as David Huron has shown, tends to max out at around three streams, after which "confusions [over contrapuntal lines] become commonplace."[4] It would seem that part of the effect of Bach's

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[1] Various, "Transhumanist Declaration," *The Transhumanist Reader*, ed. Max More and Natasha Vita-More (Oxford: Wiley-Blackwell, 2013), 54-56, here 55.

[2] George Berkeley, *The Works of George Berkeley*, ed. Alexander Campbell Fraser, 4 vols. (Oxford: Clarendon, 1901), 2:190.

[3] Lewis Thomas, *A Long Line of Cells: Collected Essays* (New York: Book-of-the-month club, 1990), 36. The golden disc contains performances by Glenn Gould (Prelude and Fugue, WTC II, C major), Arthur Grumiaux ("Gavotte en rondeau" from the solo violin Partita no. 3 in E), and Karl Richter (Brandenburg concerto no. 2 in F, first movement). The selection committee was chaired by Carl Sagan. For details see: http://web.mit.edu/lilybui/www/ [accessed 6 October 2016]

[4] David Huron found that "for musical textures employing relatively homogenous timbres, the accuracy of identifying the number of concurrent voices drops markedly at the point where a three-voice texture is

polyphony depends on precisely that limitation, but there is no reason to suppose that a hypothetical alien would have the same limitation, if it were sensitive to this frequency range; the alien might just as easily find Bach's fugue elementary, even trivial.

Extrapolating from this distancing exercise, this article is about transhumanism and hearing. It takes a lateral approach to writings in the history of materialism to plot a course for the *human* ear between two reciprocal paradigms: a receptacle of vibrational force and an augmentable prosthesis creating new sensory feedback. These two paradigms structure the article's two parts: Part I sets out the materialist context, including—briefly—a study of empirical sense augmentations (and their illusions) in the nineteenth century; Part II extrapolates from this a critique of hearing-enhancing technologies that exist today under the tenets of transhumanism.

The last decade has witnessed entwined debates over listening and media, in which contributors have sought to place both the sonic phenomenon and the experience of performed music at the heart of the matter.[5] I'd like to begin with two—I hope uncontroversial—claims: performance acts necessitate a witness, however remediated they become; and music, as something that is perceived, is a sensible phenomenon. Ears and eyes structure our relation to music, while at the same time being constitutive of our sense of self within an environment; as apparatus for mediating sound and light they attest to the body as "the pivot of the world" in Maurice Merleau-Ponty's memorable phrase.[6] Approaches to sound as vibrational event imply a need to relativize

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augmented to four voices" in Huron, "Voice Denumerability in Polyphonic Music of Homogeneous Timbres," *Music Perception* 6 (1989): 361-82, here 361.

[5] Within musicology, discursive approaches to performance and sensation include Carolyn Abbate, "Music: drastic or Gnostic?" *Critical Inquiry* (2004); Nicholas Cook, *Beyond the Score* (New York: Oxford University Press, 2014); and Elizabeth Le Guin, *Boccherini's Body: an Essay in Carnal Musicology* (Berkeley and Los Angeles: University of California Press, 2006). Within sound studies, Nina Eidsheim proposes a "vibrational theory of music" and reframes the concept of sound as "merely a trope" of understanding music, one that neglects the wider phenomenon of vibrational force. See *Sensing Sound: Singing and Listening as Vibrational Practice* (Durham and London: Duke University Press, 2015), 6, 9. Non-music-centric texts include Shelley Trower, *Sense of Vibration: A History of the Pleasure and Pain of Sound* (New York: Continuum, 2012), while empirical studies include: Christian Gaser and Gottfried Schlaug, "Brain structures differ between musicians and non-musicians," *The Journal of Neuroscience* 23 (2003): 9240–9245; *Musical Networks: Parallel Distributed Perception*, ed. Niall Griffith and Peter M. Todd (Cambridge MA: MIT Press, 1999); and *Sound – Perception – Performance*, ed. Rolf Bader (Cham and New York: Springer, 2013).

[6] Maurice Merleau-Ponty, *Phenomenology of Perception* [1945], trans. Donald A. Landes (London and New York: Routledge: 2013), 84.

hermeneutic or metaphysical knowledge with a theory of matter. Despite a long tradition of philosophical materialism in the West, such disciplinary reorientation is potentially unsettling. After all, music can animate matter; as Carolyn Abbate reminds us, it "can ban logos or move our bodies without our conscious will."[7] Without reifying sonic communication entirely, such a condition defines sound's communicative agency itself as animate matter – a delicate dance of vibration and physiology.

Historically, this view first gained credence in the mid-nineteenth century when Hermann von Helmholtz posited the ear as a mechanism for sympathetic vibration: "a peculiar apparatus, partly elastic, partly firm, which may be put in sympathetic vibration under the influence of external vibration."[8] Stemming from this, and adapting Brian Massumi's formulation of affect, we may say the vibrations of the haptic environment touch us manifestly and without prejudice, impacting listeners with a "prepersonal intensity corresponding to the passage from one experiential state of the body to another." In this reading, the communication network is primarily between bodies: "an encounter between the affected body and a second, affecting body."[9] It applies as much to the plucking of a monochord as to a subwoofer's vibrations that palpably shake us. This is not to deny the life of the mind—from what is phenomenologically given to the mind, to the truism that even during absorption in performance we may reflect momentarily on formalist or hermeneutic meanings[10]—only that once music as sounding experience becomes an object of study, the sensory means by which we register that experience are also implicated as structural constituents of the identity of that music.[11]

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[7] Abbate, "Drastic or Gnostic," *Critical Inquiry* (2004), 505-536, here 532.

[8] Helmholtz, *On the Sensations of Tone* [1863 / 1875], trans. Alexander J. Ellis (Cambridge University Press, 2011), 142. By positing an automatic mechanism that could not be ignored (we lack "ear lids"), Helmholtz required a discrete role for auditory perception, beyond the causal mechanism of stimulus and specific sensation identified by Johannes Müller in 1835.

[9] Brian Massumi "Foreword" to Gilles Deleuze and Félix Guattari, *A Thousand Plateaus* [1980], trans. Massumi (Mineapolis and London: University of Mineapolis Press, 1987), xvi.

[10] On this point, see particularly Karol Berger, "Musicology According to Don Giovanni, or: Should We Get Drastic?", *Journal of Musicology* 22 (2005): 490-501, here 497.

[11] Such an argument stretches back at least to David Hume's empiricism and the theory of primary and secondary sense qualities.

So far so good. But there are already compositions whose sound exceeds human sense capacity. The totality of their performance is unavailable to us, in other words, which is to say: literally non-sensical.[12] Two examples concern pitch and duration:

(i) There are ultrasonic dog whistles in Per Nørgård's Fifth Symphony (1994), and seemingly inaudible harmonics in Schoenberg's Violin Concerto (b'''' at mm. 544 and 568, given in example 1), which André Mangeot declared "beyond the *musical* range of any ear" because at 3951Hz their pitch and relative consonance become impossible to discern, he felt.[13]

(ii) Consider the inhuman length of John Cage's "As SLow aS Possible" for organ (1987), whose ongoing performance in Halberstadt—lasting 639 years—will exceed an average American lifespan by a ratio of 8:1. As Alexander Rehding notes, there can be "no performer in the ordinary sense" for this work, and indeed the work concept itself falters "for the simple reason that it is humanly impossible to hear the piece from beginning to end."[14] If we accept the view that musical performance is to be understood as lived experience, bodies that could conceivably perceive the totality of these works are not ordinarily human. In the context of Bach's alien we may ask: for whom are such super-sensory effects intended? Who, in such contexts, is the listener?[15]

[Example 1 near here]

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[12] Merleau-Ponty stands in a long line of theorists aligning the identity of art with its physically embodied existence. "The meaning of a work of art or of a theory is as inseparable from its embodiment as the meaning of a tangible thing—which is why the meaning can never be fully expressed." In Merleau-Ponty, *Sense and Non-Sense* (Illinois: Northwestern University Press, 1964), 4.

[13] Mangeot seeks to verify the inaudibility of the super B by arguing that "this can be proved by striking a major seventh with the top C of a piano that has the two extra notes; it will sound exactly like an octave." If this verdict is debatable for a pitch still within the 88-key span of the piano, it is worth recalling that the overtones of any acoustic instrument continue beyond our auditory threshold. See André Mangeot, "Arnold Schoenberg's Concerto for Violin and Orchestra, op. 36," *The Strad* 50, No. 599 (March 1940): 420-24 and No. 600 (April 1940): 450-56, here 450. Emphasis added.

[14] Alexander Rehding, "The Discovery of Slowness in Music," *Thresholds of Listening*, ed. Sander van Maas (New York: Fordham University Press, 2015), 211-212.

[15] In many cases, such effects may simply be the unintended consequences of notational decisions that need not be taken too seriously. After all, such moment are anomalous in Western art music. Yet anomalies clarify what is consistent in non-anomalous phenomena, presenting the possibility of difference, and of other categories. Thomas Kuhn famously argued that it was anomalies—becoming the insistent focus of practitioners—that lead to paradigm changes. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1970).

To an extent, this line of enquiry recontextualizes a familiar eighteenth-century empiricist debate about reality: George Berkeley's immaterialist proposition that "the objects of sense exist only when they are perceived" (which finds parlance today as the old adage about a tree falling in a wood).[16] For present purposes, it is a related, potential blind spot of semiotic approaches to music that reveals common assumptions about the "normal" body at the dawn of the twentieth century. We recall Charles S. Peirce, in 1909, saw a triadic relation between sign, object and interpretant wherein the latter becomes an *active* witness to the sign, and actively makes the bond between sign and object. Signs nevertheless retain their absolute character in this bonding, for what Peirce grandly calls the "final interpretant" constitutes nothing less than "the effect the Sign would produce *in any mind* upon which the circumstances should permit it to work out its full effect."[17] The totalizing nature of such a sign is like "a light wave"—in Massumi's words—whose spectrum-rich vibrations emit more "than any necessary perception of it picks up on."[18] With a similar rationale, Wolfgang Ernst calls acoustic sound "the deceptive top of an iceberg" vis-à-vis the vast, inaudible electromagnetic spectrum.[19] By definition, music insensible to us does not work out its full effect, reminding us that Peircean semiotics presupposes a known receptor apparatus in the (human) interpretant. Semiotic approaches to music have arguably been enthralled to this Berkeleyian complement: signs or signals only become such—i.e. tangibly received stimulation—upon contact with a witness' means of perception.[20]

Hearing ultrasonics ca. 1876

Historically, this realization came to a head most clearly in the last quarter of the nineteenth century, i.e. a shortly before Pierce's "final interpretant," when German

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[16] George Berkeley, *A Treatise Concerning the Principles of Human Knowledge*, rpt ed. Jonathan Dancy (Oxford: Oxford University Press, 1998), § 45.

[17] Peirce to Lady Welby, 14 March 1909, in *Semiotics and Significs*, *The Correspondence between Charles S. Peirce and Victoria Lady Welby* (Bloomington and London: Indiana University Press, 1977), 110. Emphasis added.

[18] Brian Massumi, *Parables for the Virtual: Movement, Affect, Sensation* (Durham: Duke University Press, 2002) 92.

[19] Wolfgang Ernst, *Sonic Time Machine* (Amsterdam: Amsterdam University Press, 2016), 21.

[20] This precedes even the basic assumption from structural linguists that all communication rests on a principle of common coding. See Roman Jakobson, *Language in Literature*, ed. Krystyna Pomorska and Stephen Rudy (Cambridge, MA: Harvard University Press, 1987), 451ff.

scientists debated the upper threshold of human hearing within the triangulated framework of physiology, emergent phenomenology, and empirical psychology. It caused a minor scandal that is worth recalling here for the startling readiness with which sensory limits were re-written.

During the 1870s, the Hanau-based German instrument maker Anton Appunn produced a series of 31 high-pitched tuning forks. These were listed as corresponding to the 4.5 octaves of the diatonic scale, from c^4 to e^8. After empirical studies based on these unprecedented objects, the Anglo-German physiologist Wilhelm Preyer issued a striking claim in 1876:

> Thus we can lay to rest the doubt, repeated all too often, as to whether or not it is possible to hear from 24,000 up to 40,000 double vibrations per second. It appears we can not only perceive tones in this omitted eighth octave, but also differentiate them.[21]

Empirical work with Preyer's listening subjects appeared to prove the upper threshold for hearing was somewhat higher than previously thought. To look at a chain of prior acousticians researching the same phenomenon, he infers, is to plot a rising auditory threshold for humankind. Joseph Sauveur (6,400Hz; g^5), Ernst Chladni (8,192Hz; c^6), and Jean Baptiste Biot (8,198Hz; c^6) were seemingly cut adrift by William Hyde Wollaston (25,000Hz; g^7) and César-Mansuète Despretz (36,864Hz; d^8), the latter of whom only refrained from venturing higher, we learn, because he was unable to make a smaller fork resonate.[22]

By Autumn 1875, Preyer had pipped his immediate rival by a whole tone, achieving what he gave as an audible e^8 at 40,960Hz with a midget fork 13mm long, 14mm wide, with prongs 3mm thick. Human hearing had not been rising in convenient synchrony with each researcher, he concluded, so the new threshold too was quite possibly limited only by the ability to engineer a suitably resonating fork rather than the physiology of the ear, which continued to recognize relative pitch:

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[21] 'Sodann werden die allzuoft wiederholten Zweifel beseitigt, ob es möglich sei, 24000 bis gegen 40000 Doppelschwingungen in der Secunde zu hören. Es ergab sich, dass man noch Töne der achtgestrichenen Octave nicht allein wahrnehmen, sondern auch von einander unterscheiden kann.' Wilhelm Preyer, *Über die Grenzen der Tonwahrnehmung* (Jena: Hermann Dufft, 1876), iii.
[22] Ibid., 19.

> I and several others have heard all 31 tones often, and, if they resound along the row from c^6, I recognize quite clearly that they rise up to e^8 [40,960Hz]. Until c^7 we hear the scale without difficulty. To be sure, pitches in the 7th and 8th octaves are close to being very painful; nevertheless we recognize they always rise and we hear the octaves very well until e^8 ... One cannot claim, though, that it is impossible to bring forth even higher tones just because the e^8 fork becomes silent when shortened further. For it must be proven whether it still vibrates at all after shortening, and indeed encounters sufficiently strong vibrations, before we conclude the ear falls short.[23]

The exact pitch of Appunn's highest folk was debated, and Preyer appears to have been unaware that for different commentators this "exceedingly diminutive" object resonated at either 49,152Hz or 50,880Hz.[24] Nevertheless, his eye-widening claim that a bowed fork was audible to humans at 40,960Hz and that our physiological limit may be higher still received a supreme endorsement when Helmholtz repeated it uncritically in the fourth edition of *Die Lehre von den Tonempfindungen* (1877).[25] This augmented auditory range "shows what a great variety of different pitch numbers can be perceived and distinguished by the ear," he remarks of the 11-octaves between 20Hz - 40,000Hz. "In this respect the ear is far superior to the eye," he concluded in a countercultural opinion that would hold little sway over the visualist bias of the age.[26]

Helmholtz had no reason to doubt Preyer's science (which also examined the lowest perceivable frequencies, and identified silence as "a true, positive sensation ... different from deafness").[27] The Appunn family had long supplied tuning forks to Helmholtz, and Georg Appunn (*père*) had lectured in Leipzig during the 1860s, supporting Helmholtz's work and helping to popularize it in print; there was a mutual bond of

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[23] "Ich und mehrere Andere haben alle 31 Töne oft gehört, und, wenn sie von c^6 an der Reihe nach erklingen, vollkommen deutlich erkannt, dass sie bis zum e^8 immer höher werden. Bis zum c^7 hört man auch ohne Schwierigkeit die Tonleiter. Die 7 und 8-gestrichenen Töne sind zwar in der Nähe sehr schmerzhaft; man erkennt jedoch, dass sie immer höher werden und hört auch sehr gut bis e^8 die Octaven. ... Man kann jedoch nicht behaupten, es sei unmöglich, noch höhere Töne hervorzurufen, weil die e^8-Gabel bei weiterer Verkürzung tonlos wird. Denn ob sie nach der Verkürzung überhaupt noch in Schwingungen, und zwar genügend starke Schwingungen geräth, muss nachgewiesen werden, bevor man den Schluss zieht, dass das Ohr versagt." Ibid., 21, 23.

[24] See John Zahm, *Sound and Music* (Chicago: A. C. McClurg and Co., 1892), 83; and Carl Stumpf, "Ueber die Bestimmung hoher Schwingungszahlen durch Differenztöne," *Annalen der Physik und Chemie. Neue Folge* 68 (1899): 105-116, here 105.

[25] Hermann von Helmholtz, *Die Lehre von den Tonempfindungen als Physiologische Grundlage für die Theorie der Musik*, 4th edn (Brunswick: Friedrich Vieweg and Son, 1877), 30.

[26] Helmholtz, *Sensations of Tone*, 18, 151.

[27] 'eine wahre positive Empfindung und ebenso verschieden ist von dem Nichthören.' Preyer, *Ueber die Grenzen*, iv.

trust, it seems.[28] Other endorsements of Preyer's work ensued, owing partly to the knowledge that it was based on a new, more accurate method of tuning the highest forks.[29] Before 1876, forks above c^7 were tuned by means of the ear alone, typically by locking into the overtones of lower octaves, but Rudolph König had demonstrated as early as 1858 that from the range c^6 – c^7 this method was highly inaccurate even with the best trained musicians.[30] Between 1874 and 1876, König first effected the tuning of high-pitched rods (professing audibility up to 20,480Hz) according to their beats; Preyer followed suit with his forks, and appeared to trump his fellow instrument maker by some 20,000Hz.

König was skeptical from the outset.[31] It fell to physicist Franz Emil Melde to prove in 1894—the year of Helmholtz's death—that Appunn's forks and corresponding pitch pipes were in fact mistuned by between a minor third (c^6 fork) and a full octave (c^7 fork). "The highest pipe was only ca. 11,000 rather than ca. 50,000 vibrations," explained one commentator, continuing that the "forks too showed errors of up to ca. 36,000 vibrations."[32] It was Carl Stumpf and Max Meyer who finally put a stop to Preyer's auditory inflation when in 1897, they verified Melde's assertion using a proof based on difference tones.[33] When Stumpf returned to the fray in 1899, he refuted Preyer's protest that a visual proof (*optischer Nachweis*) of his ultrasonic pipes and forks

[28] Georg Appunn, *Ueber die Helmholtz'sche Lehre von den Tonempfindungen als Grundlage für die Theorie der Musik, nebst Beschreibung einiger, zum Theil ganz neuer Apparate welche zur Erläuterung und zum Beweis dieser Theorie geeignet sind* (Hanau, 1867). See also Benjamin Steege, *Helmholtz and the Modern Listener* (Cambridge University Press, 2012), 37-39.

[29] John Augustine Zahm writes that '[n]o one can doubt the skill of Herr Appunn as a mechanician … We are consequently, by the very necessities of the case, compelled to accept Herr Appunn's estimate as that of an expert and that he is an expert in his speciality no one can gainsay.' In Zahm, *Sound and Music*, 83-84. As late as 1925, Alexander Wood copied Helmholtz in citing Preyer's work before proclaiming: 'it may be safely asserted that our ears are sensitive to sounds having frequencies lying between about 30 vibrations per second and 40,000 vibrations per second. See Alexander Wood, *The Physical Basis of Music* (Cambridge: Cambridge University Press, 1922), 22.

[30] See James Loudon, "A Century of Progress in Acoustics," *Science. New Series* 14 (1901): 987-995, here 994.

[31] For an account, see David Pantalony, *Altered Sensations: Rudolph Koenig's Acoustical Workshop in Nineteenth-century Paris* (Dordrecht: Springer, 2009), 158-59.

[32] "Die höchste Pfeife hat nur ca. 11,000 statt ca. 50,000 Schwingungen. … Auch diese Gabeln zeigten Fehler bis zu ca. 36,000 Schwingungen." In M. Schaefer, "Literaturbericht," *Zeitschrift für Psychologie und Physiologie der Sinnesorgane* 21 (1899): 141-43, here 142.

[33] In chronological order, the principal texts referring to Preyer's claims are: Franz Melde, *Akustik: Fundamentalerscheinungen und Gesetze einfach tönender Körper* (Leipzig: Brockhaus, 1883); Carl Stumpf and Max Meyer, "Schwingungszahlbestimmungen bei sehr hohen Tönen," *Annalen der Physik und Chemie. Neue Folge* 61 (1897): 760-779; and Stumpf, 'Über die Bestimmung hoher Schwingungszahlen durch Differenztöne,' *Annalen der Physik und Chemie. Neue Folge* 68 (1899): 105-116.

may be at hand: "our results have been confirmed by experiments," Stumpf explains, referring to visual experiments by his assistant Friedrich Schulze.[34] In fact it was König who delivered visual evidence of the behavior of inaudible tones later that year. This included sound figures made by the movement of cork dust within a tube vibrating at frequencies of up to 90,000Hz, i.e. photograms of ultrasonic frequencies. Figure 1 shows the ghostly traces of c^9 to f^9 alongside three figures depicting 90,000Hz; König professes to have measured the frequencies according to beat tones, hence the cryptic dotted lines reveal little to the eye, but serve as an emblem of the empirically inaudible: captured, real "sound" that exists beyond our physiological sense capacity.[35]

[Figure 1 near here]

That serious acousticians—Helmholtz included—believed for eighteen years that our auditory range was twice the size previously thought suggests a collective contemporary skepticism towards the limits of human sensory perception. While there need be no direct link here to a Nietzschiean *Übermensch*,[36] a certain restless anthropocentrism is evident. Crudely put: if nature equipped us even more handsomely than we thought, and we continue to evolve, what has the authority to limit humanity? One contemporary example of such an attitude is the German Entomologist Karl Ernst de Baer, who was confident humans could hear up to 48,000Hz sixteen years before Preyer "verified" it. In a lecture from May 1860 he blends fantasy with rationalism to present listeners with a thought experiment concerning sensory limits. It goes as follows: if a human lifespan of 80 years consists of 29,200 days, and this were to pass by 1000 times faster giving a compressed lifespan of 29 days, which could again be sped up by a factor of 1000, it would result in a total lifespan of 40-42 minutes, he explains; the corresponding rate of perception would be a million times faster than usual. For such a

[34] 'Wie man sieht, sind durch seine [Friedrich Schulzes] Versuche unsere Ergebnisse bestätigt worden.' Stumpf, "Ueber die Bestimmung," 105, 115.
[35] Rudolph König, "Ueber die höchsten hörbaren und unhörbaren Töne," *Annalen der Physik* 69 (1899): 626-660, 721-738.
[36] The first translation of the term, by Alexander Tille in 1896, was "beyond-man," while Nietzsche's pre-eminent twentieth-century English translator Walter Kaufmann opted for "overman," both of which could be harnessed to the present discussion of what exceeds human capacity. See *Thus Spake Zarathustra*, trans. Alexander Tille (London: Macmillan, 1896); and *Thus Spoke Zarathustra,* trans. Walter Kaufmann (New York: Penguin, 1978).

person, the organic world would probably appear disappointingly static, but they could access other experiences unavailable to us, de Baer suggests. "All the sounds we hear would certainly be inaudible to such people, if their ears remain morphologically similar to ours; but perhaps they would perceive sounds that we do not hear, indeed perhaps they would even *hear* light that we *see*."[37] Returning to the first temporal compression (one thousandth of a full life), he calculates that the highest sounds we perceive, vibrating at 48,000 times between two pulsations, would vibrate only 48 times between pulsations for people of shortened lifespan, hence they would sound low.[38] At the upper end, even the second compression, resulting in a 42-minute life, would not quite open up our perceptual apparatus to an ether vibrating at "several hundred billion times a second," he argues:

> But we could take the idea of shortening a real life further, until these vibrations of the ether, which we currently experience as light and colour, actually become audible. And might there yet be in nature quite different vibrations which are too fast for us to experience as sound, and too slow to appear to us as light? ... It is not at all preposterous to believe so. ... Is there not perhaps a sounding of outer space ... that is audible to ears quite different to ours?[39]

The quasi-scientific postulate of alien auditory realities, and the apparently simple manner of calculating their relation to lived experience, suggest the degree of fascination that limited perception held for those ambitious for human nature.

It is indicative, then, that only a few years after Preyer's ultrasonic claims were rubbished, Ezra Pound would speculate on "new organs" for the body of the artist, whose brain constitutes largely undischarged chemical potential ("a great clot of genital fluid held in *suspense or reserve*"): "I believe that the species changes as suddenly as a man

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[37] 'Alle Töne, welche wir hören, würden freilich für solche Menschen unhörbar sein, wenn ihr Ohr ähnlich organisirt bleibe wie das unrrige, dagegen würden sie vielleicht Töne vernehmen, die wir nicht hören, ja vielleicht würden sie sogar Licht, welches wir *sehen*, nur *hören*.' Karl Ernst de Baer, *Welche Auffassung der lebenden Natur ist die richtige?* (Berlin: August Hirschwald, 1862), 30.
[38] "Ein Ton, der für uns zwischen 2 Pulsschlägen 48,000 Schwingungen macht und der höchste ist, den wir vernehmen können, würde für diese verkürzt lebenden Menschen nur 48 mal zwischen 2 Pulsschlägen schwingen und zu den sehr tiefen gehören." Ibid., 30-31.
[39] "Aber wir könnten die Zeitverkürzung des eigenen Lebens in Gedanken noch weiter treiben, bis diese Aether-Schwingungen, die wir jetzt als Licht und Farben empfinden, wirklich hörbar würden. Und könnte es in der Natur nicht noch ganz andere Schwingungen geben, die zu schnell sind, um von uns als Schall empfunden zu werden, und zu langsam, um uns als Licht zu erscheinen? ... Es ist keinesweges widersinning, so etwas zu glauben. ... Giebt das nicht vielleicht ein Tönnen des Weltraumes ... hörbar für ganz andere Ohren als die unsrige?" Ibid, 31-32.

makes a song or a poem … It is not even proved that man is at the end of his physical changes."[40] Pound had been trying to understand acts of creativity as the material outcome of body processes, particularly the capacity of humans through chemical impulses in the brain to detach from their corpus internal bodily tools such as the production of heat (i.e. from internal digestion to external fire): "all sorts of extravagances in nature may be taken as the result of a single gush of thought. A single out-push of a demand, made by a sea of sufficient energy."[41] In the wake of evolutionary biology, Pound acknowledges that aptitudes of auditory "genius" developed without physical change to the ear—"from the faculty of hearing four parts in a fugue perfectly, to the ear for money"[42]—and proceeds to speculate: "The 'next step,' as in the case of the male organ of the nautilus, is to grow a tool and detach it … Let us suppose man capable of exteriorizing a new organ, horn, halo, Eye of Horus. Given a brain of power, comes the question, what organ, and to what purpose?"[43] However bizarre this and de Baer's imaginative pressing on biological limits may seem, they were not alone for the period, and arguably make explicit what was implicit in the collective readiness to entertain Preyer's ultrasonic claims. For his part, Pound regarded the idea of expanded sense capacity as normative in 1921: "lying on the study table of any physician or philosopher."[44]

Leaving futurist speculations to one side for the moment, the debacle over higher pitch perception effectively marks the emergence of biosemiotics: the study of sensory signification within living organisms. The concomitant epistemology of sound based on sense acuity undermines contemporary doctrines of the ontology of art.[45] After all, a flute sonata sounds—and at some level *is*—different for you before and after you might suffer hearing loss. Several recent theorists have sought to embrace this perspective:

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[40] Ezra Pound, "Postscript" to Remy de Gourmont, *The Natural Philosophy of Love* (New York: Boni and Liveright, 1922), 206, 212.
[41] Ibid., 214.
[42] Ibid., 215.
[43] Ibid., 213-14.
[44] Ibid., 207.
[45] By this I mean artworks as immanent objects that subsist as part of the Universe, which are enfranchised by the work concept. Philosopher C. E. M. Joad, for one, posited Shakespeare's *Hamlet* as a "subsistence object"—an entity, neither material nor mental, that cannot be identified with its script or any individual production, and that constitutes part of the universe, and possess a special quality of being in its own right. Joad, *Guide to Philosophy* [1936], (New York: Dover, 1957), 266-270.

Mark Reybrouck redefined music simply as "a collection of sound/time phenomena which have the potential of being [mentally] structured" where any meaning of heard music derives not from ontological categories but from a listener's disposition to react to stimuli;[46] and Gary Tomlinson's concept of the "parahuman" listener emphasizes in part the extent to which listeners labor in acts of listening, actively participating in the creation of musical sound by setting "in motion the processes of signification" that define—in this case—the "techno-semiotic exchange" of Wagner's operas.[47]

In effect, this definition of music has long been applicable at a cognitive level through the idea that the "music" a listener identifies with performance acts is highly dependent on the perceptual acts they are able to accomplish.[48] "Like all communication," Milton Babbitt argued back in 1958, theoretically complex music "presupposes a suitably equipped receptor."[49] But this is not easily reducible to a two-way street between sound object and listener. The radical theory at issue here sees musical experience assessed not just cognitively, in this way, but sensorially—it becomes an affordance of the body, effectively created through the matrix of received stimuli generated by sense organs. This defines the limits of, as well as enables, the listener's sonic experience (much like the Jena poets of Wackenroder's generation felt constrained as their poetry "created the

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[46] Mark Reybrouck, "Musical Sense-Making and the Concept of Affordance," *Biosemiotics* 5 (2012): 391-409, here 392.

[47] Gary Tomlinson, "Parahuman Wagnerism," *Opera Quarterly* (2013): 186-202, here 192-93.

[48] Most prominently, Eric Clarke describes the experience of musical meaning as 'fundamentally—though not exclusively—a perceptual experience … [within] a highly structured environment [that is] subject to both the forces of nature … and the profound impact of human beings and their cultures.' In Clarke, *Ways of Listening* (New York: Oxford University Press, 2005), 8, 17.

[49] Milton Babbitt, "Who Cares if you Listen?" *High Fidelity* 8 (February 1958): 38-40, 126-27; rpt "The Composer as Specialist," *The Collected Essays of Milton Babbitt*, 50. This attitude has perhaps been most extensively delineated in the context of analytical training, from the theorists historically linked to notions of "structural hearing" (in which an understanding of prolongation and fundamental laws helps the ears form mental models of sonic relationships, leading—for Carl Schachter—to "hearing that is incomparably clearer and more comprehensive that it had been before"), to discourses of the "ideal" listener modeled in different contexts, from Carl Dahlhaus' "ideal" listener as the assumed perception of a composer's intentions, and Nicholas Cook's "ordinary listener," as one who hears without the apparatus of music-theoretical knowledge, to composer Frank Cox's "ideal perception," which measures the information a listener grasps aurally in performance compared to its complex notation. In all cases the perceptual acts a listener accomplishes are determined by their learning experience and cultural situatedness. See Felix Salzer, *Structural Hearing* (New York: C. Boni, 1952), viii; Carl Schachter, *Unfoldings*, ed. Joseph Straus (New York: Oxford University Press, 1999), 35; Nicholas Cook, *Music, Imagination and Culture* (Oxford: Oxford University Press, 1990), 158; and Frank Cox, "Notes toward a performance practice for complex music," *Polyphony & Complexity,* ed. Mahnkopf, Cox, and Schurig (Hofheim: Wolke, 2002), 70-132, here 72.

world" through the artificial grid of the German language).[50] This is not to say the emergent reality of music in the scientific age is nothing but sonic/somatic sensations, Massumi's "prepersonal intensities," only that material realities of sound have a bearing within an ecological approach to performance. Nor does it imply a return to frail ontologies ("the music itself" etc.). Rather, it asserts that the concept of sensory acuity is formative for our subject identity in ways empirical as well as phenomenological.

In this article, I seek not only to substantiate existing moves towards an ecological theory of listening, but also to throw into relief the organizing frame of the body that such theories have relied upon. The history of debates over technology and the body raise questions about the authenticity of our perceptual means, the potential utility of sense augmentation, and the degree to which our identities (as listeners) may depend in a broader sense on the perceptual apparatus we control. This approach tends to regard sound as a material object, stripped of applied meanings, rather than a sign rooted in schemes of mimesis and representation. A turn of this kind towards materialist epistemologies challenges some of the basic assumptions that have underpinned our understanding of sound in recent decades, including perhaps even our "normative sense of the human and our belief about human agency" wherein performance and listening—practices forever in contact with sensible objects—beg a corresponding enquiry into how matter itself can animate and define experience.[51]

Jakob von Uexküll

A touchstone for this approach is J. J. Gibson's theory of ecology, whose central thesis famously relates organism to environment, and whose unifying principle between

[50] If you believe that language can contain and circumscribe reality, it follows that what cannot be said—or in our case, heard—does not exist. The point is linked *prima facie* to Herder's critique of language in which thought is bounded in scope by language, and meaning becomes concerned with identifying the usage of words; see particularly "Fragments on Recent German Literature" [1767-8], in *Herder: Philosophical Writings*, 33-65. The broader debate between language that "expresses" and that which "regulates" the world in the late eighteenth century has been summarized by Charles Taylor, "Language and Human Nature," *Philosophical Papers*, 2 vols. (Cambridge University Press, 1985), 1: 215-247, esp. 228ff.

[51] Diana Coole and Samantha Frost, "Introducing the New Materialisms," *New Materialisms*, ed. Coole and Frost (Durham and London: Duke University Press, 2010), 4.

disciplines has been "the question of what can stimulate a sentient organism."[52] Historically this view found expression in the fields of both psychology and theoretical biology in the decades surrounding the First World War.[53] When, in 1923, Freud formalized his division of the psyche into *Es* (id), *Ich* (ego), and *Über-Ich* (super-ego), he identified the ego, the seat of our self-identifying conscious awareness, as "first and foremost a bodily ego."[54] His footnote to the later English translation clarified that:

> The ego is ultimately derived from *bodily sensations*, chiefly from those springing from the surface of the body. It may thus be regarded as a mental projection of the surface of the body, besides … representing the superficies of the mental apparatus.[55]

In fact, Freud was adapting biological research to "the mental apparatus" (much as Helmholtz had adapted physiological research to what he termed the "mental ear").[56] Fourteen years earlier the Baltic German biologist Jakob von Uexküll had effectively grounded Freud's claim empirically in relation to cell structure. He argued that each sentient organism has a peculiar, limited sphere of perception, and that this exists in dialogue with the objects of that organism's environment. His theory emerged a decade after Preyer's claims of hearing 40,960Hz had been overturned; it cries out for reinspection amid recent moves towards the listening subject, and my interest here is to suggest the extent to which it relates disproportionately to contemporary understandings of sound and otology, and, as such, would become foundational for twenty-first-century debates over auditory prosthesis, as we shall see.

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[52] James Jerome Gibson, *The Senses Considered as Perceptual Systems* (Boston: Houghton Mifflin, 1966), 29.

[53] In this context the First World War has been read by Peter Sloterdijk, among others, as a cultural event predisposed towards annihilation of the liberal subject, after which the concept of ego rings hollow even before it was named, "an inheritance without testament" as he put it. See Sloterdijk, *Critique of Cynical Reason*, trans. Michael Eldred (London: Verso, 1987), 386.

[54] Sigmund Freud, "The Ego and the Id" [1923], in *The Standard Edition*, ed. J. Strachey et al., trans. J. Rivière, 24 vols. (London: Hogarth Press, 1953-74), 19: 26.

[55] Ibid. This footnote is appended to Freud's line: "The ego is first and foremost a bodily ego; it is not merely a surface entity, but is itself the project of a surface." ("Das Ich ist vor allem ein körperliches, es ist nicht nur ein Oberflächenwesen, sondern selbst die Projektion einer Oberfläche."). The Standard Edition explains that it first appeared in the English translation of 1927 where it is described as "having been authorized by Freud." It does not appear in the German edition.

[56] In its narrowest meaning, Helmholtz's concept of a "mental ear" (*geistige Ohr*) connotes how directed attention alters the perception of what is empirically given via the senses. Benjamin Steege contextualizes Helmholtz's terms in *Helmholtz and the Modern Listener*, 73-79, and Veit Erlmann offers a nuanced account of how he came to terms with "the growing sense of distance between interior and exterior" where anatomical science is "blind" without "some sort of philosophical guidance." See Erlmann, *Reason and Resonance* (New York: Zone, 2010), 217-70, here 220.

Uexküll introduced the concept of *Umwelt* to describe this bubble of perceivable space within which we live; it combines an individual's *Merkwelt* (everything an organism perceives physically) and its *Wirkwelt* (everything it acts upon mentally or produces through the use of its perceptual tools). Another way to put this would be that it combines physiological limits with directed or learned perceptual attentiveness that abstracts some sounds—in the case of listening—in preference over others, a practice Jonathan Sterne recently conceived as "audile technique [that] problematizes the shape … [and] content of audile space."[57] These two elements, innate physiology and mental honing, remain conceptually separate for Uexküll. Acknowledging his nourishment on Kant,[58] Uexküll effectively articulates a new noumenal realm: "the space that surrounds us is always bounded. We can perhaps imagine an unbounded space in our thoughts, but our sensory tools have no knowledge thereof. They teach us that we remain constantly surrounded by a bubble ~ breakable perhaps, but for us just as inaccessible as impenetrable."[59] Figure 2 presents the chain of signification schematically, using Uexküll's terms of reference from 1920.

[figure 2 near here]

His main thesis, first set out in *Umwelt und Innenwelt der Tiere* (*The Outer and Inner World of Animals*; 1909), is that each sentient organism creates its unique environment by its capacity to receive only signals that register on its peculiar sense organs.[60] Hence, these perceptual limits define the nature of all that is, materially speaking, for the organism.

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[57] Jonathan Sterne, *The Audible Past* (Durham: Duke University Press, 2003), 94.

[58] "The task of biology consists in expanding in two directions the results of Kant's investigations: (1) by considering the part played by our body, and especially by our sense-organ and central nervous system, and (2) by studying the relations of other subjects (animals) to objects." See Uexküll, *Theoretical Biology* [1928], (New York: Harcourt, Brace & Company, 1926), xv.

[59] "Immer ist der Raum, der uns umgibt, begrenzt. Einen unbegrenzten Raum kann man sich vielleicht in Gedanken vorstellen, unsere Sinneswerkzeuge kennen ihn nicht. Sie lehren uns, dass wir stets umgeben bleiben von einer vielleicht zerbrechlichen, aber fuer uns gleich unerreichbaren wie undurchdringlichen Seifenblase." Uexküll, "Wie sehen wir die Natur und wie sieht sie sich selber?", *Die Naturwissenschaften* 12-14 (1922): 265-271, 296-301, 316-322, here 265. On the relation to Kant's argument about how we perceive the world, see Ernst von Glasersfeld, *Radical Constructivism* (London: Falmer, 1995), 55; and John Deely, "Semiotics and Jakob on Uexkull's concept of Umwelt," *Sign Systems Studies* 32 (2004): 11-34.

[60] Uexküll, *Umwelt und Innenwelt der Tiere* (Berlin: Springer, 1909).

Uexküll's classic example is the tick: blind and deaf, it smells the butyric acid of its prey, so knows when to jump onto the passing animal; the warm skin confirms this as a source of nutrition, and on sensing a patch of hairless skin, the tick begins boring for blood. It will feed only once before dying, so can neither learn nor refine the procedure.

Just as the tick's concept of an environment relates to only three "perception signs"—smell of acid, detection of temperature, touch of skin—so our human environment is multiplied by the complexity of our sensory apparatus:

> All animal subjects, from the simplest to the most complex, are inserted into their environments to the same degree of perfection. The simple animal has a simple environment; the multiform animal has an environment just as richly articulated as it is.[61]

Different "perception signs"—things that living animals notice—create the significance of different experiences of the same objective space: the night sky differs for an astronomer, a commercial pilot, a child dreaming, an astrologer, a poet, a UFO-spotter. In other words, the night sky does not exist as a fixed object. Nor does sound. In fact, for Uexküll, the animal-environment axis explains a familiar disconnect between different disciplinary approaches to sound: "the environment of a researcher of airwaves and of a musicologist show the same opposition. In one, there are only waves, in the other, only tones."[62] If the perspective of sound studies is weakening this divide today, Roger Scruton underscores its resilience by emphasizing, in mirrored fashion, the incommensurability of perspectives from an acoustician who hears frequencies and

[61] Jakob von Uexküll, *A Foray into the Worlds of Animals and Humans*, trans. Joseph O'Neil (Minneapolis: Univ. of Minnesota Press, 2010), 50.

[62] Ibid., 135. In fact this was not a new observation, Uexküll merely inserted it into an argument about biological determinism. Back in 1852, the writer and Wagner-advocate Richard Pohl made much the same point when questioning utopian claims for an equal artistic-scientific culture: "the physicist concerned with sensory impression fails to ask where he is going … the composer with facts of harmony fails to ask where he is coming from." Pohl, "Akustische Briefe: erster Brief," *Neue Zeitschrift für Musik* 2 (1852): 13. The history of species-specific perception is itself anticipated in early nineteenth-century phrenology. Johann Spurzheim declared that "the world is different to every species of animal, and even to every individual of the same species … it is evident that every sentient being perceives impressions in proportion to the number and energy of its sentient faculties." See Spurzheim, *The Physiognomical System* (London: Baldwin, Cradock & Joy, 1815), 528-29.

durations and a music theorist who hears harmonic tension and voice leading in the opening theme of Beethoven's Third Piano Concerto:

> Each way [of apprehending what is heard] is cognitively complete—that is to say, it apprehends and orders everything that is there. … The reductivist would argue that … the music is *nothing but* the sequence of pitched sounds, since if you reproduce the sequence, you reproduce the music. … But to hear the music it is not enough to notice the sounds. Music is inaudible, except to those with the cognitive capacity to hear movement in musical space, orientation, tension and release, the gravitational force of the bass notes, the goal directedness and action-profile of melodies, and so on.[63]

Uexküll's musical reference—unwittingly elaborated by Scruton—is indicative of sound's special capacity to draw attention to what the biologist called "constitutional differences" (*konstitutionelle Unterschiede*) between the environments of different people, to split apart simultaneous realities. For these differ from one another as a result of combining an individual's sensory means of perception (the *Merkwelt*) with the actions, attentiveness, and habitual uses to which they are regularly put (the *Wirkwelt*). Examples are defensively qualitative,[64] but the principle is clear:

> Since the perceptual capacity of humans varies enormously, so their *perceptual worlds* [*Merkwelten*] must differ from one another. The individual human is connected to his environment not only by means of his sensory tools that enable him to notice [things], but also thanks to his actively used perceptual 'tools' [*Handlungswerkzeuge*], which connect him to his *effect world* [*Wirkungswelt*]. Together perceptual world and effect world create the environment. … The environments [of different individuals] are constituted so very differently that we can even speak of *occupational worlds*.[65]

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[63] Roger Scruton, *The Soul of the World* (Princeton: Princeton University Press, 2014), 38-9.

[64] Two examples concern differing degrees of myopia among people, and different common environments: "[t]he stars are still more different [than the sun, for different viewers]. A person with medically flawless eyesight looking at the night sky sees small, shiny discs while another sees themselves illuminated by small bright lamps surrounded by a corona … All those who spend long periods of time in the countryside 'discern many more things [among nature] than city dwellers." Uexküll, "Wie sehen wir die Natur und wie sieht sie sich selber?", 265-66.

[65] "Da die Merkfähigkeit der Menschen ausserordentlich wechselt, müssen auch ihre *Merkwelten* voneinander abweichen. Mit seiner Umwelt steht der einzelne Mensch nicht nur mittels seiner Sinneswerkzeuge, die eben das Merken ermöglichen, in Verbindung, sondern auch dank seiner Handlungswerkzeuge, die ihn mit seiner *Wirkungswelt* verbinden. Merkwelt und Wirkungswelt bilden gemeinsam die Umwelt. … Dadurch warden die Umwelten so entscheidend umgestaltet, daß man von *Berufswelten* reden kann." Ibid., 266.

It would seem odd to ignore the applicability this has for different listeners witnessing the same performance.[66] Different human environments are challenging for Uexküll to exemplify, but between species the parameters of variance concern the experience of time (speed of cognition), the sensible electromagnetic spectrum, sound frequency range, and spatial awareness.[67] Uexküll's visual illustration of a street scene perceived by a human, a fly and a mollusk, given in figure 3a-c, is artful in its supposition, but may nevertheless be helpful as an ocular analogue to the varying "skill" of different listeners' experience of complex music, envisioned by the likes of Babbitt and Scruton. The hierarchy implied here compares to the ranking of sentient organisms by their perceptual acuity within the one world of classical biology. By contrast, for Uexküll each organism's relation to the environment is equally perfect, from amoeba to elephant, their perceptual worlds reciprocally exclusive and uncommunicating, corresponding as an ensemble to the world composed by the totality of its perceptive inhabitants. In the end, however, all matter within this totality remains unknowable in itself. Animals "never enter into relation with an object as such" he concluded, which is to say all sensory relations remain representational.[68]

[Figures 3a-c near here]

Musical *Umwelten*

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[66] For Uexküll the critical difference to Helmholtz's sensory qualities ("signs of an external phenomenon … [which] remains forever unknown to us"), was that of materialism to transcendentalism: received sensation—for him—constitutes itself the real of an external object rather than its sign: "Helmholtz indeed acknowledged that all objects must appear different to each subject," he qualifies, "but he was seeking the reality behind appearances." By analogy, Helmholtz's position would imply the work concept as the neo-Platonic "reality behind [the] appearance" of performance. See Uexküll, *Theoretical Biology*, xiv, xv. See also Stefan Helmreich "Remixing the Voyager Interstellar Record. Or, As Extraterrestrials Might Listen," *Journal of Sonic Studies* 8 (2014).

[67] While, for Uexküll, the cinematograph offers proof that the smallest conceptual moment of human perception lasts an eighteenth of a second, a tick is capable of waiting eighteen years without eating before the signal of butyric acid from a passing mammal stimulates it to activity. "[T]ime stands still in the tick's waiting period," concludes Uexküll, who assumes an unchanging environment could only be endured by perceptual hibernation, "not just for hours but for years." Uexküll, *A Foray into the Worlds of Animals and Humans,* 52.

[68] Timo Maran, Dario Martinelli, Aleksei Turovski (eds.), *Readings in Zoosemiotics* (Berlin: De Gruyter Mouton, 2011), 62. Translation adapted.

Accepting Uexküll's argument means accepting the existence of an infinite variety of perceptual worlds. Hence the task he set himself was speculative – to find a way of "thinking himself into" other perceptual worlds.[69] Some musicologists have followed suit in the service of deconstructing the Western canon. Bruno Nettl adopted the same strategy when he hypothesized how "an ethnomusicologist from Mars" might listen to Mozart, and Nicholas Cook recently crystalized the perceptual gains, positioning "western music as world music."[70] (As these illustrate, any strategy of distancing oneself is of course not exclusively physiological. In answer to the question "What is it like to be a bat?" philosopher Thomas Nagel argued that materialist theories of mind omit what is essential to consciousness, i.e. that there is a state that it feels like to be a particular conscious thing; in tandem with physiological differences between organisms, he affirms a non-materialist "subjective character of experience" that subsumes the sum of an organism's perceptual parts.)[71] But physiologically, the direction of travel for any distancing operation is necessarily reductive, from greater to lesser acuity, as figure 3 demonstrated: humans with unimpaired sight could simulate color blindness but not vice versa, "just as little can the unmusical man conjure up the world of melody in which lives the man who has a musical sense," Uexküll adds.[72]

For skeptics, this amounts to little more than a metaphor for "getting outside yourself" and seeing another point of view. But a lateral glance reveals related intellectual enquires during the early twentieth century, which help corroborate Uexküll's theories as part of a broader impulse to destabilize (and historicize) the monopoly of human perception. Nietzsche, in disparaging the hubris of anthropocentrism in 1873, anticipated the singularity of an animal perspective in stark terms:

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[69] That is, perceiving the world of a bee or a bat, for instance, by seeing the polarization of light or by seeing into the ultraviolet range of the spectrum. Though he clarifies "the observer can advance in no way other than on the basis of the picture offered to him on the inside of his own bubble." ["Der Beobachter kann gar nicht anders vorgehen, als durch Zugrundelegung des Bildes, das sich ihm auf der Innenseite seiner eigenen Seifenblase bietet.'] Uexküll, "Wie sehen wir die Natur und wie sieht sie sich selber?", 266.

[70] Bruno Nettl, "Mozart and the Ethnomusicological Study of Western Culture," *Disciplining Music*, ed. Katherine Bergeron and Philip V. Bohlman (Chicago: University of Chicago Press, 1992), 137-55, here 138. And Nicholas Cook, "Western Music as World Music," *The Cambridge History of World Music*, ed. Phillip V. Bohlman (Cambridge University Press, 2013), 75-100.

[71] Thomas Nagel, "What is it like to be a bat?" [1974 / 1982] *Mortal Questions*, 166ff. Cf. Ian Bogost, *Alien Phenomenology* (Minneapolis and London: University of Minnesota Press, 2012).

[72] Uexküll, *Theoretical Biology*, 76.

> There have been eternities when [human intellect] did not exist; and when it is done for again, nothing will have happened. For this intellect has no further mission that would lead beyond human life. If we could communicate with the mosquito, then we would learn that it floats through the air with the same self-importance, feeling within itself the flying center of the world.[73]

If this relativizes human perspective, Edmund Husserl massified it two decades later when he defined the aim of phenomenology as unprecedented "epistemological clarity" (*erkenntnistheoretische Klarheit und Deutlichkeit*) whereby philosophers were to hold their assumptions about the world's existence in abeyance in order to reach a higher state in which they could analyze the contents of their own perception. The resulting state of heightened self-consciousness, the so-called phenomenological reduction, seeks unmediated perception, knowing the particular appearance of objects for "me" as such. Though distinct, both seek to interrupt perception and estrange customary associations—to break the spectacles through which we normally look at reality. If this often takes effect at the level of tactility (figured as the "interplay of the senses, rather than isolated contact"),[74] here sensory labor is precisely the point: the lynchpin around which a philosophy of materialism pivots.

Amid these developments it seems uncontroversial, methodologically, to argue that a musician's perceptual "world" relates both to the art he or she produces, and his or her way of perceiving it. Writers of all stripes have interpreted known mental or physical conditions deterministically in this manner. A recent analysis of such determinism is given in Joseph Straus' application of disability theory to the analysis of *Formenlehre* principles, where harmonic "abnormalities" in sonata form movements by Schubert and Beethoven become explicable by the disease and aberrant physical conditions of their composers.[75] Such approaches are grounded in a theory of embodied cognition

[73] Nietzsche, "On Truth and Lie in an Extra-Moral sense" [1873], *The Portable Nietzsche,* ed. and trans. Walter Kaufmann (London: Viking Penguin, 1982), 42.
[74] Marshall McLuhan, *Understanding Media* (Cambridge, MA: MIT Press, 1994), 314.
[75] Joseph Straus, "Normalizing the Abnormal," *JAMS* 59 (2006), 113-184. Straus, in his pioneering work of disability studies and music, emphasizes the historicity of the concept of physical normality, and its emergence around the early nineteenth century from which disability became understood as a deviation: "neither natural nor permanent, and thus subject to possible remediation" (p. 114). This is set against the broader view within disability studies that any concept of normal is relative to a given culture, within

wherein individuals experience and interpret the world differently through the idiopathology of their bodies;[76] correspondingly everything from spatial metaphor to the visual spectrum is experienced as an interpretation thereof. Yet the point is rarely made that if the mind-body complex becomes a means of understanding music by deviation from a posited, problematic "normal," the obverse was equally true: at the turn of the century, music was seen by some as a phenomenon uniquely suitable for studying the mind-body complex. Carl Stumpf's two-volume *Tonpsychologie* (1883/1890) set a precedent for positing musical sounds as the ideal material for scientific scrutiny of the mind: "perhaps nowhere will the collected tools of psychological research allow for the same combination—self-observation and external data, statistical collection and data sets, physiological facts and hypotheses, comparison of peoples and times, biographical factors etc."[77] This interlocking condition suggests an emergent, special role for sound as a tool in the study of human perception at the turn of the century, one whose cultural work continues under the rubric of sound studies, but whose history has arguably been overlooked.

Given the influence of Stumpf's beliefs and the subsequent tradition of connecting perceptual world and artistic production, it is surely no coincidence that music turns out to be central to Uexküll's way of thinking. In fact, his investigation is shot through with musical allusion. He uses musical paradigms—from the spatial organization of the diatonic scale to the perceived unity of individual works—to illustrate principles of cellular organization and function. It seems sounding music, as an invisible, apparently self-organizing phenomenon in three-dimensional space, provided him with a double analogue: for the unseen patterning of biological composition, and for experiencing music and environmental sound in dialogue with that composition.[78]

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which it represents a statistically predominant physical condition. Impairment, by contrast, represents an empirical deviation therefrom. The most cogent historical account to date is Michel Foucault, *Abnormal* (Picador, 2007), 26ff. For a comprehensive overview of this burgeoning field, see *The Oxford Handbook of Music and Disability Studies*, eds. Blake Howe, Stephanie Jensen-Moulton, Neil Lerner, and Joseph Straus (New York: OUP, 2015).

[76] For an overview, see R. Pfeifer and J. Bongard, *How the Body Shapes The Way We Think* (Cambridge MA: MIT Press, 2006); and Francisco Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind* (Cambridge MA: MIT Press, 1991).

[77] Carl Stumpf, *Tonpsychologie* (Leipzig: Hirtel, 1883), 1:vi.

[78] See for instance Uexküll's comparison of two-part counterpoint and "factors [in Nature] that together form a unit." In *A Foray into the Worlds of Animals and Humans*, 172,

To take one example, Uexküll asks his readers to imagine a Russian choirmaster tasked by Peter the Great with imitating European choral music at court, but who is only able to draw singers from army ranks, where voices are untrained and often musically illiterate. To solve this problem each soldier is taught to sing only a single pitch irrespective of the stimulus he receives, and so the choir can be "played" like a pipe organ. Since multiple singers are assigned the same pitch, each note constitutes "objective energy" (i.e. a predefined frequency) but with subjective quality (it is performed by individual singers – what philosophers call joint collective action). Following this compound analogy in which each singer—primed to sing only one pitch—represents an organ pipe, which in turn represents a human cell, Uexküll concludes: "Our entire corporeal organization is built according to the principle of hearing and sounding organ pipes. That means we consist entirely of individual totalities, each of which possesses its own law."[79] Music's internal logic becomes a cipher for unseen biological processes and cellular ontogeny, in other words.

At first blush this serves as a check against materialism: "to find in the properties of living matter nothing more than the expression of a dance of atoms," Uexküll remarked in 1930, "is not only to be hard of hearing but to be stone deaf."[80] Hence "melody" is the organizing principle for an organism's cellular structure; the sensory stimuli an animal receives constitutes "rhythmically arranged melodies of impulses;" the process of cellular division arranges each body "into a resounding carillon according to a certain formative melody;" and "every organism … is a melody that sings itself."[81] What significance should we accord such analogies? As Derrida reminds us, verbal surfaces are not superficial: "metaphor is never innocent. It orientates research and fixes results,"[82] so it seems reasonable to ask whether there may be an anchoring effect at play, wherein the idea of music is creating a value for its position within Uexküll's

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[79] "Unsere ganze Körperorganisation ist nach dem Prinzip hörender und tönender Orgelpfeifen aufgebaut. Das will besagen, daβ wir aus lauter individuellen Ganzheiten bestehen, von denen jede ihr eigenes Gesetz besitzt." Uexküll, *Die Lebenslehre* (Potsdam and Zurich: Müller, Kiepenheuer and Füssli, 1930), 71.

[80] Uexküll, *Theoretical Biology,* 205.

[81] Uexküll, *A Foray into the Worlds of Animals and Humans*, 48, 171, 202-03.

[82] Jacques Derrida, *Writing and Difference* [1967], (Abingdon: Routledge, 2001), 19.

theory before that theory was formulated.[83] We may never know, but the sustained metaphors lend credence to the view that a listening environment may be the theory's purest exemplification, its natural telos.

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PART II

Transhumanism and The Posthuman

If Uexküll's achievement was to map the biological limits of each species schematically, the recent discourse of "transhumanism" calls these limits into question. Specifically, transhumanism regards biology itself as the limitation. "We extropians don't want just to be normal," futurist Max More exhorts, "we want to be supernormal, superhealthy, superstrong, superintelligent."[84] Of course, the technological context of the last few decades differs radically from that of Preyer's ultrasonic pretensions and Uexküll's *Umwelten*. Both espoused a reversible proposition we might extrapolate concisely as "sound defines human," yet both also characterize a readiness to press at the physiological boundaries of what was understood at the time to constitute *homo sapiens*. By contrasting this turn-of-the-century German discourse with Anglo-American affirmations of a transhuman subject a century later, I now seek to demonstrate that despite differences of context and of certain framing epistemologies, a difference of technological capacity has not altered fundamentally attitudes towards the biological limits of sentient bodies within human modernity. My second claim is that this discourse has previously played out, and continues to play out, in a conspicuously auditory context. As well as decentering a dominant visualist tradition in scientific hermeneutics, such an approach offers a historical foundation on which to reconsider the fundamental role of sound in understanding sense perception, what Stumpf back

[83] This principle of experimental psychology—when people "consider a particular value for an unknown quantity before estimating that quantity"—applies typically to numerical values in experiments, but there is no reason to restrict the principle it espouses to numbers. See Daniel Kahneman, *Thinking Fast and Slow* (London: Penguin, 2011), 119-28.

[84] "Wir Extropianer wollen nicht normal sein, wir wollen supernormal sein, supergesund, superstark, superintelligent." From Max More's interview with Gundolf Freyermuth, in *Cyberland: Eine Führung durch den High-Tech-Underground* (Reinbek: Rowohlt, 1998), 201.

in 1883 dubbed "ensounding revelations" (*heraustönend[e] Offenbarungen*) about human nature.[85]

First, a clarification of terms. A certain confusion haunts discussions of transhumanism, the posthuman, and posthumanism, each of which denotes a separate category. While this article cannot settle definitions for the array of disciplines implicated, a summary of my usage of the terms in the context of music and the humanities will be helpful.

In brief:

Transhumanism:	an optimistic belief in the enhancement of the human condition through technology in all its forms.
Posthuman:	the new condition attained after stages of technological enhancement render the subject no longer normatively "human"
Posthumanism:	a discursive web of philosophical positions defined against, and seeking to supplant, the autonomous liberal human subject and its concomitant anthropocentric bias.

Transhumanism (H+) encompasses a futurist-orientated intellectual and cultural impulse pertaining to human-technology relations, shared between the literary humanities, computer science, and the bio-medical sciences. Its advocates believe in fundamentally enhancing the human condition through applied reason and a corporeal embrace of new technologies. It is rooted in the belief that humans can and will be enhanced by the genetic engineering and information technology of today, as well as anticipated advances, such as bioengineering, artificial intelligence, and molecular nanotechnology. The result is an iteration of *homo sapiens* enhanced or augmented, but still fundamentally human. Merely using devices that compensate for natural functions that have become deficient, e.g. wearing glasses or having a pace-maker, would not count as transhuman under such terms. To date, areas of change include natural aging

[85] Stumpf, *Tonpsychologie*, 1: viii. See also Don Ihde's argument for a philosophy of listening as the "hope to find material for a recovery of the richness of primary experience." Ihde, *Listening and Voice: Phenomenologies of Sound*, 2nd ed. (Albany, NY: State University of New York, 2007), 13;

(including, for die-hards, the cessation of "involuntary death,") as well as physical, intellectual, and psychological capacities.[86] As such the tenets of transhumanism bear genealogical traces to earlier discourses of embodied identity and the machinic body, including notably Donna Haraway's cyborg and its call to expose the production of universals, whether nature or human: "what counts as nature – a source of insight and promise of innocence – is undermined, probably fatally."[87]

A central premise of transhumanism is that biological evolution will eventually be overtaken by advances in genetic, wearable and implantable technologies that artificially expedite the evolutionary process. This was the kernel of More's founding definition in 1990,[88] and article two of the multi-authored "transhumanist declaration" (2012) continues to assert the point:

> We believe that humanity's potential is still mostly unrealized. There are possible scenarios that lead to wonderful and exceedingly worthwhile enhanced human conditions. ... We favor morphological freedom – the right to modify and enhance one's body, cognition and emotions.[89]

The very idea of such freedom illuminates Uexküll's theory of *Umwelt* afresh. Now it would seem to emphasize how a totality of all perceivable existence remains beyond our sensory limits, the ontic nature of what is, philosophically speaking. Brushing against this postulate are technological prostheses that enhance our naked sensory knowledge, including sonic amplification, which appeared already in the age of Preyer and Stumpf to offer privileged access to this ostensibly inaccessible realm. Anticipating later techniques of sonification, Alexander Graham Bell's photophone sought to enable its users to hear the very burning of the sun, for instance, while advocates of the

[86] Robert Ranisch & Stefan Sorgner, *Post- and Transhumanism: An Introduction* (Peter Lang, 2014), 7.
[87] Donna Haraway, "A Cyborg Manifesto" [1983], in *Posthumanism*, ed. Badmington, 73.
[88] He defined transhumanism as "philosophies of life ... that seek the continuation and acceleration of the evolution of intelligent life beyond its currently human form and human limitations by means of science and technology, guided by life-promoting principles and values." Max More, "The Philosophy of Transhumanism," *Transhumanist Reader*, 3.
[89] "Transhumanist Declaration," *The Transhumanist Reader*, 54-5.

microphone claimed it allowed one to eavesdrop on the footsteps of a fly.[90] But this hope for "metaphysics materialized"—as Abbate eloquently put it—ultimately reinscribes our perceptual limits.[91] For prior to a transhumanist worldview, such technology could not reside within human bodies.

The **posthuman** is essentially a state of completed transhumanism, wherein one's "basic capacities so radically exceed those of present humans as to no longer be unambiguously human by our current standards," in futurist Nick Bostrum's words.[92] Elsewhere he specifies the bar for entry as a being with "at least one posthuman capacity."[93] In its more radical iterations, this condition even does away with the biological body altogether, where information patterns uploaded to a fantastical supercomputer suffice to constitute a posthuman identity. In an extreme form of noetics, such existence become all mind, more powerful than present minds, employing "different cognitive architectures or includ[ing] new sensory modalities."[94] Despite advocacy from leading scientists such as Hans Moravec and Raymond Kurzweil, for non-converts such ideas reside squarely within the domain of science fiction.

Posthumanism, by contrast, is typically conceived discursively. It presents a range of philosophical positions that seek to supplant humanism, along with its attendant anthropocentrism, excessive valuation of human achievements, and preoccupation with humanity's supposed differences from (and superiority to) the rest of animate life. The first explicit articulation of a modern posthuman worldview, Ihab Hassan's article "Prometheus as Performer" (1977), inaugurated the discourse through the entertaining spectacle of a "University Masque" between eight symbolically humanistic characters, wherein his prediction that "five hundred years of humanism may be coming to an

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[90] See Sean Cubitt, "The Sound of Sunlight," *Screen* 51, no. 2 (2010), 118-128, and John M. Picker, "The Tramp of a Fly's Footsteps," *The American Scholar* Vol. 71, No. 2 (Spring 2002), 85-94. I am grateful to Carolyn Abbate for drawing these to my attention.
[91] Carolyn Abbate, "Sound Object Lessons," talk given at 4th Music and Philosophy Conference, Kings College London (2014), revised for *JAMS* 69 (2016): 793-829.
[92] Nick Bostrum, "The Tranhumanist FAQ," *Readings in the Philosophy of Technology*, ed. David Kaplan, 2nd ed. (Plymouth: Rowman & Littlefield, 2009), 346.
[93] Bostrum, 'Why I want to be posthuman when I grow up', *Transhumanist Reader*, 28.
[94] Bostrum, "The Transhumanist FAQ," 347.

end" has become a touchstone.[95] Indeed, while posthumanism has been overdetermined across media and scholarly contexts, its commentators consistently regard an autonomous, self-determining liberal human subject as no more than an idea with a traceable history. Posthumanist attitudes anticipate an increasing incorporation of artificial technologies into the body not primarily as enhancement of the human condition (as in Transhumanism), but as its anticipated dissolution: this is seen as part of a more fundamental dissolution of literal boundaries between subject and object, body and environment, and a corresponding recalibration of our sense of self-identity within a world of objects.

Related theorizing under the rubric of "new materialism" opposes the separation between human and nonhuman environments, emphasizing instead the interrelatedness and interdependency of biological and non-biological forms of agency.[96] This asserts no definite break between sentient and non-sentient matter in the relational fields of an environment because matter is no longer conceived as passive or inert, but capable of "self-transformation, self-organization, and directedness."[97] At the radical fringe, it is invested with agency that subsumes nothing less than human intentionality, freedom, and cognitive ability. The anticipated result is a move towards models of existence constituted by a distributed cognition, an identity accepting of non-biological thinking parts, one built on agency distributed non-hierarchically between animate and non-animate, sentient and non-sentient parts, where the conscious mind becomes "a small subsystem running its program of self-construction and self-assurance while remaining ignorant of the actual dynamics of complex systems."[98] The result is an identity defined ever more by its controllable architecture rather than its cultural history.

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[95] The eight characters have absurdly humanistic names: text, pretext, context, heterotext, mythotext, paratext, metatext, and postext. Ihab Hassan, "Prometheus as Performer," *The Georgia Review* 21 (1977): 830-50, here 843. Hassan acknowledged the term posthumanism as a "dubious neologism," but anticipated the transhumanizing process not as a sudden change but as a natural part of being human, a condition which combines "Imagination and Science, Myth and Technology;" it began with the discovery of fire by prehistoric "man," he asserts, that is, with the mind of Prometheus (835)

[96] Among the scholarly literature, two representative contributions would be Donna Haraway's seminal essay "A Cyborg Manifesto" (1983) and Jane Bennett, *Vibrant Matter* (Durham: Duke University Press, 2010).

[97] Coole and Frost, "Introducing the New Materialisms," 10.

[98] N. Katherine Hayles, *How We Became Posthuman* (Chicago: University of Chicago Press, 1999), 286.

In academic circles, posthumanism has repurposed scholarly trends persuasively, rationalizing why, for instance, structuralist thought of the late twentieth century was preoccupied with dissolving the subject, with obliterating the hard Cartesian ego which distinguishes itself from the world by turning the world into an object. "Man is an invention," Foucault remarks in the closing pages of *The Order of Things*, "whose recent date, and whose nearing end perhaps, are easily shown by the archeology of our thought."[99] That is, in this instance of posthumanist revisionism, the discursive networks of metaphysics and epistemology that had universalized *man* and *his* history, notably during the Enlightenment, are revealed to be increasingly parochial to a time past. Beyond the historicizing of gender constructions, race studies have also co-opted the liberating tenets of the debate to highlight what Alexander Weheliye calls an aporetic relationship between "New World black cultures and the category of the 'human.'"[100] In both cases, "human" becomes a culturally and historically specific designation. This explosion of antiquated canonical values helps explain why, for the literary humanities, posthumanism is positioned as a response to a perceived crisis, "the crisis of the last remaining metanarrative, namely humanist anthropocentrism, and its origins," in Stefan Herbrechter's words.[101] By evacuating this traditional anthropocentric core, and capping a more than 500-year-old tradition of *studia humanitatis*, discourses of posthumanism have emerged as a more radical branch of humanism whose affordances are touted by commentators such as Rosi Braidotti as a positive resource in countering a perceived malaise inhabiting the humanities.[102] Regardless of whether there may be a whiff of technological utopianism here, from an academic standpoint, it seems, the discourse is self-consciously one of renewal and rejuvenation.

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[99] Translated adapted from Michel Foucault, *The Order of Things*, 387.
[100] Alexander G. Weheliye, "Posthuman Voices in Contemporary Black Popular Music," 21. My thanks to Griff Rollefson for bringing this to my attention.
[101] Herbrechter, *Posthumanism: A Critical Analysis* (London: Bloomsbury, 2013), 76.
[102] Braidotti optimistically anticipates a "technologically mediated post-anthropocentrism [that] can enlist the resources of bio-genetic codes, as well as telecommunication, new media and information technologies, to the task of renewing the Humanities." Rosi Braidotti, *The Posthuman* (Cambridge, UK: Polity, 2013), 145.

For present purposes, it is transhumanist hopes for enhancement that bear on a listening ear in reach of ultrasonics. If automatic, material communication was once epitomized by what Helmholtz called the "material ear" (our physiology's mechanism when confronted with vibrating air, i.e. sympathetic resonance), more recent listening practices materialized through devices such as cochlear implants indicate that 'automatic' processes are central to the engagement between the ear's physiology and technology. Below, this materializing impulse is reassessed under the rubric of a transhumanist discourse.

Origins of a non-human Ear

The idea of understanding the body as a communication matrix whose functions are refineable can be traced back to the Macy conferences in cybernetics between 1946-53, in which mathematician Norbert Wiener established so-called first-order cybernetics as "the scientific study of control and communication in the animal and the machine."[103] The origins of a posthuman worldview bear witness to the conceptual symmetries—human part: object part—that enabled this paradigm shift. Tracing it reveals afresh our current position vis-à-vis bodies, and not coincidentally, this returns us one last time to the closing decades of the nineteenth century. In 1877 Ernst Kapp published his *Grundlinien einer Philosophie der Technik* (*Principles of a Philosophy of Technology*), a wide-ranging study of the effects on human society of the use of technology.[104] In this text he coined the phrase "philosophy of technology," and for this reason it is commonly cited as the originator of this field of inquiry.[105] In his second chapter, Kapp argued that tools and technologies are projections of human organs: the eye is the model for the camera obscura, the teeth provide a formative image of the saw, the forearm with clenched fist does the same for the stone hammer, the crooked finger becomes a hook, etc. Such relationships, as Kapp puts it, constitute "a projection of organs

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[103] Norbert Wiener, *Cybernetics* (Cambridge, MA: MIT Press, 1948).

[104] Ernst Kapp, *Grundlinien einer Philosophie der Technik* (Brunswick: Westermann, 1877)

[105] Accounts that cite Kapp as the originator of the field of Philosophy of Technology include: Friedrich Rapp, *Analytical Philosophy of Technology*, 4; Frederick Ferré, *Philosophy of Technology*, 10; Peter Fischer, "Zur Genealogie der Technikphilosophie", in Fischer (ed.), *Technikphilosophie*, 309; Thomas Zoglauer, "Einleitung," in Zoglauer (ed.), *Technikphilosophie*, 9; Marc J. de Vries, *Teaching About Technology*, 68; Günter Ropohl, *Allgemeine Technologie*, 13.

[*Organprojektion*] or the mechanical afterimage of an organic form."[106] The ear does not escape Kapp's purview; he saw the vibrating hairs of the cochlear duct as a biological model for both the overstrung piano and the wind harp, that most natural and automatic of instruments.[107]

But two aspects of Kapp's projection of organs need to be separated. On the one hand, he is concerned with technological genesis, where the technical means are seen as unconscious "after-images" (*Nachbilder*) of human organs. On the other hand, he thematizes the cultural dimension of technology, wherein this technical means is posited as a medium through which we recognize ourselves. Herein lies the conceptual pivot towards transhumanism. For while the natural human body is primary for Kapp, and the technological "after image" secondary, media theorist Friedrich Kittler grittily reversed this relationship in his pathbreaking analysis of human referentiality in media for communication and data storage, arguing in 1986 that media technology is a primary constituent of identity, the body its conceptual copy; "so-called man" was now the secondary product of technologies that are conceptually prior.[108]

While already in 1964 Marshall McLuhan had envisaged media as prosthetic extensions to the human sensorium, Kittler went further.[109] He effectively envisioned a feedback

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[106] "eine Organprojektion oder die mechanische Nachformung einer organischen Form." Kapp, *Grundlinien*, 71. The book drew broadly on an Aristotelian techné—the ability to make (something) that depends on correct awareness of, or reasoning about, the thing to be made—and more specifically on Democritus' view of technology as the imitation of nature, in which human house-building and the craft of weaving were first invented by imitating swallows building their nests, and spiders weaving their webs, respectively.

[107] Kapp, *Grundlinien*, 93. The most widely accepted instance of organ projection, one that Kapp cites simply as "obvious," is that between the nervous system and networks of telegraphic communication being established throughout Europe and North American during the middle decades of the nineteenth century. This parallel—asserted by such respected academic physiologists as Du Bois Reymond, Helmholtz, and Werner Siemens—serves to authenticate his substantialist conception of organ projection: "nerves *are* cable installations of the animal body, telegraph cables *are* human nerves. And, we might add, so must they be, for the characteristic feature of organ projection is the unconscious occurrence." ["Die Nerven *sind* Kabeleinrichtungen des tierischen Körpers, die Telegraphkabel *sind* Nerven der Menschheit! Und fügen wir hinzu, sie müssen es sein, weil das charakteristische Merkmal der Organ projection das unbewußte Vorsichgehen ist."] In Kapp, *Grundlinien*, 141. For a detailed, discursive study of the parallelism between nerves and networked telegraphic cables in nineteenth-century Germany, see Laura Otis, *Networking* (Ann Arbor: University of Michigan Press, 2001).

[108] Friedrich Kittler, *Gramophone, Film, Typewriter* [1986], trans. Geoffrey Winthrop-Young and Michael Wutz (Stanford: Stanford University Press, 1999).

[109] The classic text is McLuhan, *Understanding Media: The Extensions of Man* [1964], where he argues that with electronic communication technology "we are extending our central nervous system itself in a global

loop between technical and cerebral data-processing operations, wherein the one models the other with scant regard for the difference between computer circuits and human biology. Or as he puts it: "Sensory aphasia (while hearing), dyslexia (while reading), expressive aphasia (while speaking), agaphia (while writing) bring forth machines in the brain."[110] When the technological differentiation of media channels—optics, acoustics, and writing—broke the monopoly of alphabetic writing ca. 1800, he continues:

> the fabrication of so-called Man became possible. His essence escapes into apparatuses … Machines take over the functions of the central nervous system, and no longer, as in times past, merely those of muscles. And with this differentiation … *a clear division occurs between matter and information*, the real and the symbolic. … So-called Man is split up into physiology and information technology.[111]

At a minimum, Kittler is arguably saying that the emergence of analog media in the late nineteenth century is fatally tied to similar advances in the analysis of human cognition and perception. But subsequent theorists have taken a harder line, and his unrelenting focus on data streams obliquely highlights the "clear division" he asserts "between matter and information."[113] This division would underpin a landmark study fifteen years on, Katherine Hayles' *How We Became Posthuman* (1999), which seeks to undo the concept of embodiment, or rather, to define human being "first of all as embodied being."[114] For Hayles the central move posthumanism makes is to separate information from its body. Information in the form of data patterns become the ultimate, indispensable reduction of meaning, beyond which no further substance inheres. (To be sure, pushback against this infatuation with data/information as units of identity

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embrace." Media, he continues, are effectively metaphors that "translate experience into new forms" and he prophesies a dominant culture of electronic data transfer accordingly: "[b]y putting our physical bodies inside our extended nervous systems, by means of electric media, we set up a dynamic by which all previous technologies that are mere extensions of hands and feet and teeth and bodily heat-controls … will be translated into information systems" (3, 57).

[110] Kittler, *Gramophone, Film, Typewriter*, 189.

[111] Ibid., 16. Emphasis added

[113] Brian Massumi, for one, proposes that "things and objects are literally, materially prosthetic organs of the body." Massumi, *Parables for the Virtual*, 96.

[114] Hayles, *How we Became Posthuman,* 283.

has a parallel history,[115] just as the desire to exceed our biological limitations stretches back at least four millennia, and for this reason might be considered fundamentally human.)[116] After asserting the posthuman "privileges informational pattern over material instantiation" where consciousness constitutes "an epiphenomenon ... an evolutionary upstart," Hayles characterizes the posthuman's remaining tenets accordingly:

> Third, the posthuman view thinks of the body as the original prosthesis we all learn to manipulate, so that extending or replacing the body with other prostheses becomes a continuation of a process that began before we were born. Fourth, and most important, by these and other means, the posthuman view configures human being so that it can be seamlessly articulated with intelligent machines. In the posthuman, there are no essential differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot technology and human goals.[117]

By viewing prosthesis as part of an ongoing evolutionary process, from the blank canvas of a congenital body onwards, the third and fourth tenets remain fundamentally anthropocentric; and ultimately Hayles doesn't subscribe to them. Why? Because the history of biological evolution cannot simply be eradicated by devices of artificially

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[115] Six years before Claude Palisca published his famously positivistic definition of "American Scholarship in Western Music" (1963), the American intellectual Dwight Macdonald launched a related critique: "we want to know how, what, who, when, where, everything but why." Rolling his eyes at the practice of weighing criminals before and after execution, he saw in its quest for different weights an emphasis on data and a lack of theory: "[w]e are obsessed with technique, hagridden by Facts, in love with information ... our scholars—or more accurately, our research administrators—erect pyramids of data to cover the corpse of a stillborn idea." See Macdonald, *Masscult and Midcult* (New York: New York Review of Books, 2011), 208, 203. More recent resistance to a posthuman philosophy include complaints from computer scientist David Gelernter, for whom a "roboticist" worldview has well-nigh become "a social disease" that adheres to a "fatally flawed" analogy between mind and software. See Gelernter, "The Closing of the Scientific Mind," *Commentary Magazine*, https://www.commentarymagazine.com/article/the-closing-of-the-scientific-mind/ [accessed 10 January 2015].

[116] Bostrum locates its origin in the Sumerian *Epic of Gilgamesh*, ca. 1800 BC (where King Gilgamesh learns of, and seeks, a natural means for attaining immortality—via a seabed dwelling herb—but is thwarted by a snake), and it is thereafter traceable across a densely spun web of historical documents, from Giovanni Pico della Mirandola and Frances Bacon to Nietzsche and Aldous Huxley. See Nick Bostrum, "A History of Transhumanist Thought," see http://www.jetpress.org/volume14/bostrom.pdf [accessed 10 July 2014]. Tendencies towards genealogy are ever present, and while Bostrum avoids asserting specific links between Nietzsche's *Übermensch* and transhumanism, others have affirmed continuities. See most prominently Stefan Sorgner, "Nietzsche, the Overhuman, and Transhumanism," *Journal of Evolution & Technology* 20 (2009): 29-42.

[117] Ibid., 3.

intelligent listening / sensing /cognizing, regardless of whether the body is considered primary (Kapp) or secondary (Kittler) to technological tools. It is incarnated with a sedimented history, Hayles explains: "a physical structure whose constraints and possibilities have been formed by an evolutionary history that intelligent machines do not share." For this reason, humans may enter into "symbolic relationships with" or be "displaced by" intelligent machines, she concludes, but the discursive difference between machines and humans in their embodiment means "there is a *limit* to how seamlessly humans can be articulated with intelligent machines."[118] For present purposes, this postulated limit point is exemplified by the case of auditory prosthesis and augmented auditory sensation, to which we now turn.

Musical listening & Transhumanism

So what is at stake for a theory of musical listening? We have already seen that individuals reside in empirically different perceptual worlds. Transhumanist attitudes destabilize the idea that an individual inhabits a singular *Umwelt*. If even the biological given of our bodies becomes potentially changeable, what multiplied complexities would result for our perception? Meaning would no longer be guaranteed by a coherent origin in the (purely) human body. How would this affect music aesthetics? Aesthetics itself—as the (human) study of the beautiful—may no longer even be applicable.

Amid such alarm, possibilities also lurk. To date, music-orientated discussions of transhumanism and the posthuman have focused principally on simulations of the human voice as signifier of human identity.[119] Moving beyond this, the music

[118] Ibid., 284. Emphasis added.

[119] In 2003, Joseph Auner diagnosed how vocoder and computer simulations of voices play on the associations of mechanical and organic sounds in songs by Radiohead and Moby. Far from deconstructing the human, these present songs as 'a sort of cyborg system that attempts to splice the human and technological thus … illuminat[ing] its peculiar expressive character.' The ensuing anxiety of identity is embedded in the manipulation of vocal signifiers within a continuum of human and synthetic computer sounds. For Auner, the resulting cyborg persona 'becomes a way of reconstructing expression,' which is to say, both a topos of pop culture and a referential language. Joseph Auner, "'Sing it for Me,'" *JRMA* (2003): 98-122, here 110-111. See also Frances Dyson, *The Tone of Our Times* (Cambridge MA: MIT Press, 2014), 70ff; and Stefan Sorgner's loose composition-based speculations, "Music" in Robert Ranish and Sorgner (eds), *Post- and Transhumanism*, 299-314; and Sorgner, "Music, Posthumanism and Nietzsche," *The Agonist* 5 (2012): 1-26.

potentially implicated is numerous and varied. It incorporates algorithmic composition and artificial intelligence, music generated by somatic feedback[120] and data audialization in general, as well as machine-led musical training, computer-aided performance of complex music, and the imitation of inhumanly complex sound configurations that occur in nature (such as the irregular rhythm of pedestrians on a bridge or the polyphony of beating wings as a flock of pigeons takes off). In a material theory of communication, the ear—unclosable and inert—is perhaps the most profoundly implicated sense organ for theorizing historically the limits of human sensation. Hence I delimit the remainder of this article to developing the material theory of listening with which we started, and music conceived in relation to auditory thresholds.

Musical sounds situated at the boundaries of our sense perception play on Uexküll's theory of *Umwelt*. When the ear is no longer restricted by biology and becomes a site of potential technological augmentation, the very idea of normal auditory perception becomes inherently vulnerable; it follows that what is at stake in the dance with technology is nothing less than sound as music. Two examples can help to ground this bold claim.

Our sonic *Umwelt* 1: Sciarrino

In 1979, the Sicilian composer Salvatore Sciarrino (b. 1947) advanced an explicit manifesto that future developments of modern music should investigate "the

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[120] This extends from Alvin Lucier's *Music for Solo Performer* (1965) and Raymond Kurzweil's Brain Generated Music to the Brain-Computer Music Interface developed at Plymouth University, UK. While Lucier's approach was to amplify alpha waves, creating a signal to excite loudspeakers attached to percussion instruments, Brain Generated Music Interface analyses the electrical activity in the Brain (via electroencephalography) and converts the signal into music played on a midi keyboard. An overview is given in Eduardo R. Miranda and J. Castet, *Guide to Brain-Computer Music Interfacing*. Kurzweil describes BGM as a "brain-wave biofeedback system" whose stated purpose is to encourage "the generation of alpha waves [associated with meditative states] by producing pleasurable harmonic combinations upon detection of alpha waves, and less pleasant sounds and sound combinations when alpha detection is low." See his description in *The Age of Spiritual Machines,*152. An analysis of Lucier is given in Volker Straebel and Wilm Thoben, 'Alvin Lucier's *Music for Solo Performer*.'

boundaries of auditory perception."[121] Music itself is the medium *par excellence* for cultivating an aesthetic of perceptual limits, he asserts:

> [M]usic inhabits a threshold region. Like dreams, where something both exists and does not yet exist, and exists as something else as well. And where these sensations, the most fleeting of them, cross the threshold of unconsciousness with the blink of an eye: outside, they are prolonged, sharp and clear, having survived the passages from drowsiness. These are the sounds found close to the horizon of the sense.[122]

Sciarrino's *Sei capricci* for solo violin (1976) play on a very particular "horizon of sense," the threshold of audibility, including both upper frequencies and minimal sound intensity. While this fact cannot circumscribe the sum value of *Sei capricci,* I would like to explore the claim that the caprices, distantly modeled on Paganini's Op. 1, can be read as transhumanist for reveling in human limits, for pushing beyond our natural capacity, sensory as well as technical. It is a fitting genre for transhuman exploration because, historically, the roles and activities of the virtuoso reside within a set of paradoxes, one of which is the contradictory embodiment of human and other. The tension between the identities of mechanical executant and inspired supra-human leave unspecified the origins of the non-human agent.[123] Just as certain early nineteenth-century listeners accepted that Paganini was possessed by the devil because of his uncanny mastery of his instrument, so the virtuosity and de facto unrealizability of Sciarrino's late twentieth-century caprices potentially invokes the need for extra-human means.

Situated in the instrument's uppermost range, the six caprices utilize artificial harmonics almost exclusively (producing distortion, in contrast to natural harmonics). They outline a fragile tissue of sound that—in the present context—can function as a metaphor for the fragility of our perceived reality itself. The notation indicates where to place fingers on the fingerboard rather than a sounding pitch; the resulting pitches

[121] Salvatore Sciarrino, "Di una musica d'oggi," *Chigiano. Rassegna annual di studi musicologici* 33 (1979): 371-75, here 371.
[122] Sciarrino, notes from *Hermes* in *L'Operer per Flauto* (Milan: Ricordi, 1984), 7.
[123] The literature on virtuosity has grown considerably over the last decade. On the question of paradoxical identities, see particularly Susan Bernstein, *Virtuosity of the Nineteenth Century*; Dana Gooley, *The Virtuoso Liszt*; Richard Leppert, "Cultural Contradiction, Idolatry, and the Piano Virtuoso," 252-81.

depend on how firmly the finger depresses the string and any distortion produced from the bow contact, hence it is illegible for the purposes of silent reading (the historical archetype for which is surely Brahms' comment on reading *Don Giovanni* in 1887). Unlike traditions of 19th-century virtuosity, the totality of these works remains genuinely unplayable and inaudible as written; the artificial harmonics resulting from Sciarrino's extended techniques are effectively indeterminate distortions whose configurations on the fingerboard do not fit under the ordinary human hand. The playing techniques themselves draw attention to the artificiality of producing musical sounds; the rapid switching between *tasto* and *ponticello* in No. 3 is typical in foregrounding the bow-as-medium, producing almost pitchless noises as the hairs brush against the string. A transhuman reading would see the (prescriptive) notation as a challenge to biological limits: by ensuring a performer deals in the residue of musical materials rather than in musical pitches as such, it becomes less a critique of notation, more a threshold aesthetic that goads us with what we cannot quite perceive and cannot quite execute.

At the level of notation, the first caprice is modeled on Paganini's E-major caprice (No. 1) in its brilliant rising and falling ricochet bowings across broken chords. This texture is interrupted by a chromatic glissando figure, either ascending or descending, that co-opts the broken chords in sequences of between six and twelve chordal iterations. There are seven such "glissando interruptions" in total. As example 2 shows, the first of these uses the perfect fifths of the violin's open strings, though later interruptions deviate into sixths and sevenths. The highest notated pitches are beyond the auditory threshold of musical pitch: g-sharp'''' (just beyond the 88-key piano) occurs five times. Its sounding frequency is 6644.876 Hz in equal temperament, but the likely pitch of its harmonic is d-sharp''''' (19,912Hz), which, if detected at this sub-*PPP* level, would be perceived as infinitesimal noise: what Helmholtz in 1863 called *sensations* (sense impressions we become conscious of only as conditions of our body, especially of our nervous apparatus) as opposed to *perceptions* (sense impressions from which we form a mental image of an external object).[124] The same strategy is revisited in more truncated fashion at the close of the fifth caprice, which proceeds into upper auditory limits

[124] Hermann von Helmholtz, *On the Sensations of Tone*, 94.

through a rising harmonic on the g string marked: "glissando without tightening the hand position! Until the end of the string!"[125] This is given in example 3.

But as the data in figures 4a and 4b show, according to the American National Standards Institute, Sciarrino's d-sharp at 19,912Hz, played sub-*PPP*, is officially inaudible for humankind.[126] As such, the ascending glissandi effectively mimic a threshold test, not unlike those of König, Stumpf, and Preyer ca. 1890, probing the correlation of sound pressure (volume) with frequency (pitch).

[Figures 4a-b near here]

Frequency and sound pressure are of course interdependent parameters, and each of the glissandi in Sciarrino's first caprice begins and ends with silence framed by minute dynamic increments.[127] As example 4 shows, two-thirds of the way through the work the opening broken chord is simply repeated seven times at different dynamic levels while a crescendo / diminuendo frame the passage in silence; it is a kind of intensity test, as though a *messa di voce* were being extended into the lower dynamic threshold. It presents an artistic vision of music hovering between what Aristotle called actual and potential sounds. Perception of actual sound requires "a certain form or power in a magnitude." The need to control magnitude at the upper extreme is commonly understood; it helps us understand why excessive stimulations destroy the organs of sense:

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[125] "gliss. senza stringere la posizione! Sino alla fine della corda!" Sciarrino, *Sei capprici* (Milan: Ricordi, 1976), 11.

[126] Officially, thresholds of audibility are calculated in laboratory conditions as the smallest level of sound pressure needed for an individual to perceive a certain frequency. They are plotted as the thresholds in decibels (sound pressure level: SPL) versus frequency (Hz). Of course, the auditory system remains insensitive to some frequencies no matter how intense the sound. Values are calculated through psychometric testing where subjects are deemed to have heard a tone if they correctly detect it 75% of the time. The American National Standards Institute (ANSI) publishes data for the audibility thresholds of "ontologically normal persons" between 18-25 years old. See http://webstore.ansi.org/RecordDetail.aspx?sku=BS+ISO+28961%3A2012 [accessed 26 August 2014].

[127] A crescendo leads to a peak dynamic ranging from *PPP* to *FF*, before a diminuendo. Typically for Sciarrino, the passage into silence is specified by a circle at the head or tail of each pair of lines, as the preface explains: "crescendo dal nulla / diminuendo fino al nulla." Sciarrino, *Sei capprici*, 1.

> If the movement set up by an object is too strong for the organ, the form which is its sensory power is disturbed; it is precisely as concord and tone are destroyed by too violently twanging the strings of a lyre.[128]

Sciarrino's music resides at the opposite end of the spectrum—too delicately "twanging" the strings for human perception. If our auditory system cannot detect sound being produced, it becomes "potential" sound, philosophically speaking, and a politics of posthuman difference deals precisely in "potential becomings that call for actualization."[129] That is, actualizing the potential, or what Salomé Voegelin calls the possibility of the "sonic impossible."[130] But to reiterate an earlier question: what kind of listener does such music imply?

[examples 2-4 near here]

To say the music resides at the extremities of sound itself is also to say it depends on the listener's perceptual apparatus, the *Umwelt* they create. For there can be no concept of silence, in the sense of what cannot be heard, without limited auditory perception. Sciarrino explores the spectrum between silence and sound, but the poles are not absolute, biologically speaking.[131] The composer himself cites auscultation to deny the existence of silence, where heartbeats and breath remain audible in any sealed chamber: "[a]s long as one is human there is no silence: and where there is perception, there is music." We tend not to adopt a transhuman position that sees the physiology of listening as a performative factor in this context. "Is there a metaphysics of silence?" Sciarrino asked in 1990:

> I don't know ... Certainly silence, a 'zero-sound' ... presents unsuspected theoretical problems. How does one decide the frontier, the point of passage? There is a sort of reversal in my music,

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[128] Aristotle, *de Anima*, book II, 424a, ll.28-32.
[129] Braidotti, *The Posthuman,* 100.
[130] Salomé Voegelin, *Sonic Possible Worlds* (New York and London: Bloomsbury, 2014), 167.
[131] Brenden P. McConville, "Reconnoitering the Sonic Spectrum of Salvatore Sciarrino," *Tempo* 65 (2011): 31-44, here 32. See also Gavin Thomas, "The Poetics of Extremity," *Musical Times* 134 (1993): 193-96.

> in that the sounds preserve traces of the silence from which they come and into which they return, a silence which itself is an infinite rumbling of microscopic sonorities.[132]

Here, silence becomes a word for sounds for which we have no ears. And Sciarrino's bridging of sound and silence arguably implies a desire to hear into what is ordinarily silent, what is ordinarily beyond human nature.

In the end, this approach may seem reductive: a merely biological-scientific reading of musical listening, voided of the cognitive activity of expectation, fulfillment, denial, and patterning that we identify with musical experience. An alternative, transcendental interpretation is to hear the music melting into a noumenal realm, one increasingly inaccessible without technological assistance. Sciarrino's caprices effectively make art by ensounding this process.

Our sonic *Umwelt* 2*:* Nørgård

If these caprices inhabit a threshold region, other works categorically exceed it. Composed between 1986-90 for Danish Radio (and revised in 1991), Per Nørgård's Fifth Symphony is a single-movement work lasting thirty-five minutes; it requires six percussionists and a battery of high-pitched percussion, including mouth sirens, Peking Opera Gongs, sleighbells, metal chimes, swanee flutes, and ultrasonic dog whistles. The music explicitly plays with our lens of perception, as Nørgård recalls:

> What has fascinated me in the Fifth Symphony is the way a particular hearing range is made possible to our imagination as something analogous to what we see in our surroundings – where we usually see only one side of things. Our imagination is therefore already attuned to the fact that we see in parts, so why should this not apply to our listening experiences too?[133]

Like Uexküll thinking himself into other perceptual worlds, the hope here is that imagining other auditory ranges encourages us to accept the existence of other

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[132] Sciarrino, "Entretien avec Salvatore Sciarrino," *Entretemps* 9 (1990): 135-42, here 139.

[133] Per Nørgård's comment cited in Anders Beyer, "Om Nørgård 5. Symfoni," *Dansk Musik Tidsskrift* 3 (1990-91): 75-81, here 81.

environments, what Voegelin has called the "aesthetic inaudible" – what is imagined to exist as sonic materiality but for which we lack the "sensibility, will, and wherewithal to hear."[134] If this comparison of visual and auditive regimes appears insufficiently critical, it arguably finds a more stable footing through empirical research: recall Rudolph König's visualization of sound at 90,000Hz (figure 1), and the "deceptive ... signal transductions such as the *imaging* of ultrasound" that create images from time-based sonic articulations far above human hearing.[135]

Musically, Nørgård's symphony presents geysers and avalanches of pitched sound that ascend into inaudibility then descend to muffled timbres of muted double bass and bass drum. Where previous ascents had risen to the uppermost register of the three piccolos, supported by rising glissandi in the harp, glockenspiel, and piano, Nørgård's sound images hover above human thresholds through the use of two dog whistles at the apex of the highest ascent. In such a context, they literalize the poetic metaphor of inaudible music. As example 5 shows, two such whistles are blown *ff* and the resulting difference tone is intended to be heard.[136]

[Example 5 near here]

What is inaudible in such passages cannot advocate the morphological freedom sought by transhumanists to hear higher frequencies. But it raises the question, even if the symphony's play with thresholds of auditory sensation could just as easily be viewed as reliant on biological limits as protesting against them.

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[134] Voegelin, *Sonic Possible Worlds*, 170. Imagining inaudible sounds becomes a metaphor in Voegelin's reading for political open-mindedness. She moralizes that the possibility is always there, and that "*[w]e need ... the* [idea of the] *inaudible*, to become able to imagine the as yet unimaginable and let it infiltrate actuality." Ibid.

[135] Ernst, *Sonic Time Machine*, 30.

[136] The ultrasonic pitches, while calculable, are not determined as such. Directions in the score explain: "2 'dog whistles,' poss. high pitched, (together producing deep difference tone by *ff*)." Nørgård further requests that players take 'great care ... to maximize the "overall-production" of difference-(beat)-tones' by adopting stable tone quality, before the two whistles outlast the chord proper and a general pause on the rest clears the altitudinous sound. The second and final appearance of the whistles hears their difference tones emerge as the sole sound from within a sustained chord of dissonant semitones, struck *fff* and slowly detuned via quartertones in a descending glissando. Nørgård, *Fifth Symphony* (Copenhagen: Wilhelm Hansen Edition, 1991), 53, 57.

Promethean dreams: expanding the auditory range

Transhumanism's embraces of morphological freedom—"one's right to one's body"[137]—includes augmenting our auditory system, as noted above: replacing some of our biological apparatus with prostheses, the better to connect to other sounds, including Sciarrino and Nørgård's music. Self-identifying transhumanists such as Anders Sandberg and Max More have already broached a range of ways in which to augment or "enhance" the biology of living people, while companies such as Cyborg Nest and Cochlear are marketing artificial senses.[138] More, in an audacious "Letter to Mother Nature," explicitly seeks an amendment to the human condition in these terms: "We will expand our perceptual range through biotechnological and computational means. We seek to exceed the perceptual abilities of any other creature and to devise novel senses to expand our appreciation and understanding of the world around us."[139] Counterintuitively, musicians may have a distant affinity with this impulse. Theorist Mark Reybrouck has already argued that it is in the nature of composition to push beyond perceptual limits, that composers construct an "internal model" that allows them to "go beyond the constraints of perceptual bonding and to carry out mental operations on virtual elements."[140] That is, where the reality of sensory input is impossible, it is replaced by representation and the universe of a symbolic order. But new sensory input is critical, as Reybrouck acknowledges. This need not imply the improbable growth of antennae, sensitive to hitherto unnoticed tremblings in the ether, as Pound imagined in 1921, and de Bear quantified in 1860. For changes to our auditory reality already occur in those who suffer hearing loss; following this logic,

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[137] Anders Sandberg, "Morphological Freedom – Why We Not Just Want It, but Need It," *The Transhumanist Reader*, 56-64, here 56.

[138] Enhancements already underway include an implantable compass that vibrates when facing magnetic north; see http://www.cyborgnest.net [accessed 6 October 2016] and the auditory streaming of digital sound to a cochlear implant; see http://www.hearyourway.com/wps/wcm/connect/uk/n7/adults [accessed 8 August 2017]. Others include decreases in age-related muscular decline, AIDS and cancer prevention, DNA repair, as well as "possible cognitive enhancements." See Sandberg, "Morphological Freedom," 58. See also Gregory Stock and John Campbell, *Engineering the Human Germline*; and in the field of biochemistry, Migliaccio, Giorgio, Mele, Pelicci, Reboldi, Pandolfi, Lanfrancone, and Pelicci, "The p66shc adaptor Protein Controls Oxidative Stress Response and Life Span in Mammals," *Nature* 402 (1999): 309-313; Tang, Shimizu, Dube, Rampon, Kerchner, Min Zhuo, and Tsein, "Genetic Enhancement of Learning and Memory in mice," *Nature* 401 (1999): 63-69.

[139] Max More, "A Letter to Mother Nature" [1999], *The Transhumanist Reader*, 449-50, here 450.

[140] Mark Reybrouck, "Adaptive behaviour and epistemic autonomy," *Musical Creativity: Multidisciplinary Research in Theory and Practice,* ed. Irène Deliège and Geraint Wiggins, (Hove: Psychology Presm 2006), 44.

augmenting unimpaired hearing need be no different in principle to correcting impaired hearing.[141]

But there are two problems with this: first, that it may be impossible; second, that few if any medical professionals have asked the question before, and hence no empirical research into this field has been funded. It is indicative that a recent article for the World Economic Forum predicts five human enhancements that "could be commonplace by 2020" but makes no mention of the ear; the skin, vision, memory, and decision making assume priority.[142] There is nevertheless evidence that existing technologies provide the means by which ears may potentially become sensitive to sounds below 20Hz and above 16-20,000Hz. These include:

- **transposing algorithms**: would shift frequencies from above 16,000Hz to a perceivable range, in just the manner a hearing aid operates for individuals who may have "dead regions" in the cochlea. The bandwidth in high-end hearing aids can produce effective gain up to about 10,500Hz, though most stop at 6000Hz (g''''). Shifting frequencies distorts the sound, however, so this is currently a poor option for music.
- **cochlear implants (auditory nerve)**: would use a potentially enhanced speech processor capable of transposing an extended range of sounds, and which is connected to the auditory nerve, though the limited signal channels of implants were not designed for the spectrum-rich sounds of music, and the transposing algorithm again results in considerable distortion. In response, work to mitigate this effect through compositions adjusted or written specifically for cochlear implant users is tentatively underway.[143]

[141] The distinction between medical treatment that enhances function rather than ameliorates an illness, has been regarded as fuzzy by philosophers in this context. Witness Carl Elliott, who argues that what seem to us like straightforward examples of medical treatments 'will look differently to people from other times and other places, and ... the line we often draw between enhancements and treatments is not as sharp as we would like to think.' Elliott, "What's Wrong with Enhancement Technology?" *Readings in the Philosophy of Technology*, ed. Kaplan (Plymouth et al: Routledge, 2009), 431-37, here 435.
[142] Joe Myers, "5 human enhancements that could be commonplace by 2020," https://www.weforum.org/agenda/2016/06/5-human-enhancements-that-could-be-commonplace-by-2020/ [accessed 11 July 2016].
[143] One example is the Interactive Music Awareness Programme (IMAP) based at Southampton University, UK. See http://morefrommusic.org [accessed 27 September 2016].

- **cochlea implants (brain stem)**: would use a similarly enhanced processor, but connected directly to the brain stem (bypassing the auditory nerve by inserting iridium microelectrodes into the stem).[144] The two reservations above remain valid here.
- **bone conduction:** of ultrasonic frequencies is possible using a piezo-electric 'buzzer' (a piezo disc glued to a metal disc). Methods of ultra-high-audio-frequency stimulation are typically used in treatment for tinnitus where residual neuronal function exists in the range 10-14KHz, or for absorbing medicine through the skin. Ultrasonic frequencies become perceptible via bone conduction only with much higher sound pressure levels (typically between 80-100dB for a sound at 8KHz), with data indicating that no absolute threshold operates for this method.[145] While bone conduction fulfills the criterion of sensing ultrasonic sound frequencies, it offers mere buzzing, with no way of receiving meaningful sound communication, i.e. speech or music.[146]
- **Cilia regeneration:** stem cell and gene therapy can be used to repair damaged structures of the auditory system, where the principal focus has been regenerating hair cells (cilia) within the cochlear duct; the possibility of engineering organic hairs sensitive to ultrasonic frequencies cannot be ruled out. For advocates, such methods represent "the future treatments for hearing loss" but at present such treatments are "years if not decades away."[147]

[144] Douglas McCreery of Huntingdon Medical Research Institute has pioneered this method for patients with type 2 Neurofibromatosis (NF2), where a tumour along the auditory nerve leaves it without function after surgery to remove the tumour. See McCreery, "Cochlear Nucleus Auditory Prosthesis," *Hearing Research* 1 (2008): 64-73.

[145] See particularly figure 1 in Barbara A. Goldstein, Abraham Schulman, and Martin L. Lenhardt, "Ultra-High-Frequency Ultrasonic External Acoustic Stimulation for Tinnitus Relief," 112. See also K. Fujimoto, S. Nakagawa, and M. Tonoike, "Nonlinear explanation for bone-conduction ultrasonic hearing," 210-15; and T. Nishimura, S. Nakagawa, and T. Sakaguchi, and H. Hisoi, "Ultrasonic masker clarifies ultrasonic perception in man," 171-77.

[146] By contrast, commercial headphone manufacturers have developed bone-conduction technology for normative hearing ranges as a means of bypassing the eardrum, but this ceases to function beyond normative thresholds. One example is AudioBone; see http://www.audioboneheadphones.com [accessed 2 May 2015].

[147] See Mark A. Parker, "Biotechnology in the Treatment of Sensorineural Hearing Loss: Foundations and Future of Hair Cell Regeneration," *Journal of Speech, Language, and Hearing Research* (2011): 1709-1731.

In all but the last case, the degree of signal change (distortion) introduced to sounds received is so considerable that the methods initially appear unviable for music.

Phenomenologically, however, this simply transforms vibrations into electrical impulses in a different way to that which occurs naturally in the auditory nerve; in this sense, it is only a different kind of sonic representation, or virtuality.[148] For writer and implant wearer Michael Chorost, there is nothing inherently truthful about sensory organs' representation of the universe: "reality is ultimately a matter of software" he argues, "people with normal ears are not off the epistemologist hook, because their 'software' was written haphazardly by millions of years of evolution and has no greater claim to reality."[149] As Mara Mills has shown, signal processing within the auditory nerve has been researched through patient response since 1957, and continues to be "the major site of cochlear implant development today."[150] She foregrounds Graeme Clark's work on implant processors during the 1970s, wherein he explicitly took decisions about what elements from the sonic environment to filter into coded signals for the auditory nerve; prioritizing speech led him to seek "a more limited number of stimulus channels [that would] still adequately stimulate the physiology," as he puts it, and to extract "only the essential speech information that can be processed by the auditory nervous system."[151] Music was simply deemed less important than speech for those early patients seeking to go about their daily lives; but implants could equally well be optimized for music. For Mills, the selected competencies of such processors are "political" to the extent they encapsulate a "range of cultural and economic values ... deliberately

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[148] For theorists of virtuality such as Massumi, the discovery of aesthetic stimuli in newly accessible objects would not constitute an "authentic" reach into the world of supersensible sounds. Adapting his critique of sensation, any technological extension of the cochlea duct's acuity points to the virtual: "Sensation and thought, at their respective limits as well as in their feedback into each other, are *in excess over experience*: over the actual. They extend into the nonactual [i.e. what cannot be perceived]. If the alternative mode of abstraction into which perception extends is the possible, the intense mode of abstraction into which sensation potentially infolds is, at the limit, the *virtual*." Massumi, *Parables for the Virtual*, 98.

[149] Michael Chorost, *Rebuilt: How Becoming Part Computer Made Me More Human* (London: Souvenir Press, 2005), 147.

[150] Mills, "Do Signals Have Politics," *Oxford Handbook of Sound Studies*, ed. Pinch and Bijsterveld (New York: Oxford University Press, 2011), 319-339, here 334.

[151] Graeme Clark, "The Development of Speech Processing Strategies for the University of Melbourne/Cochlear Multiple Channel Implantable Hearing Prosthesis," *Journal of Speech-Language Pathology and Audiology* 16 (1992): 95-107, here 95. Cf Mills, "Do Signals have Politics," 331-33.

‘scripted’ into the design.”[152] Apparatus for other sense modalities, such as the “hearing glove” (attributable to Norbert Wiener), which stimulates the finger of a deaf person with electromagnetic vibrations, or the implanted color sensor that—for its color-blind recipient, Neil Harbisson—converts the color spectrum into sounds, including ultraviolet and infra red signals, present comparable instances.[153] As do the media through which humans increasingly hear or otherwise “tune in” haptically to auditory vibrations underwater, from oceanic recordings to the Wet Sounds Festival.[154] Technology transforms signals for perception, in other words, and all sentient signals operate through analogy in this sense, which is why Hayles can plausibly summarize the principle historically, via the founder of cybernetics: “for Wiener, analogy was communication, and communication was analogy.”[155]

Turning from the abstract to the concrete, Eisuke Yanagisawa’s CD *Ultrasonic Scapes* (2011) offers one illustration of ultrasonic analogy. His frequency-modulated field recordings of bats, cicadas, and street light drones transpose a motley array of sounds from beyond our auditory threshold.[156] As indicated above, this technology could be adapted to hearing aids or implants, giving the wearer a positional advantage over “normal” listeners. Yet two potential flaws in the proposals above are: (i) the overlaying of transposed sounds onto those perceived “naturally” at target frequencies, leading to a new challenge of channeling auditory input simultaneously from multiple sources; and (ii) the tonotopic mapping between the cochlea and auditory cortex. That is, specific nerve fibers of the cortex have evolved to be most sensitive to specific frequency inputs from the specific cilia hairs of the inner ear. This spatial correlation between perceiving brain area and stimulated cochlea area implies that the range of sounds we recognize as

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[152] Mills, “Do Signals Have Politics,” 323.
[153] See Mills, “On Disability and Cybernetics,” *Differences* 22 (2011): 74-111; and Neil Harbisson’s TED talk, https://www.ted.com/talks/neil_harbisson_i_listen_to_color/transcript?language=en [accessed 11 July 2016].
[154] A concise summary of aesthetic and scientific approaches to “underwater music” over the past half century is given in Stefan Helmreich, “Underwater Music: Tuning Composition to the Sounds of Science.” See particularly Nina Eidsheim’s critique of underwater singing, “Sensing Voice: Materiality and the Lived body in Singing and Listening,” and *Sensing Sound*, 27-57; and Douglas Kahn’s intellectually playful *Noise - Water – Meat* (Cambridge, MA: MIT Press, 2001), 242-89.
[155] Hayles, *How We Became Posthuman*, 99.
[156] Eisuke Yanagisawa’s album *Ultrasonic Scapes* (2011) sold out of its initial release of 50 copies, but is available as a digital download: http://www.gruenrekorder.de/?page_id=5260 [accessed 17 January 2015].

sound is limited by an interdependence of the auditory cortex and cochlea, not by the latter's physiology alone.[157] One implant wearer frames any changes to this in terms of an insurmountable learning curve: "I probably get more total information from the implant, because it triggers nerve endings that hadn't had hair cells before. But I'm limited by having an auditory cortex that's not developed enough to use the additional information."[158] While further research would be needed to begin to draw conclusions on the matter, brain plasticity is a proven characteristic; if the brain receives unfamiliar auditory stimuli, it would almost certainly adapt to accommodate those stimuli, which is to say new stimulation would drive change in the auditory cortex over time.[159] For some, this may epitomize an expedited evolution, but the challenge of educating users to make use of any new sense capabilities remains indeterminate. At this stage, then, the idea of auditory sense augmentation amounts to little more than a thought experiment, one in which, for skeptics, "music" in the strong sense would not have anything to gain.

Current futurist predictions for cochlear implants in nondisabled listeners bypass aesthetics altogether, focusing on application for the military and information-intensive business.[160] And admittedly, Yanagisawa's transposed sounds are but irregular crackles and blips. To imagine such sounds in opposition to familiar music immediately makes us opponents of the idea, as per reactions to Stockhausen's compression of a Beethoven symphony into half a second ("then you have a new sound"), or to Dustin Carr's music for a microscopic guitar where strings fifty nanometers thick vibrate at 10,000,000Hz,

[157] See Thomas Talavage, Martin Sereno, Jennifer Melcher, Patrick Ledden, Bruce Rosen, Anders Dale, "Tonotopic Organization in Human Auditory Cortex Revealed by Progressions of Frequency Sensitivity," *Journal of Neurophysiology* 91 (2004): 1282-96.
[158] Chorost, *Rebuilt*, 174.
[159] In 1999 Rainer Klinke (et al.) demonstrated a seven-fold increase in the brain size of congenitally deaf cats whose auditory nerves received electrical stimuli (via neural implants) from a microphone for the first time; the implant was connected to a microphone, effectively creating a prosthetic ear that allowed the hitherto deaf cats' functioning auditory nerve to "hear." See R. Klinke, A. Kral, S. Heid, J. Tillein, R. Hartmann, "Recruitment of the auditory cortex in congenitally deaf cats by long-tem cochlear electrostimulation," *Science* 285 (1999): 1729-1733.
[160] Postulated military applications include "implanted computing and communication devices with new interfaces to weapons, information and communications" while business applications would seek "expanded information transfer capacity." See G. Q. Maguire and Ellen M. McGee, "Implantable Brain Chips? Time for Debate," *The Hastings Report* 29 (1999): 7-13, here 9.

both unplayable by human fingers and inaudible to human ears.[161] More broadly, the implications of virtually extending our *Umwelt* are unknown. Such an extension may be intriguing but appears at present unnecessary and potentially undesirable: it has an uncertain aesthetic claim, serves no current utility, and—in the extreme instance of surgical alteration—may be unethical. Critics of the view that "morphological freedom" is a basic right cite the need for protection from any such coercive biomedicine. Were established musicians to adopt a postulated surgical auditory extension technology, it may pressurize others to do likewise. As Isaiah Berlin once put it: "[f]reedom for the wolves has often meant death to the sheep."[162] There remains, then, an unanswered question about why such an innovation would be desirable. But such hesitation need not shut down further discussion. After all, wearable hearing aids and headsets can simply be taken off. On the one hand, any advocacy of auditory augmentation would need to respect the preferences, autonomy and sensibilities of listener choice; but on the other hand, the unrealized possibilities implied by transhuman discourse bear open-mind consideration.

Stelarc's *Extra Ear*

As is well known, prosthetic extensions of our senses already exist, and not all answer a perceived disability.[163] In 1964 Wiener, the founder of cybernetics we encountered earlier, predicted a "new engineering of prostheses" involving mixed systems of both human and mechanical parts that "need not be confined to the replacement of parts that we have lost, ... parts ... which we never have had."[164] The postulate of a modified

[161] Stockhausen's comment is cited in Robin Maconie, *Other Planets* (Lanham: Scarecrow Press, 2005), 145; Carr was a graduate student in Physics at Cornell at the time of the nanoguitar's invention. See: http://www.news.cornell.edu/stories/1997/07/worlds-smallest-silicon-mechanical-devices-are-made-cornell [accessed 3 September 2014].

[162] Isaiah Berlin, *Four Essays on Liberty* [1969], (Oxford: Oxford University Press, 1979), xlv.

[163] One example, developed at the Swiss Federal Institute for Technology, is the "bionic hand" whose neurally embedded electrodes offer a vicarious sensation of touch. Dennis Aabo Sørensen's 'hand' conducts electrical signals from his prosthetic fingers to his brain, giving him a replacement sensation of touch in his amputated hand. Electronic sensors detect tension in the artificial tendons that control his finger movement; this information is converted into an electric current; a computer in the hand sends an impulse to ultra thin electrodes that have been surgically implanted into the nerves in the upper arm, which then relay to signal the brain. See Stanisa Raspopovic, et al., "Restoring Natural Sensory Feedback in Real-time Bidirectional Hand Prosthesis," 1-10, see http://biofag.com/files/Sci_Transl_Med-2014-Raspopovic-222ra19.pdf [accessed 25 August 2014].

[164] Norbert Wiener, *God and Golem* (London: Chapman & Hall, 1964), 75-6.

ear is clearly within such parameters. And there is no need to tamper with existing ears. In 2007 the Cypriot-born Australian performance artist Stelarc (aka Stelios Arcadiou) began a series of three surgical procedures to insert a soft prosthetic ear into his left forearm. The result is given in figure 5.[165] Far from an act of replacement, this no longer replicates human hearing as such. As conceived, the *Extra Ear's* purpose is not merely to receive new acoustic signals, but additionally to transmit them. A miniature microphone was initially implanted within the ear and functioned as a means of transmitting sound signals via Bluetooth to an external device ("the [surgeon's] voice was clearly heard and wirelessly transmitted"). It worked briefly, in other words. But a subsequent infection meant the microphone had to be removed; to date it has not be re-implanted.[166]

It is tempting to read the remaining shell of an ear as subdued, an object of forlorn silence, and testimony to the inevitable collision between transhuman optimism and recalcitrant physiology. But ongoing commercial ventures point to this as an advancing frontier. Emphasizing enhanced connectivity, Apple and Cochlear's joint processor *Nucleus* 7 (2017) connects compatible implants directly to the audio-visual services of Apple's mass-market devices, meaning that digital auditory data are transmitted wirelessly to a surgically embedded implant without the need of a functioning congenital ear. Current advertising speaks of enhancing the experience of 'talking on the phone … enjoying music or watching videos, we well as audio apps.'[167] If this constitutes "the first mass market cyborg enhancement,"[168] Stelarc likewise envisages re-implanting a microphone in his third ear to enable a bespoke, "wireless connection to the internet, making the ear a remote listening device for people in other places. For

[165] The ear itself is part subcutaneous Medpor scaffold, part organic matter grown from stem-cells and mature adipocytes; it was developed in consultation with surgeons Malcomb A. Lesavoy, Sean Bidic and J. William Futrell in Melbourne. Stelarc had discussed the project with medical consultants as early as 1997, he explains, and it went through a decade of frustrated attempts—including consideration of various possible locations—before proceeding to a permanent modification of his body architecture. See http://stelarc.org/?catID=20242 [accessed 9 August 2017].
[166] See Stelarc's own account on his website, http://stelarc.org/?catID=20242 [accessed 17 January 2015].
[167] See https://cochlearimplanthelp.com/tag/nucleus-7/ [accessed 20 October 2017].
[168] John Koetsier, *Forbes Magazine* (26 July 2017), see https://www.forbes.com/sites/johnkoetsier/2017/07/26/icyborg-apple-just-announced-the-first-mass-market-cyborg-enhancement/ [accessed 7 August 2017]. I am grateful to Alexander Rehding for drawing my attention to this.

example, someone in Venice could listen to what my ear is hearing in Melbourne."[169] The speaker and receiver will not embed microelectrodes into the brain stem or auditory nerve, a prospect certain to affect the artist's biological hearing. Rather they are to be placed inside his mouth, creating the illusion for Stelarc that the voices received are in his head, while offering the possibility for him to share the sounds with others by opening his mouth in a kind of vicarious speech: a displacement that literalizes the rhetorical technique of prosopopoeia.[170] The decision not to embed into the stem or auditory nerve is not addressed in Stelarc's writing on the project, but marks a limit for performance art that pauses at the prospect of irreversible neurological change.

The consistent preoccupation with the body's obsolescence in Stelarc's work is perhaps unsurprising; it typifies a certain strain of activist futurism (aka "bodyhacking") at the sharp edge of the transhumanist debate. As early as 1982 (aged 36) he declared the body an evolutionary fossil in need of technological complement.[171] By 1991, the tone was unapologietic in its provocation: "It is no longer a matter of perpetuating the human species by REPRODUCTION, but of enhancing male/female intercourse by human-machine interface. THE BODY IS OBSOLETE."[172] His projects reflected this outlook. Prior to the third ear project, he devised a *Third hand* (1980) in collaboration with engineers at Waseda University and the Tokyo Institute of Technology. A robotic arm, mounted on his forearm, could be manipulated by electromyography signals from his abdominal muscles to draw letters. Detailed discussions of the project have appeared elsewhere;[173] for present purposes the iconic image of the three hands writing "evolution" in 1982, shown in figure 6, captures at once the stubborn alterity of wearable enhancement technology, while inscribing the need for harmony and synchrony between "parts" in any claim for a transhuman evolution. This image

[169] See http://stelarc.org/?catID=20242 [accessed 17 January 2015].
[170] To an extent, ventriloquizing an illusory voice inside one's head externalises the function of Theodor Reik's figurative third ear, that of unconscious psychoanalytical intuition, from *Listening with the Third Ear* (New York: Farrar, 1948).
[171] Stelarc, 1982 interview reprinted in James D. Paffrath and Stelarc (eds), *Obsolete Body* (Davis CA: JP Publications, 1984), 17.
[172] Stelarc, "From Psycho-Body to Cyber-Systems: Images as post-human entities," *The Cybercultures Reader*, 457.
[173] Jane Goodall, "The Will to Evolve," in *Stelarc: The Monograph* (Cambridge MA: MIT Press, 2005), 1-32; Andy Clark, *Natural Born Cyborgs*, 115-42; Paffrath and Stelarc, *Obsolete Body*.

constitutes a momentary semblance, however, for it is only with the surgical permanence of the third ear that Stelarc's performance art begins to tip into the category of morphological enhancement with its uncertain claims towards evolutionary change.

[Figures 5 & 6 near here]

By dissociating one's self from a biological body, self-identity becomes the lost referential (Freud's *bodily ego*), and it may be no coincidence that, in a performance as early as 1970, Stelarc explicitly modelled the basic question Uexküll asked of *Umwelt* theory—whether it is possible to experience the perceptual world of other organisms—by donning a helmet designed to scramble binocular vision, superimposing fragmented rear and side views onto the usual frontal view in an attempt to replicate for his two eyes the compound eye of the insect. The *Ear* accomplishes a similar task but its environment is the transhuman (enhanced body) rather than the non-human (insect), though both result from a drive to alter the body's architecture, thereby "adjusting and extending its awareness of the world."[174] While this does not yet include transposing algorithms or implants for accessing ultrasonic ranges, it theoretically could.

In the end, the *Ear* along with existing devices for sensory augmentation from the sphere of virtual reality can inform our estimate of how auditory frequency augmentation might effect musical perception. The materialized twittering blips and scratchy white noise of Yanagisawa's *Ultrasonic Scapes* elicit no auditory pleasure bound to familiarity, form or harmonic proportion. As such we would not judge them aesthetically beautiful, though the inappropriateness of measuring such noise against nineteenth-century aesthetics is old; as Eduard Hanslick put it in 1854, the scraping of a knife on glass conveys "the physical effects of sounds waves, which pass along to the other nerves through the auditory nerve ... But this is not music."[175] Accepting this, access to fuller materialized sounds within our environment would nevertheless empower our sense of place, and push against our limitations regarding "the ontic

[174] Stelarc, "From Psycho-Body to Cyber-Systems," 458.
[175] Eduard Hanslick, *On the musically Beautiful*, trans. Geoffrey Payzant (Indianapolis: Hackett, 1986), 52.

nature of what is." There would seem to be a certain pleasure in that. So at this initial stage, one of hypotheses and thought experiments, the pleasure of extending the range of hearing is best regarded as a kind of virtual play: a game of giddiness, of looking over the edge, hearing the hyperreal heights—*ilinx* in Roger Caillois' classification. By altering perception, pleasure is no longer only that of haptic or aesthetic manifestation (*seductio*), but becomes sheer fascination and psychotropic distraction (*subductio*).[176]

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Epilogue: naked vs mediated sound

When in 1876 Wilhelm Preyer believed he had proven the natural audibility of sounds at 40,960Hz, Helmholtz was glad of the gain in perceptual reach but expressed dismay at the idea that such unmusical sounds were now part of human physiology. If each nervous fiber registers its own peculiar pitch, he remarked, "we should have to regard the auditory cilia as the bearers of squeaking, hissing, chirping, crackling sensations of sound, and to consider their reaction as differing only in degree from that of the cochlear fibres."[177] The noises were not imaginary (*La domaine de la fantasie)*;[178] Preyer and Helmholtz's ears *did* bear these actual sound sensations, but at a frequency closer to 11,000Hz. As we have seen, such sounds—conceived as auditory reality defined by the listening subject—are not atechnological. By hypothesizing the extension of our auditory threshold, one is confronted with the realization that our relation to music hitherto depends in large part on the limitation of what transhumanists would call the "home" body, and what Uexküll theorized as our *Umwelt* – the reciprocal interchange between innate physiology and habitual use. Here ultrasonics function merely as an index for the material limits of the body. While enhancement is palatable as a check against debilitating medical conditions, it also raises heady questions about subject identity in an ongoing dialogic between body and prosthesis.

[176] Roger Caillois, *Man, Play and Games* [1958], trans. Barash (London: Thames & Hudson, 1962), 12ff.
[177] Helmholtz, *Sensations of Tone*, 18, 151.
[178] Rudolph König's term for imagined ultrasonics at the time.

On this basis, I propose the need for a new, categorical distinction between naked and mediated sounds. Between unamplified acoustic sounds we hear without any form of electronic mediation, and sound that is artificially converted into electrical signals before we experience it as sound. Naked sounds are auditory vibrations converted into electrical signals *within* the congenital ear (e.g. listening to the rain thundering on your roof, unaided by devices); mediated sounds are vibrations transformed into an electrical signal at least once before reaching the inner ear (or transformed artificially, via an implanted processor), whether in signal transmission, amplification, distortion or other processing. We already fetishize such distinctions in controversies over "live" music, simulcasting and discrete amplification. Such distinctions do not actually matter in experiential terms, however. Rather than privileging the congenital body as such, then, the purpose of such a distinction is to clarify an historically human identity for the perception of sound in light of emerging enhancement technologies. That the vast majority of sounds and popular genres we encounter are electronically mediated under such terms is indicative of just how fluid our relation to the auditory environment is. The concept of naked sound offers a means of anchoring this relation to our biology amid ongoing technological change.

Finally, a few red flags. Perhaps the central problem of transhuman enhancement of the ear is that it appears to promise unlimited capacity yet remains untempered by reality and experience. It is indicative, then, that Stelarc's *Ear* rapidly became non-functional, and that Chorost, in his auto-ethnographic reflections on cochlear implants, cautions against unchecked optimism:

> [R]eplacing the ear with a metal/ceramic/silicon substitute is akin to fixing a spider web with yarn. This is no insult to the engineers … [i]t is rather a recognition of how exquisitely complex and integrated a normally functioning body is, and how little we understand of it. And that's just the *ear*. … In real life, cyborg body parts need frequent tinkering and constant battery changes, and they are never as good as the natural organs they replace.[179]

[179] That Chorost's device only just achieved parity with his earlier auditory environment (hearing aids)—he explains—doubtless colors this cautious conclusion. Chorost, *Rebuilt*, 175, 177.

If auditory cilia and the vestibulocochlear nerve are part of an "original prosthesis" that defines the bubble of our musical-auditory environment, the story of prosthetic auditory technology teaches likewise that this cannot be replaced straightforwardly, that it is unrealistic to assume cyborg technologies "will in themselves lead to expanded human capabilities."[180] Related to this, tensions between the reality of amputation and the literary metaphor of "prosthesis" can give rise to frustrating imprecision, even insensitivity, in enabling a discourse unmoored from first-hand experience. For Vivian Sobchack, herself an amputee, the metaphor has becomes a "catchword that functions vaguely as the ungrounded and 'floating signifier' for a broad an variegated critical discourse on technoculture that includes little of these prosthetic realities. ... I've no desire for the 'latest' in either literal or figural body parts."[181] Here one ultimately begins to reckon with the hubris and—for some—potential futility—of an anthropocentric drive to enhance human sensory apparatus.

Further pushback emerges when one asks what index or regulatory force will establish boundaries for the limits of perception if one's sense capacities were to be extended. Experiential boundaries—whether gravity, lifespan or auditory apparatus—guarantee the concept of reality for each individual, and are therefore essential for the stable conditions needed for meaning creation. With sensory enhancement technology, it is the means by which we shore up identities—our own ego as well as others'—that are at stake. And what is potentially frightening, as Bernard Williams once put it, is not so much the "evil uses of technology as the evil consequences of its good uses, [whose] results ... we are afraid to dream about."[182] We glimpse such anxieties in comments by Charles Graser, one of the first patients to receive a portable implant, who reflected on his alien vulnerability: "This electric cochlea testing does bother you. It's like having someone say, 'Have a seat in the electric-chair while I fiddle with controls.' It may not hurt, but it is sometimes frightening in its intensity and your inability to control it."[183]

[180] Ibid., 174.
[181] Vivian Sobchack, "A Leg to Stand On," *The Prosthetic Impulse: From a Posthuman Present to a Biocultural Future*, ed. Marquard Smith and Joanne Morra (Cambridge, MA: MIT Press, 2006), 21, 38.
[182] Bernard Williams, "Two Faces of Science," *Essays and Reviews 1959-2002* (Princeton and Oxford: Princeton University Press, 2014), 48.
[183] Charles Graser Papers, 921-HSG, Cochlear Implants, 1961–1995 Collection, John Q. Adams Center;

By integrating a definition of self with the environment in this way, one view would be to say this condition ultimately leads to an indeterminate self, a distributed ego that is no longer conceptually autonomous; another would be to say it expands the self by redefining the ego-body axis according to the sensory apparatus we *control*. After all, it is precisely the lack of control (and concomitant rupture of identity) that gave rise to Graser's anxiety in early implant testing.

In this context, agency is negotiated. The least stable act here is the dissociation of the body from a sense of self. The body remains our bastion of ego and—for many—continues to assert alterity relations with technology. Emmanuel Levinas coined the term (alterity) to capture the radical difference posed to any human by another, rather than by the machinic. Extrapolating drastically from the tradition's emphasis on the non-reducibility of the human either to an object (in epistemology) or to a means (in ethics), he positions the otherness of humans as a kind of *infinite* difference, one that is expressed concretely in face-to-face encounter. Adapting his term to the present discussion tacitly requires us to efface conceptual differences—no less—between biological and non-biological parts as a first principle. In some respects, anthropologists and biologists have been doing this for years,[184] however, meaning that any conceptual leap is perhaps beside the point, and Levinas' concept still provides the discursive framework within which "users" may in future come to terms with the technological other.

Within the slew of quasi-scientific speculations that pepper the transhumanist literature, depictions of evolution through technology often proceed too quickly to be palatable. When Darwin first defined evolution, its key characteristic was incremental change: "[i]f it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications," he proclaimed, "my theory [of evolution] would absolutely break down."[185] Put another

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cited in Mills, "Do Signals have a politics," 329-30.

[184] For an example of this argument, see Jean-Francois Lyotard, "Can Thought go on Without a Body?" [1987], in *Posthumanism*, ed. Neil Badmington (Hampshire: Palgrave, 2000), 129-41, here 132.

[185] Charles Darwin, *On the Origin of Species* [1859], 6th ed., ed. Gillian Beer (Oxford: Oxford University Press, 2008), 142.

way, successive, slight modification celebrates human frailty, and perhaps the simplest reading of *Umwelt* theory is precisely that of gradually shifting characteristic limitations that "make us human." Is it not the straining against the possible in performance that elicits empathy (or envy)? If so, to what extent can this view remain intact in a transhuman context? The dilemma appears intractable if one adheres to an alterity relation between human and other, for a machine's version of the Chopin-Godowsky études is considerably less arresting than David Saperton's, just as a "human" performance of Conlon Nancarrow's rhythmic Studies for Player Piano excites our empathy in a way quite different to that of its intended mechanical performance. But alterity is not the only way of conceiving oppositional identity, as noted above. And a similar mediating logic underscores Tomlinson's argument in the context of prehuman sonic cultures that "humanists will have a central role to play" in the debate over biological emergence "insofar as [this] concerns human cultural attainments, even across evolutionary time scales."[186]

Such arguments return us to the underlying matter of what status the biological body has in music perception and performance for a century saturated in ongoing technological endeavor. Apple / Cochlear now transmit digitally captured music and voices directly to the nervous system of hearing impaired listeners, and against the cautionary red flags above, such conspicuous innovations cannot be ignored. As we have seen, the discourse of transhumanism sees the body as an assemblage subject to variation. Viewing the body as upgradable technology carries the startling corollary that music need not always be conceived and composed accordingly to our biological limits; and that new perceptual tools may eventually help us to hear, or otherwise experience, existing repertories afresh.[187] Naked listening may itself become ever more quaint vis-à-vis the creative largesse of mediated listening (casting listeners out of a kind of otological Eden?). Transhumanism in this sense offers a new intellectual framework for measuring the connection and compatibility between listeners and their environment. One need not buy into the relentless linear narrative—that we must become cyborgs or

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[186] Gary Tomlinson, *A Million Years of Music* (New York: Zone, 2015), 296.

[187] Don Ihde, speaking of a "postphenomenology" in which digital mediation renders accessible male mice singing courting songs and the changeable cycles of whale song, reflects in similar vein that "the possibilities of musics not yet heard ... are far from exhausted." Ihde, *Listening and Voice*, 264.

risk extinction—in order to create the intellectual elbow room within which to conceive of musical sound as a mediation of environment, listener physiology, cognition, technology, and sense mechanism. Rather, this assemblage of agencies, its distribution across multiple platforms, and our capacity for physical change mark the beginnings of what we might usefully call a transhuman understanding of the musical ear.

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