Feeling Machines: Immersion, Expression, and Technological Embodiment in Electroacoustic Music of the French Spectral School

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ABSTRACT

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This dissertation considers the music and technical practice of composers affiliated with French spectralism, including Hugues Dufourt, Gérard Grisey, Tristan Murail, Jean-Claude Risset, and Kaija Saariaho. They regularly described their work, which was attuned to the transformative experiences that technologies of electronic sound production and reproduction could inspire in listeners, using metaphoric appeals to construction: to designing new sounds or exploring new illusory aural phenomena. To navigate a nascent but fast-expanding world of electronic and computer music, the spectralists appealed to physical musical attributes including gesture, space, and source-cause identification. Fascinated by gradual timbral transformations, they structured some of their pieces to invite speculative causal listening even while seeking to push it to expressive extremes.

I hypothesize that, much as the immersive technology of the cinema can create the illusory feeling of flight in viewers, electronic music can inspire listeners to have experiences in excess of their physical capabilities. Those feelings are possible because listening can be understood as empathetic and embodied, drawing on a listener's embodied and ecological sensorimotor knowledge and musical imagery alongside referential, semiotic, and cultural aspects of music. One way that listeners can engage with sounds is by imagining how they would create them: what objects would be used, what kind of gestures would they perform, how much exertion would be required, what space would they inhabit. I cite recent research in psychoacoustics to argue that timbre indexes material, gesture, and affect in music listening.

Technologies of sound production and reproduction allow for the manipulation of these tendencies by enabling composers to craft timbres that mimic, stretch, or subvert the timbres of real objects. Those electronic technologies also suggest manipulations to composers, by virtue of their design affordances, and perform an epistemological broadening by providing insight into the malleability of human perceptual modes. I illustrate these claims with analytic examples from Murail's *Ethers* (1978), Saariaho's *Verblendungen* (1984), and Grisey's *Les Chants de l'Amour* (1984), relating an embodied and corporeal account of my hearing and linking it to compositional and technological features of spectral music.

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Introduction: Imagination Beyond The Body

1.1 Three illusions

While watching a movie at the Mugar Omni Theater, a large IMAX movie theater at the Boston Museum of Science, I suddenly had the feeling that my body was flying through the air. The camera, adopting a literal bird's eye view, soared above a landscape and darted about, and in my chair I darted with it. When the camera-as-bird took a sudden dive, I literally fell out of my chair as if it was my body that had plummeted – and several of my fellow moviegoers did the same.

The Museum of Modern Art in New York devotes an entire room to a triptych of Claude Monet's *Water Lilies* (1914-26). Having seen the paintings only in textbooks, I was unprepared for their massive size when I viewed them in person: each panel is 6'6" tall and nearly 14' wide. The immersive scale coupled with the serene aquatic subject matter led me to see movement where there was none, a soft undulation in the stationary painting. I felt, at least for a moment, that I had entered Monet's garden in Giverny. It felt more than merely metaphorical—not "*like I was there*," so much as "*I was there*." But where is "there"? The garden—its space and its depth and its movement—was conjured by my imagination but experienced by my whole body.

In her song "Fade" from her 2012 album *Movement*, Holly Herndon sings the line "Reach out your hand" (2:02). The vocal signal is rearticulated every 16th note so that it creates a chopped, stuttering effect in time with the drums. She is singing quietly but, through reverb and mixing, sounds louder than the rest of the instruments. Her voice fills up a large space but sounds as if it does so easily, without strain. In listening to this moment of this song, I imagine that I have that voice, that I fill up that cavernous space with that dense rhythm. I feel effortlessly powerful.

All three of these experiences have several commonalities.

First, they are illusions: an experience of inhabiting the fictive world of the movie, the painting, or the song rather than (or within, and touched by) the actual world that my body was inhabiting. They constituted an imagined sensorimotor engagement with the world of the artwork.

Second, they are technologically mediated and technologically enabled. Following from scholarship on the cinema by Sobchak (2004), Agamben (2009), and Richmond (2015), the components of the IMAX theater—its scale, the positioning of the projector at the back of the silent and darkened theater—form an apparatus, which structures and guides the attention and behavior of a viewer. In my experience, the apparatus of the theater coaxed me into empathizing with the perspective of the camera. I assigned false and impossible sensations to correlate with the perceptual information I was being presented, to produce the illusory experience of flight. The arrangement of Monet's paintings in the room at MoMA coupled with aspects of his color palette and technique constitutes a similar kind of apparatus; as does the technological assemblage of, on the one hand, the techniques of the recording studio, and, on the other hand, my headphones and .mp3 compression rate and even room layout when I listen to Herndon's song.

Third, these experiences are bodily sensations that draw on my bodily knowledge, but they imply experiences outside of the physical nature and design of my body, in spaces that do not or cannot exist. I cannot actually fly; I cannot actually produce the same sounds as Herndon in "Fade."[1]

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[1] And, strictly speaking, Herndon's voice sounds as it does in "Fade" only when her voice merges with the technical apparatus of the recording studio. But she can admit those tools into her sense of her own voice when she performs with them, just as I can assimilate the sound of her processed voice into my embodied sensorimotor schema.

Fourth and finally, these experiences both rely on and cultivate an experience of immersion: of being in a position to deploy empathetic and imaginative capacities, often without conscious awareness, in a virtual world within the actual world.

1.2 Technologies of sound creation and production

This dissertation has two interconnected objectives, aimed at better understanding some of the phenomena I just described. First, I consider the emergence of the idea that computers and digital audio techniques could be used to construct virtual and surreal sounds: sounds that evoke materials, gestures, and spaces that were at or past the limits of what could happen in the real world, but which were nevertheless measured in relation to real-world phenomena (rather than something "alien"). Second, I construct a psychological and perceptual framework for considering how listeners might engage with these novel sounds. What might need to be in place for a listener to hear, in all its corporeal fullness, an electronic sound as being a 40-foot piano? Both of these goals are in service of the analysis of electronic musical practices, including but not limited to fixed works produced using the tools of the studio.

Music theory has struggled to account for electronic music with the same nuance that it has for acoustic music. I believe this is largely because electronic music is not score-centered, but also because the technical knowledge used to make electronic music has been siloed away from the skills considered necessary to be a music theorist. But by attending to corporeal signifiers in music that are, I will argue, always operating at least on a background level, any listener can articulate aspects of the listening experience that lead to relevant pathways through a piece and which are intersubjectively communicable.

Concerning my first thesis that computers emerged as a tool for the construction of virtual sonic worlds, consider a hypothetical example: It is possible for the sound of an acoustic guitar to exist in a recording alongside the synthesized sound of a hybrid piano with strings made out of a mixture of rubber and wood.[2] The coexistence of these two sounds is the product of two subsets of the electronic revolution in music (and across the arts), which László Moholy-Nagy termed, in his prescient discussion of the phonograph, "production" and "reproduction" (1922). The two are intertwined in the context of the recording studio, and it is tempting to refer to aspects of recording as "reproduction" and aspects of synthesis as "production."[3] But the demarcation is not so clear. In fact, the techniques of recording do not merely *represent* space: they *create* it, by using microphones to place instruments at various distances from the imagined position of the listener (e.g., drum set back and to the left, singer directly next to my left ear, guitar three feet away and in the center). Or recording engineers can use signal processing techniques like reverb and equalization to suggest a distance between object and listener, and thus to create an aural space with depth of field. Even in the stereophonic world of most audio recordings, these constructions take on a kind of three-dimensionality, similar to the way that depth can be achieved in a flat painting.[4] Imaginary aural spaces are not all that studios construct: for listening purposes, new instruments can be invented in these aural environments. Some early synthesizers seemed to defy description, and

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[2] These are some of the parameters that Logic Pro X's physical modeling synthesizer "Sculpture" gives users, for example.

[3] The clash between Pierre Schaeffer's work with musique concrète at the *Groupe de Recherches Musicales* (GRM) and Stockhausen's synthesis experiments at *Westdeutscher Rundfunk* (WDR) during the early 1950s is commonly held up as an example of this conceptual schism. See, for example, Demers (2010).

[4] Echo and reverb's capacity to create a sense of space are addressed in Doyle (2005). Numerous other authors have written about recording and space but most instructive for my study is the account in Lennox (2017), whose embodied cognition framework is similar to mine without making reference specifically to mimesis.

these sounds came to stand in for an alien or uncanny aesthetic. But there was also an effort at using synthesizers to recreate acoustic instruments, which proved more difficult than engineers initially anticipated.[5] Indeed, it ultimately required—and elicited—new knowledge of the acoustics of sound production, and a set of computer synthesis algorithms aimed at reproducing those production methods. The effort to study sound for means of making better synthesizers was not merely a means to an end of solving a practical problem. Rather, it illustrates the way that different technological needs altered ways of thinking about sound. Using computers to synthesize sound often required parametric thinking: atomizing a sound gestalt into aspects like fundamental frequency, overtone spectra, amplitude, attack envelope, formant frequencies. But it also invited consideration of the way that those variables are interdependent, for instance in learning that playing an instrument louder does not uniformly increase the amplitude of all of its partials.

This study considers how the idea of fabricating surreal or non-real musical objects and spaces evolved within the historical and aesthetic context of French spectral music in the 1980s, particularly in light of emergent computer music technology. Appearing in the wake of mid-twentieth century continental European high modernism, French spectral composers—including Gérard Grisey, Tristan Murail, Hugues Dufourt, and Kaija Saariaho—developed a complicated and at times contradictory set of aesthetic aims surrounding perceptual immediacy and timbral transformations. Their music is fundamentally mediated by technologies of sound synthesis and analysis, even when that mediation is masked or oblique. These synthesis technologies had an epistemic function for spectral music: the tools of the recording studio revealed aspects of sound (especially timbre) which became metaphorical and structural

[5] Critical accounts of the early schism between Schaeffer and Stockhausen appear in DeSouza (2018), Kane (2014), and Taylor (2001).

resources for their compositions (whether acoustic or electroacoustic). Recounting the early work of Saariaho, Jean-Baptiste Barrière cites the microphone as an important part of her compositional development. Saariaho "was first 'orchestrating through amplification,' using microphones like microscopes, observing and revealing modes of playing, timbres that could not be heard in purely acoustical music. Amplifying these sonic worlds actually provided a natural bridge to her work with computers, which started by detailed analysis of vocal and instrumental sounds with spectral analysis" (Campion, Barrière, Saariaho 2015, 11). Grisey makes a similar point, writing that "spectral music offered a formal organization and sonic material that came directly from the physics of sound, as discovered through science and microphonic access" (2000, 1). Conceptually, spectralism oscillates between two poles that might seem contradictory. Many landmark acoustic pieces from the 1970s—Grisey's *Partiels* (1975), Murail's *Ethers* (1978)—focus on large perceptual gestalts. Technologically mediated acoustic knowledge is applied metaphorically and sometimes with fairly broad leeway. In the 1980s, many works using the computer necessitated a return to the kinds of parametric thinking associated with total serialism, which the spectralists had spent the past decade critiquing on perceptual grounds. Spectralism has always evinced an interest in the atoms of sound—partials of harmonic and inharmonic sound spectra, attack and decay envelopes, etc.—and in large-scale perceptual gestalts often expressed by way of clear and repeating gestural content.

1.3 Perceiving aural worlds

My other objective in this dissertation is to establish a framework for considering some perceptual and cognitive mechanisms behind these illusory experiences in music. How am I able to feel what it is like to have a voice that isn't mine, to play an instrument that can't exist, to

inhabit an impossible space? The answers I wish to consider here are psychological and technological, but also social: on the one hand, the human (and mammalian, and possibly even broader) capacity for imagination, empathy, and mimesis shapes not just our learning but our perception of the world. Upon seeing something, I might imagine an interactive relationship with it: how would I hold that object? How would I act to produce that sound? Recent evidence from psychology and neuroscience has given some experimental evidence to support two claims: First, that perception and action are inextricably linked; and second, that aesthetic perception is less a difference in kind than in degree in relation to everyday or utilitarian perception.[6] Mimetic perception is "hacked" by constructed aesthetic objects. Part of what those objects communicate, in addition to any semantic or referential content, is an affective experience made legible by imagining what it would be like to make an object or do a performance.

An early theorist of embodied perception's role in the imaginative experience of art is Gombrich (1962). He observes that "the context of action creates conditions of illusion. When the hobbyhorse leans in the corner, it is just a stick; as soon as it is ridden, it becomes the focus of the child's imagination and turns into a horse" (206). More recently, Starr (2013) has undertaken work in what has come to be called neuroaesthetics, an attempt to find explanations for different varieties of aesthetic experience within the workings of the brain. Such a discipline risks both brain reductionism and value-laden causal linkages between works of art and the effects they elicit (i.e., "this painting is better because it activated the motor cortex more strongly in study participants"). Brain reductionism is particularly tempting if such research adopts a work-centric approach. But Starr's account highlights how neuroscience can be used to combat

[6] I take aesthetic perception to encompass looking at art objects, but also engaging with aspects of the natural and recast world.

a much older and often invisible reductionism rooted in the work concept. "The complex thoughts, sensations, actions, and feelings that make up aesthetic experience are best understood first as events," she writes. "That is, we encounter an urn, and walk around it; a landscape, and we seek to dwell in it, a piper's melody, and we savor its movements; a poem, and we read and reread it; a dance, and we watch and the reimagine it. When we approach aesthetics thus in terms of events—and not primarily in terms of objects—we foreground dynamism and temporality" (17-18). It is possible to deploy findings from neuroscience and cognitive psychology to further nuance our understanding of what constitutes a musical work: from a classical, Western understanding of works transmitted and reified through scores toward a view that incorporates an assemblage of social contexts and actions and actors (from performers to listeners) in what Small (1998) calls acts of "musicking."

In electronic music there is a sometimes yawning gap between how a sound was designed and produced and how it is perceived by a listener; what is heard as a massive kick drum sample could be comprised of a low sine wave and triggered by the lazy flick of a computer key. The first objective I outlined in section 1.2 is largely focused on historical analysis of compositional process, and my second objective outlined in 1.3 is concerned with aspects of reception (which are equally subject to historicization). But I want to suggest that these two strands are not always so separate, and indeed that considering both together has great explanatory value for considering the interpenetration of humans and technology within a particular historical moment. After all, many aspects of computer music have collapsed the distinction between composer, performer, and listener: sitting in front of a synthesizer, one is all three at once. (Indeed, the way in which electronic music lays bare this fuzzy distinction makes it possible to retrospectively see that these subject positions have always been blurry—yet

another way in which technology performs an epistemic broadening.) Iverson (2017) notes that for composers in the 1950s "the studio held incredible potential for investigating and even overturning acoustic realities" (363), and that even when Stockhausen's electronic music experiments were failures "the electronic studio immediately began to revolutionize his perspectives on what was possible" (ibid.).

However, I wish to avoid the trap of technological determinism: that a new gadget emerged which yielded a particular shift in practice. From what did the gadget emerge? Our relationship with our tools and techniques is co-constitutive and constantly co-evolving. Clark (2004) writes that "human thought and reason is born out of looping interactions between material brains, material bodies, and complex cultural and technological environments. We create these supportive environments, but they create us too. We exist, as the thinking things we are, only thanks to a baffling dance of brains, bodies, and cultural and technological scaffolding" (11). Computers occupy a dual position in this formula: on the one hand, computer technology *is* an environment: we do things within the world of the computer. On the other hand, the computer alters other environments through epistemic revelations.

In a fascinating and wide-ranging book on software design, Harrell (2012) puts forth the concept of a technological phantasm: "Phantasms are a combination of imagery (mental or sensory) and ideas" (4). He poses a question: "How can one better understand and design computing systems that effectively prompt human imagination in the forms of narrative imagining and poetic thought (e.g., metaphor, theme, emotional tone. narrative, social categories, and imaginative worlds)?" (21) This is one question that computer music software designers were beginning to grapple with in the 1970s. Faced with perceptual and aesthetic impasses in extant modes of synthesis, composer/programmers including Jean-Claude Risset,

Barrière, Max Matthews, and John Chowning sought to design methods of sound creation and organization that better reflected certain causal tendencies in listening. Once the architecture of these synthesis tools was established, their potential to push past the bounds of the material world became clear, opening new expressive possibilities for engaged and empathetic listeners. It is impossible for technological design to exist outside of or transcend culture and identity: that race and gender and class and sexuality are all inscribed in software, because software is a form of discourse. But Harrell's book argues that it is possible for software to use this identity embeddedness to shape the world for the better: to have software's text-like constructedness be actively in service of shaping the world rather than to have that shaping be an unconscious byproduct. "A computational system prompts humans to conceptualize and interact with world events, emotional experiences, and/or social exchanges," Harrell writes. "The process of designing such a system involves having a concept one wishes to express and finding a computational means of expression" (115). The concepts expressed by software like the CHANT physical modeling synthesis software (discussed in chapters 4 and 5) leave their traces in the works created using CHANT. When a CHANT user can manipulate the attack and resonance of a signal to sound like a human voice, what kinds of manipulations seemed attractive? If musical timbre indexes musical expressivity, and instrumental design has historically both preceded and causally determined the kinds of timbres a musician can produce, what happens from the listening standpoint when timbre is produced *first*? Does the arrow travel backward to an imagined source?

While I will suggest in chapter 5 that Gérard Grisey was concerned with expressions of gender and sexuality in his music, the subjects of race and gender are generally left out of the spectralist's discursive work. There is a long legacy of considering whiteness (not to mention

maleness and heterosexuality) as normative and thus invisible, which critical race theorists have called "exnomination." Fiske (1994) writes that "exnomination is the means by which whiteness avoids being named and thus keeps itself out of the field of interrogation and therefore off the agenda for change" (quoted in Lewis 2002, 224). It seems fair to observe that mindset in the relative absence of discussions of race and gender in the writings of the spectral school. I expect it is also due to then-contemporary stylistic norms for academic writing (inseparable from the aforementioned exnomination) meant to conceal the author: avoiding first-person pronouns and biographical information in favor of linguistic constructions and topics that seemed "impartial."

Many musicians since the 1960s have used the recording studio in a way reminiscent of Harrell's account of software: as a tool for constructing visions of alternate worlds, alternate social configurations, alternate identities.[7] That this is not considered a part of the spectral project in light of their work with synthesis software and the recording studio is significant. Such an approach presents openings for analytic paths through their output. In particular, it allows for a way around the problem of score-centered analysis. By analyzing the capabilities of various software and hardware, an analyst could start to draw correlations between equipment and creative result that have high explanatory value but which are invisible in the score alone.

1.4 Virtuality and Illusions

There has been much written about virtuality and illusions in the realm of explicitly interactive, virtual reality spaces (musical and otherwise). For instance, entries in the *Oxford Handbook of Music and Virtuality* (Whiteley and Rambarran 2016) cover topics like the immersive online world "Second Life" (Gagen and Cook 2016) and the YouTube symphony orchestra (Tan

[7] For example scholarly accounts, consider Weheliye (2002), Chapman (2008), and Auner (2013).

2016). Or in Grimshaw and Garner (2015), the focus is largely on video games and similar virtual reality environments that feature sound and music. But these experiences also inhere in less explicitly interactive musical environments, such as sitting in a concert hall or listening to music at home. Interactivity is a fact of existence; we do not sit and passively observe an aesthetic object, but rather constitute our aesthetic experience through the active application of embodied physiological and cultural know-how. When I am engaged watching a movie, I am not merely observing a two-dimensional image: I am (to varying extents) inhabiting it, empathizing with various characters or even with technological artifacts like the camera (as in my iMax example). Similarly, when I listen to music with attentive engagement, I am not a passive listener but am actively considering various subject positions: of performing a given part, of imagining someone else performing it, and incorporating various instruments and spaces and gestures into my imagining. This experience may be amplified or attenuated depending on listener biography. My background as a performer (principally on percussion and electronics) and composer likely predisposes me to consciously attend to questions of performance more than some other listeners, though I will argue that it is impossible to listen completely detached from questions of causality (including the nuances of performing). And, as I discuss in more detail in chapter 3, different performance backgrounds can attenuate perceptions of exertion: a pianist and a bassoonist will have different responses to the bassoon passage that famously opens Stravinsky's *Rite of Spring* (1913)—the bassoonist will likely have a better conception of the strain and difficulty required to play that melody in such a high register. But everyone is capable of some kind of active, imagined first-person engagement with music. This imagined engagement may happen unconsciously and involuntarily, and what might be construed as detached or rational cognitive "understanding" or knowledge of music is

in fact predicated on some kind of first-person relationship with sound production. (Even putatively "neutral" approaches to music analysis embed the subject position of the author and the pretense of neutrality is, itself, an articulation of a particular historical and social subject position.) Aesthetic experience is relational, and as such it becomes important to consider not just technical features of a work of art but the sensory mechanisms that allow us to register those features — and that may have enabled us to conceive of and produce those features in the first place. The tools we use for creation are not passive: as Clark (2004) observes, we think with our tools, and they condition both the range of our thought and enable ideas that were beyond our conception.

I also hasten to note that the illusions I refer to are different from what are conventionally thought of as being auditory illusions, such as the Shepard-Risset glissando (a tone that seems to ascend or descend infinitely without actually moving, like a barber shop pole).[8] Such *trompe l'oreille* effects can inspire thinking about the illusory nature of media, but they are ultimately a more specific instance of the broader capacity for art to inspire illusory sensations. If anything, aural illusions like the Shepard-Risset glissando can have the effect of *reducing* an experience of immersion by making a viewer more aware of the medium's role in facilitating the illusion. As Grau (2003) writes of optical illusions, such media "stage symbolically the aspect of difference. They leave the observer outside and are thus unsuitable for communicating virtual realities in a way that overwhelms the senses" (14). Grau notes that there is aesthetic pleasure to be had in knowing that one is being tricked, but that this is different from "the concept of the virtual and its historic precursors, which are geared to unconscious deception" (16).

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[8] One online example of a Shepard-Risset glissando can be found at https://www.youtube.com/watch?v=MShclPy4Kvc

Grau's analysis suggests a response to authors who have discussed experiences of the virtual as a fundamental revolution brought about by digital techniques of virtual reality. Calleja (2013) writes that "virtual worlds are enabling experiences that were not previously available through other media" (1). He is working with a more narrow definition of virtuality than some other writers. In contrast to his definition, I am interested in identifying ways in which broader definitions of virtuality have inhered in pre-digital media, and thus been accentuated (rather than created anew) in digital art. Whiteley (2016) observes that "as a concept, 'virtuality' can initially be understood in relation to its very opposite: the, as it were, un-virtual (i.e. the real, the actual)…The pivotal question, then is not 'what is real/actual" and "what is virtual,' but rather the extent to which the experience or degree of mediation is virtual" (1). Virtuality insofar as we are aware of it is constructed, and that constructedness can be historicized. Grimshaw (2013) echoes this point, suggesting that virtuality is nothing new but that "digital technology simply provides new ways to conceptualize, to use, and to experience that virtuality" (quoted in Whiteley 2016, 3). The use of computer technology to synthesize and structure sound marks a new shift in *perspectives of* the virtuality of musical experience, and a proper analysis of musical works using digital techniques of sound synthesis would need to account for capabilities of the new technologies and for the ways their users conceived of those capabilities.

1.5 Immersion

Grau (2003) writes that an experience of immersion in visual art is built on "seal(ing) off the observer hermetically from external visual impressions," so as to "appeal to him or her with plastic objects, expand perspective of real space into illusion space…The intention to install an

artificial world that renders the image space a totality, or at least fills the observer's entire field of vision" (13). I posit aural immersion to be the product of an analogous enfolding of the observer by sound; for me, the most familiar means of this experience is wearing over-ear headphones in an environment where my attention is devoted exclusively to listening. This experience is acousmatic: it entails listening to music where the source of the sounds are unclear or underdetermined or altogether unknowable. There are pre-electronic means of inducing this immersive effect, too: assuming one can habituate to the mannerisms of the concert hall, the expectation of total silence from the audience coupled with the acoustic refinements of the space seem meant to facilitate an experience of immersion and envelopment.

Grau (2003) defines virtual reality as "a space of possibility or impossibility formed by illusionary addresses to the senses. In contrast to simulation, which does not have to be immersive and refers primarily to the factual or what is possible under the laws of nature, using the strategy of immersion virtual reality formulates what is 'given in essence,' a plausible 'as if' that can open up utopian or fantasy spaces" (15). This definition does not implicate any kind of technological component: it does not make recourse to electricity or the cinema or any other technologies thought to imply the virtual. Instead, immersion would seem to be something that we do as perceivers as much as something that is done to us by media. Immersion is evident in the experience of musical trancing, for instance, which Becker (2004) discusses in her book *Deep Listeners*. In Becker's account, trancing elicits heightened and extreme emotional experiences: deep listeners are "persons who are profoundly moved, perhaps even to tears, by simply listening to a piece of music…These folks, I believe, experience a nearness to trance" (2).
I would suggest that this trance state is not dissimilar from the imaginative and illusory experiences that recorded music can conjure, in that "deep listening" experiences can entail a

kind of engrossed immersive engagement, which in turn implicates the imagination. Becker's study nods in both title and methodology to the work of composer, performer, and philosopher Pauline Oliveros. Among her many endeavors, Oliveros was an electronic music pioneer, producing pieces like "Bye Bye Butterfly" (1967) that used synthetic means to similar ends as her probing acoustic works.

In an essay titled "What would disembodied music even be?" Noë (2012) offers one answer to his titular question that is illustrative of the importance of immersion for certain varieties of active and empathetic musical experience. Noë describes a portable record player from his childhood that produced tinny, low-fidelity sound. "In some sense that is an example of disembodied sound. It is sound coming out of a cheap speaker; there is nobody making the sound there. It is disembodied sound as compared to what it would be like to be sitting in front of Mick Jagger and the Rolling Stones, having them sing *to* you: *that* would be embodied sound" (2012, 73). Noë is subscribing to an object-oriented ontology of sound here that has been critiqued in numerous sources including Kane (2015), one that is at odds with the broader aims of embodied understanding that he is considering. Sound itself is not embodied; our perception of it is. (Later in the essay Noë seems to acknowledge this, writing: "our musical sensitivity to movement is really a sensitivity to intelligibility; it is really a form of understanding" (79), which I take to be a reference towards the relational nature of music perception rather than its object-centeredness.) What Noë calls disembodiment in this example is in fact the destruction of an experience of imaginative immersion. The technical apparatus for reproducing the recording (including not just the quality of its speakers but its very portability) was insufficient for fostering the kind of immersive engagement with music that allows for a more fully imaginative engagement with the virtual world of sound. It may have enabled other kinds of experiences:

social uses of music, for example, such as signifying group membership or marking public spaces. But it did not allow Noë to have the imaginative experience with the recorded performance that he associates with embodiment. Grau's "space of possibility or impossibility" that he describes as a condition of immersion became uninhabitable.

Noë concludes provocatively, writing "electronic music doesn't take the body away. It gives us a new body" (79). That is to say, electronic music broadens our sense of what our body is and what it can be. That this is possible owes to twin factors: on the one hand, our embodied and embedded perceptual faculties rooted in mimesis and imagination. On the other hand, the tools and techniques of sound creation, inscription, distribution, and consumption, which guide and direct perception even while they are shaped by what we can perceive. If electronic music can give us a new body, that ultimately suggests that the body has always been more contingent and malleable than humanistic notions of bounded individuality would have suggested. The tools of music analysis and media archaeology can deepen a listener's aesthetic appreciation of (which is, perhaps, their imaginative engagement with) particular musical works and practices, and it can suggest explanations for certain compositional maneuvers within a historical and cultural context. But this can also be a way to think about the nature of perception, of techniques and technologies. It is a way of thinking about the boundaries of humanity with music and through music.

1.6 Chapter summary

Chapter 2 situates French spectral music in the context of musical modernism, particularly in continental Europe. Grisey, Murail, and other spectral composers continued some aspects of the high modernist project while rejecting others, and their rejections usually

were described as being on perceptual and psychological grounds. For instance, Murail writes that spectralism was "a reaction against [mid-century modernist composers'] refusal to make even the slightest concessions to the phenomena of auditory perception" (Murail 2000, 6). I suggest that this reproach is rooted in part in an over-reliance on discursive statements and political posturing by composers ranging from Schoenberg to Babbitt to Boulez, and also on a corresponding preoccupation with technical method (and with the idea that a technical method's audibility corresponds to its aesthetic desirability). All of this downplays gestural and rhetorical elements of mid-century modernist music whose perceptual meaning might be quite clear and graspable, especially in terms of mimetic imagination of effort and exertion.

Dolan (2012) suggests that philosophical accounts of music's immateriality and transcendence (of the sort associated with Romantic-era thinkers like Hanslick) were correlated with the reification, beginning in the late eighteenth century, of the instruments of the orchestra. The twin technologies of recording and synthesis may perform the opposite function: by virtue of their immateriality, they forced a careful reckoning with the materiality not just of musical activity but of perception. If listening practices within the community of nineteenth century orchestral listeners coevolved with instrumental developments, listening practices in the twentieth century have been unsettled by the rapid advent of digital sonic worlds. These listening practices are also bound up in the separation of the senses under modernism, so that optical or aural perception may be refined in their isolation. The isolation of hearing is what Sterne (2003) calls *audile technique,* as when "over the long nineteenth century, listening becomes a site of skill and potential virtuosity" (93). Audile technique "is oriented toward a faculty of hearing that is separated from the other senses. Once so separated, it can be intensified, focused, and reconstructed" (93). The spectralist's use of computers for sound analysis is an extension of

this history, an interest in the molecularization of sound through the visual mediation of the spectrograph. Ironically, to deepen their ears they relied on their eyes.

Chapter 3 suggests that this molecularization of sound and its separation from other senses is controverted by an embodied understanding of musical experience. I consider how music perception is constituted by bodily knowledge, which is in turn representative of the interpenetration of bodies, tools, and ecologies across a perceiving organism's existence. In the context of acousmatic music, timbre is the catch-all musical variable that conveys aspects of object size and material, space, and modes of gestural/physical excitation. Timbre is generally defined as the way that a listener can judge two sounds of equal pitch and volume as being dissimilar, a definition by negation which leads Bregman (1994) to call timbre "an ill-defined wastebasket category" (92). As an example, the timbral differences between a bowed or plucked C#4 on a violin are touted as the way that we can infer how that sound was made. Those differences are proxies for the action of bowing and plucking as well as for the material (string, but also bow hair versus fingertips). In general, when listening to music acousmatically, it doesn't matter if our causal inference is right or wrong in as much as it matches the "correct" origin of the sound, but it does matter for our imaginative and empathetic experience of the piece. Our ability to infer cause is premised in past knowledge of specific instruments and modes of playing as well as deeper-level knowledge of what kinds of actions tend to yield what kinds of sounds. A listener might hear a lawnmower and describe it as "angry" because the act of making a lawnmower sound with one's voice would typically, for that listener, accompany feelings and statements of anger.[9] Though we don't think of it this way, this is an experience of empathetic engagement with an inanimate object. The lawnmower is not angry but has a

[9] It also depends on their experiences with lawnmower sounds (object identification) or the ways in which they are used to expressing anger (which can also be expressed by silence, for instance).

metaphoric relationship to the sounds that represent anger *in* us, which in turn informs perceptions of anger *toward* us. I would underscore that a listener might hear this way or might not — the analytic claims that the framework of embodied perception allow are by no means meant to be definitive or universal. Embodiment has been deployed in service of elucidating and even celebrating the contingent, provisional, and subjective (as well as intersubjective) experiences that music can inspire in a listener, a line of thinking best associated with feminist musicological scholarship including Cusick (1994) and McClary (1991).

To illustrate my point about imagination and perception in music listening, I discuss a wide range of work in music cognition. I focus especially on the account of mimesis and embodied music perception posited in Cox (2011, 2016), especially his discussion of mimetic motor imagery. Motor imagery is defined by Cox as "imagery related to the exertions and movements of our skeletal-motor system, and in the case of music this involves the various exertions enacted in musical performance" (2011, paragraph 2). Looking at a violin and imagining how I might play it is an example of motor imagery. Mimetic motor imagery is imitative motor imagery, which Cox says is similar to mental simulation. Looking at a violinist, or hearing a violin performed, I might imagine what it would be like to do those sound-producing actions: this is the distinction between motor imagery and mimetic motor imagery. I argue that Pierre Schaeffer's four modes of listening are at times in opposition to aspects of aural perception that are rooted in deeply embedded facets of worldly observation and mimesis —facets that are so deeply embedded that they precede the existence of homo sapiens. I consider these oppositions to be productive both as a strategy for analyzing acousmatic music and as a means of better understanding human perception (within music and without). Ultimately, I argue, practices of reduced listening or attention "solely" to timbral or

spectromorphological features of sound are unable to fully transcend aspects of perception that are preoccupied with causality and intention, which I view as proxies for embodiment writ large.

Chapter 4 delves into the idea of music listening as illusory in light of the embodied cognition work discussed in chapter 3. I focus on the technique of physical modeling synthesis as discussed in the work of Jean-Claude Risset and Hugues Dufourt. Physical modeling is a significant departure from previous synthesis methods because it focuses on constructing algorithms that govern physical parameters like excitation, resonance, and physical materials, rather than sculpting resultant waveforms (as in additive and subtractive synthesis). The results of physical modeling synthesis achieved better verisimilitude for acoustic musical sounds, but the interface and the parameters it made editable also inspired, I argue, an attitude toward sound rooted not just in realism but in surrealism: of stretching recognizability without breaking it. I pay special attention to Risset's writings, who, as a keen reader of ecological psychologist James Gibson, grasped the cognitive implications of the software he was building. Reflecting on his work with then-nascent computer synthesis techniques, Risset wrote: "The first syntheses, made by trying very diverse sound structures, and even by doing "anything," did not open at once the vast, new and surprising world of sound that was hoped for. Thus the *psychoacoustic* problem was revealed in all its magnitude" (2014, 170).[10] Sitting at the computer attempting the synthesis of sounds, Risset was learning about his own hearing as much as about the tools for synthesis. This was perceptual knowledge brought about by the synthesizer and by the local-level musical and aesthetic purposes to which it was being put. Synthesizers expressed

[10] Les premières synthèses, faites en essayant des structures sonores trè diverses, et même en faisant "n'importe quoi", n'ont pas ouvert d'emblée le monde sonore vaste, nouveau et surprenant qu'on espérait. Ainsi s'est révélé dans toute son ampleur le problème *psychoacoustique*.

sound via parameters like amplitude and frequency, but what the ear needed was physical materials and size and structure. Writing of the algorithms he and others developed for sound synthesis, Risset observes: "Digital synthesis produces sounds from the specification of their physical structure. To listen to them, one thus has the *psychoacoustic* experience of the relation between this physical structure and the audible sound effect" (2014 170).[11]

Chapter 5 examines Gérard Grisey's 1984 composition *Les Chants de l'Amour.* I consider Grisey's extensive writings about the piece in light of the capabilities of the CHANT physical modeling synthesis software, designed at IRCAM. Using sketch materials held at the Paul Sacher archive, I argue that working with CHANT contributed to a conceptual shift for Grisey. At a narrative level, the piece features shifting relations between a 12-voice SATB choir and a tape voice synthesized using CHANT. The voice is often monstrous and alien, clearly "othered" against the choir; but at times it takes on more realistic human qualities. The piece is divided into 28 sections (plus an introduction), each based on one phoneme found in a recording, made at IRCAM, of the sentence "I love you." Grisey further scrutinized the recording of "I love you" using spectral analysis to glean the content of its formants, the distinctive frequency components produced by complex sounds, which render recognizable the various vowel sounds in speech (as well as all manner of other sounds). His working method thus shows the influence of CHANT's parametric interface and inadvertently aligns Grisey with some of the technical practices of total serialism, which the spectralists roundly critiqued in their early writings.

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[11] La synthèse numérique produit les sons à partir de la spécification de leur structure physique. À leur écoute, on fait donc l'expérience "psychoacoustique" de la relation entre cette structure physique et l'effet sonore audible.

I conclude by addressing the risk of ahistorical universality implicit in an embodied cognition framework. Does embodied cognition reinscribe the problematic notion of "man as the measure of all in light things" that feminist and post-humanist writers like Braidotti (2013) and Haraway (1985) have deconstructed? Is an analytic approach rooted in applying bodily knowledge implicitly reconstructing problematic boundaries between "human" and "nonhuman"? I suggest that it does not, for two reasons. First, its emphasis is on the porousness of perception insofar as perceiving entails a constantly coevolving relationship between an organism, its world, and the objects that populate that world. Our subjectivity is not bounded but in fact extends past the traditional boundaries of the human including to objects and artifacts, which we use for a variety of functional and expressive ends. Second, embodiment destabilizes passive, object-centered approaches to art in favor of the idea that we actively create aesthetic experience via an empathetic and imaginative capacity rooted in sensorimotor action. We are thus not passively perceiving the world as though in the Cartesian theater of the mind, but actively constructing and evaluating our perceptions.

Gombrich (1960) opined that his book *Art and Illusion* was necessitated by a kind of perceptual numbness to images brought about by mass production. "That the discoveries and effects of representation which were the pride of earlier artists have become trivial today I would not deny for a moment," he writes. "Yet I believe that we are in real danger of losing contact with the great masters of the past if we accept the fashionable doctrine that such matters never had anything to do with art. The very reason why the representation of nature can now be looked upon as something commonplace should be of the greatest interest to the historian. Never before has there been an age like ours when the visual image was so cheap in every sense of the word" (6). Without wanting to make recourse to a connection between mass production

and value, I do wonder if a similar problem is present in music today. In the age of the portable music player, and of recorded music (or muzak) in public spaces, music has become an indispensable part of everyday life, and the music that we hear constantly but attend to only casually is full of sounds whose considerable strangeness has been overtaken by the loss of novelty. Whiteley writes, "all music has an element of virtuality…some artists specifically incorporate techniques that encourage listeners to understand and engage with their music in a virtual space"(2016, 2). The mundanity of certain techniques today should not mask their radicalness at their point of origin, a radicalness that may render their potential perceptual impact on a given listener more clearly. Considering the ubiquity of synthesized sounds and techniques of space in music recording, I would posit that a similar risk as the one Gombrich identified exists in music consumption: we are now at a remove from the origin of certain kinds of experiences whose novelty is critical to understanding their musical use and significance. These experiences of inhabiting a virtual world inhere in old art, and they inhere in new art, but their manifestations change over time. By paying attention to the kinds of experiences fostered by immersive deep listening to these sounds, as well as to the historical and technological contexts in which they emerged, we can uncover aspects of music listening that have been concealed and neglected even as they hide in plain sight.

Chapter 2: Spectralism and Modernism: Contexts and Disruptions

2.1 Overview

This chapter aims to situate spectral music in a lineage of musical modernism and discuss several problems in the historiography of modernist music, especially surrounding issues of abstraction and of corporeality. I suggest, following Metzer (2009), that musical modernists are united by an interest in the outer reaches of expression, characterized not just as novel means of musical expression but as a pushing of expressive musical resources near to, but not necessarily past, the point of recognizability. I introduce several core concepts in French spectralism via the composition *Partiels* (1975) by Gérard Grisey, which evinces some of the problematic qualities ascribed to musical modernism that I consider in my first section. I analyze the piece's introduction, drawing attention to pitch, timbral, and gestural aspects of the work that illustrate its corporeal residue for listeners. Despite being an acoustic piece, *Partiels* exhibits a decidedly electronic mentality: Grisey uses the instruments of his ensemble as though they were sine waves in an additive synthesizer, sculpting new and surprising sounds from his basic materials and finding new ways for those sounds to behave in time. I conclude by considering how a listener-oriented account of this music still benefits from a consideration of the writings and stated aims of composers, albeit a skeptical one.

2.2 Modernist Historiography and an Account of Musical Modernism

It can feel strange to start a discussion about "new music" by pointing out the ways in which it is not so new after all. The twentieth century is saturated with vanguardist rhetoric across all the arts, so much so that points of continuity—which are also, in a way, points of comprehensibility—can seem hard to grasp. The spectral school of composition, which emerged

in Paris in the 1970s, has been just as caught up in this rhetoric as any other, laying claim to all manner of rupture with their immediate compositional forbears, Pierre Boulez especially. Consider Gérard Grisey claiming that spectral music "is in radical opposition to all sorts of formalism which refuse to include time and entropy as the actual foundation of all musical dimensions" (2000, 2). Or Tristan Murail writing a retrospective of spectralism: "At a certain point the 'spectral movement' was seen as a reaction against the 'avant-garde'. And clearly it was a reaction against certain composers who believed that they were *the* avant-garde. But, in reality, it was a reaction against their refusal to make even the slightest concessions to the phenomena of auditory perception" (2000, 6). Adorno cautions against comparing modern art to its forebears. "Nothing is more damaging to theoretical knowledge of modern art than its reduction to what it has in common with older periods. What is specific to it slips through the methodological net of 'nothing new under the sun'; it is reduced to the undialectical, gapless continuum of tranquil development that it in fact explodes" (1973, 36; quoted in Grau 2002, 7).

As with Grisey, Murail, and Adorno, this dissertation considers claims about newness: I believe that many composers associated with spectralism were among the first composers of Western art music to see the potential for digital technology to confront listeners not just with new sounds but with new sounds that simultaneously draw on, challenge, and extend our perceptual faculties and our body's kinesthetic sense of itself. That this could be manifest in their music speaks as much to the historical situation of the spectral school (working at a time when the computer was becoming a more powerful and viable tool for music-making) as it does to the inheritance of various strains of musical modernism and their position in that network.

At the same time, I wish to be clear that this is a continuation of older attitudes toward immersion, illusion, and extension in music, sound, and art, which Gombrich (1961) has

suggested may go back to the age of the cave painting. In engaging with the sensual and felt qualities of musical experience while also exhibiting an interest in the far reaches of expression (and with certain familiar modernist tropes like alienation, abstraction, and so on) the music of the spectralists suggests that certain attributes (or even pejoratives) applied wholesale to musical modernism—that it is dry, sterile, rooted in an aesthetic rejection and negation of the past, overly cerebral, disembodied[1]—are, at least for this listener, controverted by the compositions themselves, which exemplify a distinctive but firmly entrenched fascination with the embodied, corporeal, and somatic nature of musical experience. That scholarly reception has emphasized certain of these traits may in part owe to the rhetoric of the composers themselves, which often seems disinterested in issues surrounding reception or social contexts.

The *locus classicus* for such critiques of musical modernism can be found in McClary (1989), who argues that "the prestige value of this music, in other words, is inversely correlated with public response and comprehension" (60). Despite its regular association with attacks on musical modernism (or, at least, musical modernists), I find in McClary's essay a route for rehabilitation of the reception of modernist music to which I am deeply sympathetic, and which motivates my present project. "The orthodox, self-contained analyses that appear in *Perspectives of New Music*…require little more than a specialist's grasp of combinatorial techniques; by contrast, explication of this music as historical human artifact would involve not only knowledge of serial principles, but also grounding in critical theory and extensive knowledge of twentieth-century political and cultural history. We would gain from such discussions of avant-garde music a greater sense of human connectedness…But at the same time, we would lose the mystique of difficulty, which might well be replaced by the acknowledgment of human

[1] These particular attributes are discussed and critiqued in Born (1995), which I turn to at the end of this chapter

vulnerability" (65). Mid-century musical modernists like Babbitt and Boulez defined a set of concerns around their music through a series of discursive claims that in turn influenced the reception of their music; without discounting those claims, we might do well to compartmentalize the assertions of the composers and to consider other ways in which this music is meaningful and other levels on which it operates. Critical perspectives on spectral music have been overshadowed by copious literature devoted to compositional process, much of it written by the composers themselves. This does a disservice to the reception of the music both by omitting discussion of attributes that may not interest (or may not even occur to) its composers, and thus by suggesting that those attributes are not salient aspects of the music when, in fact, they are.

To highlight some of the distinctive attributes of the work of the spectral school, it is first necessary to explore the many ways in which their work is a continuation of certain predispositions found in the music and thought of their immediate predecessors like Boulez, Messiaen, Ligeti, and Stockhausen. The spectralists harbored a set of peculiar and paradoxical aesthetic ideals. They cultivated an aesthetic of expressive immediacy while employing a highly mediated compositional practice. They decried the perceptual opacity of their serial forbears despite employing perceptually opaque methods themselves—and despite occasionally using serial-inspired methods of organization in their compositions. The math and logic-driven scientism that characterizes the discursive and aesthetic practice of mid-century modernists was exchanged for one rooted in the physical and biological sciences, including acoustics, psychology, biology, physics, and physiology. This refigured scientism was accompanied by a much more time-honored correlation of naturalism to aesthetic value, with the spectralists

asserting a privileged closeness to concepts of consonance and dissonance as given by nature and of an attentiveness to universal principles of perception.

The issue of newness and the narrative of rupture that suffuses discussions of musical modernism in the twentieth century merits some scrutiny. Perhaps no one has done more to date the origins of musical modernism in the twentieth century to Arnold Schoenberg's famed 1908 "break with tonality" than Schoenberg himself. "From the very beginning," he writes of his early atonal works, "such compositions differed from all preceding music, not only harmonically but also melodically, thematically, and motivically" (Schoenberg 1975, 105). Schoenberg's rejection of tradition, this account might hold, subsequently ushered in a radically new era of musical works and indeed musical thought, one which fetishized novelty and espoused avant-garde ideals about forward progress and the art of the future while being aesthetically challenging to the point of incomprehensibility for some lay listeners. In a similar vein, Babbitt's essay "Who Cares If You Listen?" suggests that those who cannot attend to the many intricacies of pitch, register, duration, dynamic, and timbre in a serial work will be numb to its core meanings: "Inability to perceive and remember precisely the values of any of these components results in a dislocation of the event in the work's musical space, an alternation of its relation to a other events in the work, and—thus—a falsification of the composition's total structure" (Babbitt 1958, 39). Further: "Deviation from this tradition is bound to dismiss the contemporary music of which I have been talking into 'isolation.' Nor do I see how or why the situation should be otherwise. Why should the layman be other than bored and puzzled by what he is unable to understand, music or anything else?" (ibid.., 40). For Babbitt, understanding a work means understanding its structure, a statement that implies relatively constrained definitions both of "structure" and of what it means to "understand," and which

suggests that anyone failing to grasp a piece on these terms will be met only with befuddlement.[2] It is also a statement that can be said to reflect a set of priorities specific to the act of composition. One irony that inheres in several critiques of modernist music is that the pejorative charges levied by critics tend to emerge from discursive claims made and embraced by the composers, such that the pipeline from composer to composition to critique seems to leave out the variegated experience of a range of listeners. A number of scholars in recent years have nuanced this claim enormously by considering the music in gestural and sonic terms that may overlap with certain pre-compositional concerns but may also be wholly independent of them; the introduction to spectral music I will provide in this chapter aspires toward a similar aim.[3]

Much is lost by glossing over the continuities between the music of the twentieth century and that of the preceding three hundred years. Babbitt himself acknowledges this in "Who Cares If You Listen?" writing, "Although in many fundamental respects this music is "new," it often also represents a vast extension of the methods of other musics, derived from a considered and extensive knowledge of their dynamic principles" (ibid.., 40). Recent scholarship on music and modernism by Johnson (2015a, 2015b), Albright (2000), Pierson (2015), and Cohen (2012), as well as on the relationship between modernism and modernity, has pushed back on this narrative of rupture, while also complicating the idea of modernist composers as a single unified community of like-minded artists. There are myriad strands of aesthetic and discursive modernism, from the scientistic writings of Babbitt to the cosmopolitanism of Wolpe to the craggy and contrarian eclecticism of Ives. Further, the

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[2] Seizing on these claims, McClary (1989) twists the title of Babbitt's famous essay "Who Cares If You Listen?" into the rejoinder "Who cares if you compose?" (63)

[3] For examples of listener-oriented analyses of works by Babbitt, see Straus (1986) and Dubiel (1990).

proclivities that both unite and divide these strands within modernism represent a continuation of a set of ideas about music (as transcendent, as reflecting a composer's subjectivity, as emotionally expressive works) that have become inextricable from modernity as a whole — ideas whose origins have been variously dated as far back as Beethoven, Mozart, or Monteverdi.[4] Rather than insist upon a certain set of aesthetic ideals or discursive tropes to which modernist music must intractably hew, there is much we can learn about modernism by considering music as something that people *do*: as a form of discourse in the broadest sense, and as reflecting the experience and history and corporeality of the network of subjects who *do* it while simultaneously constituting a body of expressive texts suitable for analyses and interpretations by a diverse group of listeners.[5] The notion of *musicking* advanced in Small (1998) provides a similarly useful perspective shift away from a musical work and toward a musical performance, implicating not only composers but musicians, dancers, listeners, and any other actor who makes a contribution to the sum total performance. This connects works to a particular but always-subtly-shifting historical and social context that becomes inseparable from the meanings of that work.

Understood this way, modernist music mirrors any number of the hopes and anxieties surrounding shifting realities that characterized the modern world at large. These could include the development of urban centers, the industrial revolution and the concomitant suffusion of daily life with technology, the rise of a middle class, the gradual and often tumultuous process of enfranchisement of women and people of color in civic life, the invention of the computer, the

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[4] Beethoven is cited by Taruskin (2005), Mozart by Berger (2007), and Monteverdi by Chua (1999) and Johnson (2015a).

[5] This formulation is the one made by David Lewin (1986) in his article "Music Theory, Phenomenology, and Modes of Perception," and it is approaching orthodoxy in music theory today.

way the internet exponentially enhanced access to information while also destabilizing a number of businesses (including the music industry), and many more. These social and material developments impacted a wide range of people in widely varying ways, and so impacted their art. And in the same way that the advent of train travel profits from being contextualized in relation to the technology of the horse and carriage (and certainly not as a rupture in the way we consider travel), the music commonly held under the rubric of "modernist" benefits from being considered as contiguous with the music that came before as part of the larger social history of modernity. To quote Julian Johnson's formulation, "music history might be better understood as a kind of variation form rather than solely in terms of linear development" (2015a, 4).

Marshall Berman (1982) writes that those who find themselves living and writing about the modern world "are apt to feel that they are the first ones, and maybe the only ones, to be going through it…However, great and ever-increasing numbers of people have been going through it for close to five hundred years" (15-16). Read against Frank Kermode's 1966 book *The Sense of an Ending*, which asserts that a sense of apocalyptic finality has been an inextricable part of modernity as a whole, a mindset is revealed: it is part of the modern condition to consider this historical moment as both first and last, beginning and ending. This is the impulse that nurtures some generalizations about modern music in the last 100 years: that a novel technical practice like serialism or the use of computer algorithms to generate pitch material heralds a wholly new aesthetic while at the same time signing its own death warrant—because of its eschewal of the past, or its perceived foreignness in the face of "tradition," or because it is soon seen to be supplanted by some other novel method, or any number of reasons. These vanguardist claims may owe in part (though certainly not chiefly) to economic pressures on

composers in the twentieth century (some external, some self-imposed and self-perpetuating within the community) which incentivized newness—or at least incentivized talk of newness as a manner of brandishing prestige and gaining financial support through institutionalization in the university and through commissions and grants.[6] They have been compounded by some critics and musicologists who were willing to wade into those waters on terms set by those same composers, sometimes by extolling the newness of an aesthetic or by evincing hostility towards its merits.

Berman (1983) delineates three phases of modernity; the first phase stretches from the start of the sixteenth century to the end of the eighteenth, an inchoate modern experience that nurtured the work of Galileo even while allowing him to languish under house arrest for the last chapter of his life. At least one development of this time that also finds some resonance with the twentieth century and with the spectral school is the rise of body imaging in art: the attempt by artist/physiologists to draw maps of human anatomy that are now familiar to any student of biology but were at the time largely mysterious — in effect, to image the invisible around us.[7]

The second phase extends from the "great revolutionary wave" of the 1790s through to the start of the twentieth century. Berman discusses Rousseau's account, in his novel *The New Eloise*, of the protagonist Saint-Preux's move from the country to the city. "Everything is absurd, but nothing is shocking, because everyone is accustomed to everything," says Saint-Preux. After

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6 Issues of grants and institutional patronage are discussed as they pertain to serial composers in America in Straus (1999), who maintains that the notion of serial hegemony in the realm of grants and patronage is overblown. Shreffler (2000) responds by questioning the separation of atonal and serial styles in Straus' methodology, given that much atonal music after 1950 is, in a meaningful sense, post-serial. More recently, Robin (2016) explores issues surrounding novelty and patronage in the "indie classical" scene surrounding the label New Amsterdam Records.

7 A comprehensive account of these early artistic efforts can be found in Stafford (1993). I will argue in chapter 3 that the spectralist's use of computers for spectral analysis is a new side of the same effort: to image the invisible.

a few months in this urban reality, Rousseau's Saint-Preux feels "drunken" amidst the "agitated, tumultous" life of the city. Berman summarizes: "This atmosphere—of agitation and turbulence, psychic dizziness and drunkenness, expansion of experiential possibilities, destruction of moral boundaries and personal bonds, self-enlargement self-derangement, phantoms in the street and in the soul—is the atmosphere in which modern sensibility is born" (18). Berman's mention of the expansion of experiential possibilities will be especially important for the account of modernist art that I will advance shortly, and for the account of the spectralist's music in particular that I will proffer throughout this dissertation. The third phase brings us to the present day—still immersed in modernity, still feeling as though that immersion is both the start and the end of something momentous, but gradually saturated with the emergence of mass media as well as the social and aesthetic implications of the rise of globalization.

Berman is not the only writer on modernity to suggest that historical and aesthetic periods which have been pitted against each other might in fact be different facets of the same structure. Calinescu (1987) describes "five faces of modernity": modernism, the avant-garde, decadence, kitsch, and postmodernism. Calinescu defines modernity as "reflected in the irreconcilable opposition between the sets of values corresponding to (1) the objectified, socially measurable time of capitalist civilization (time as a more or less precious commodity, bought and sold on the market), and (2) the personal, subjective, imaginative *durée*, the private time created by the unfolding of the 'self'" (5). This definition establishes an opposition that Calinescu suggests is acted out in the art and aesthetics of modernity. "Modernity has opened the path to the rebellious *avant-gardes*. At the same time, modernity turns against itself and, by regarding itself as *decadence*, dramatizes its own deep sense of crisis." (5) For Calinescu, aesthetic movements that would seem to be diametrically opposed in the twentieth century are

in fact communities within the umbrella of political modernity. Even within Calinescu's "five faces" there are factions: to pick one example from recent music history, the famous "uptown/downtown" split in New York City art music reflected two different factions of composers whose music still is best subsumed within the category of "avant-garde."

Julian Johnson (2015a) approaches musical modernism in the twentieth century in a manner that is influential for my own approach to the music of the spectral school of composition. Johnson cites Michel de Certeau's suggestion that Western history is shaped by three binaries: that of the present and the past (time); that of human labor and the idea of nature (space); and that of discourse and the body (material). Johnson's own account of music in the period of modernity uses those binaries to frame "a *sensible* history of musical modernity, a history of the feeling and experience of being modern" (10). A sensible history of twentieth century modernism pushes against a number of highly durable aesthetic critiques of certain strands of Western art music in the last 100 years — for being antiseptic, sterile, inert, gray, obtuse, impenetrable, forbidding, cognitively opaque. These charges, too, have a longer history —Schubert, for instance, was derided by a contemporary for writing music with "no sense, no order, no meaning. The composer…resembles a big waggoner…who…turns now to the right, now to the left, getting at one time out of the road without making any honest way" (quoted in Cohn 1999 213-214). In the case of this quotation, it is not that Schubert's music has no order but rather that it has (for that listener) the wrong *kind* of order. Modernist music's critics similarly see it lacking expression when in fact it lacks the wrong *kind* of expression. David Metzer has argued that modernist compositions in the twentieth century are a "mode of inquiry" (2011, 7) into the nature and limits of expression.

An important influence on the music and thought of the spectral school has been *Institut de Recherche et Coordination Acoustique/Musique* (IRCAM), the Parisian music research laboratory founded by Boulez in 1977 with unprecedented support from the French government. IRCAM and its relationship to musical modernism is one of several topics explored in Georgina Born's 1995 ethnography of IRCAM, *Rationalizing Culture*. The preceding brief historiography of modernism has in part been set up in order to respond to several aspects of Born's critique of IRCAM. To be clear, there is much to admire in Born's account, particularly her portrayal of the power structures at play at IRCAM, the economic position of the avant-garde in France (and in Western culture at large) in the 1970s and 1980s, and the pernicious presence of both sexism and racism bound up in IRCAM's power structures. But while I find her ethnographic account of the people laboring at IRCAM to be insightful, I question some of her claims about the aesthetics of musical modernism, as well as some of the values implicitly reinforced by those claims.

Born establishes a set of dualities or binary relationships between "Modernism/Serialism, Postserialism" on the one hand and "Postmodernism/Experimental Music" on the other. Here are some of Born's pairings:

Modernism/Serialism, Postserialism	**Postmodernism/Experimental Music**
Determinism	Indeterminism, nondeterminism
Rationalism	Irrationalism, mysticism
Scientism, universalism	Sociopoliticization
Cerebral, complex	Physical, performative, simple
Text-centered	Practice-centered
Linear, cumulative, teleological	Cyclical, repetitive, static

(Born 1995, 63)

Taxonomies are useful, and any taxonomy risks reducing the forms of activity that it wishes to categorize. Categories are always porous. In this instance, indeterminism of the sort practiced by Cage in his "Music of Changes" was a formative part of Darmstadt's early years, and as Iddon (2013) and Piekut (2013) have both discussed, Cage occupies a complicated

position in the modernist-postmodernist division. Mysticism, too, suffuses the work of many modernist composers. Schoenberg, for one, was deeply interested in mysticism in relation to the unconscious, and Bartók's interest in numerology must certainly register as well. I invoke Born's list not as a definitive account of musical modernism and postmodernism but rather as a reflection of some attitudes about those aesthetic and ideological movements in the 1980s in and around IRCAM that implicate bodily knowledge.

The contrast between music that is "cerebral and complex" (modernism) and "physical and performative" (postmodernism) is the tension that I wish to explore. First, there are definitional concerns: what constitutes complexity in music is far from clear: is densely notated music complex? Music that is difficult to perform? Music that sounds complex, or that sounds unfamiliar? Are non-Western musics that don't rely on notation or on aesthetic criteria rooted in novelty necessarily less complex? Complexity, in short, is a social issue, not an inherently musical one. Physicality is another descriptor that is more complex than it seems, and the fact that Born seizes on it in context of an ethnographic study of an electronic music institution is no accident. IRCAM was fundamentally enmeshed with rapid developments in high tech, and Born links an interest on the part of those laboring at IRCAM between a drive toward universalism and naturalism through scientism (which she argues is one fundamental aesthetic goal of modernism) and the extension of that scientism into high tech.

Chapter 3 presents evidence that some form of physicality inheres in all music-listening because all perception is embodied. This does not mean that a concept like "abstraction," understood perhaps as abstraction away from obvious signifiers of musical physicality, no longer exists. But it necessitates an examination of what musical abstraction might look like, and what work it is made to do, in particular musical communities in light of the physicality

that inheres in empathetic music-listening. My case study from this point forward is French spectral music, specifically by composers Grisey, Saariaho, Dufourt, and Murail.

Goldman (2010) characterizes the spectralists as "interested in microscopic fluctuations of sound, observable through its graphic three-dimensional representation in the form of a spectrogram" (210). The spectrogram is a manifestation of the visualist culture of the natural sciences, translating aural phenomena into a fixed visual object. As Don Ihde writes about the privileging of vision in the epistemology of science, "It is as if the entire sensorium, for science purposes, is reduced to and transformed into visual form." (2009, 64) We can observe a more stringent critique of this strand of musical modernism in Born's anthropological account of IRCAM:

> It is striking that the response to the deep musical and philosophical impasses that arose around early and midcentury serialist modernism has been to amend and improve the rationalism and scientism through increasingly sophisticated scientific and technological mediation. Far from rejecting the deeper epistemological character of modernism, postserialism has refined and complexified it, for example in the elision of computerized music analysis with compositional genesis…The discourse within which IRCAM is situated is a scientistic refinement of the classic concerns of modernism (Born 1995, 198).

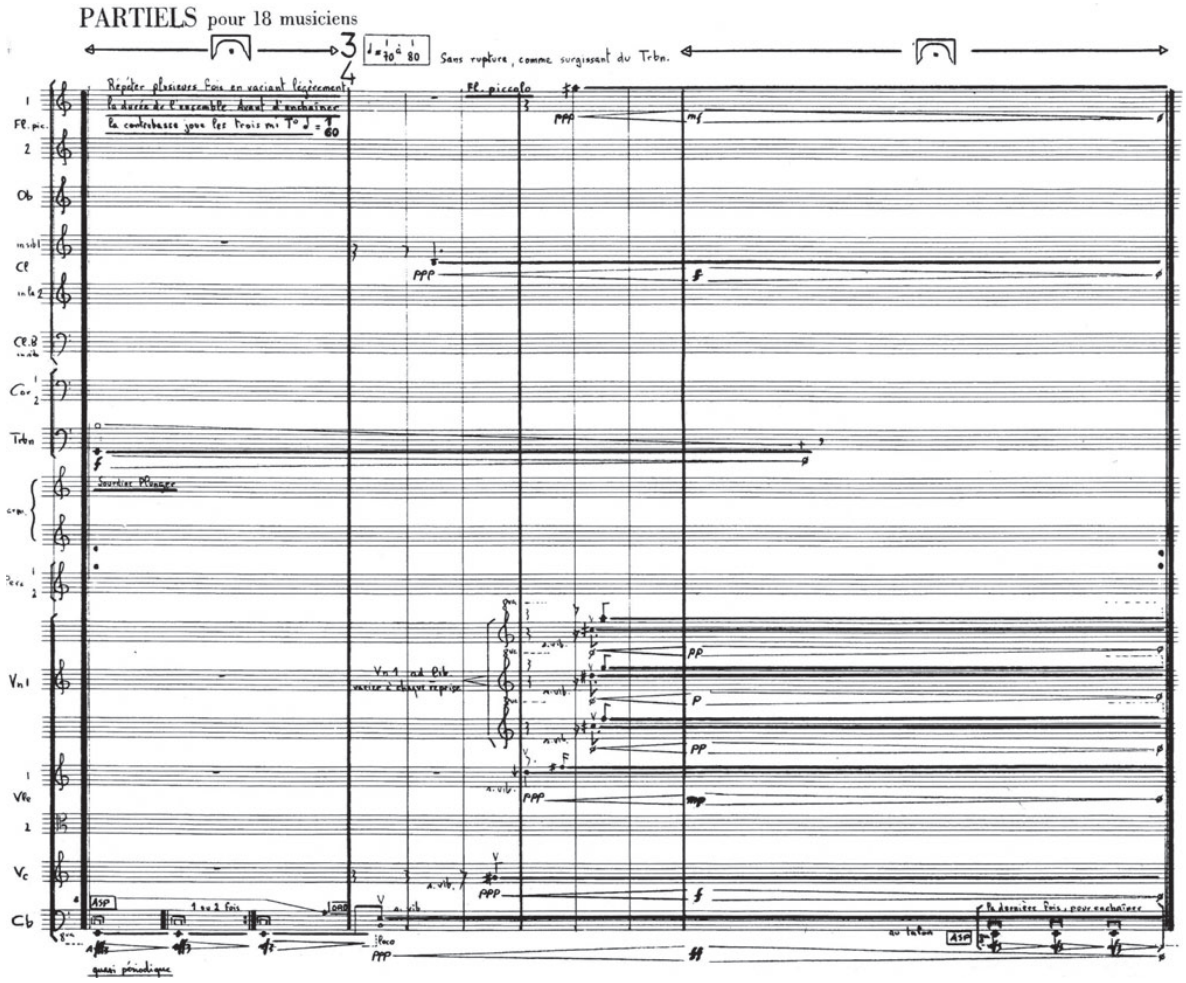
Ihde writes that "Just as perception, phenomenologically, is <u>active</u>, not <u>passive</u>, the postmodern technologies used by science are active in the sense that they are more and more constructive rather than passive." (2009, 62, my emphasis) (By "postmodern" Ihde is referring to the present historical period, as one coming after the historical period of modernism.) Spectralism, like the natural sciences, is *translating*, via its technologies, imperceptible natural phenomena into the realm of perceptibility, of readability, of phenomenological accessibility. In so doing, these IRCAM-affiliated spectral composers are not necessarily extending the legacy of universalism and positivism that Born decries. Technological tools, software in particular, become texts that are read and interpreted, and which exert agency over their interpreters.

2.3 Grisey's *Partiels* (1975) and Techniques of Spectral Composition

One of the first mature and surely one of the most influential compositions by Gérard Grisey, *Partiels* (1975) served as a cogent and prescient thesis statement for the then-nascent French spectral school. It introduced, almost didactically, concepts that would orient future spectral works: a renewed interest in consonance and dissonance, characterized as harmonicity and inharmonicity; the use of the harmonic series to generate pitch material; an emphasis on processes of gradual transformation applied to all musical parameters, especially harmony, resonance, and timbre; the translation of computer-generated acoustic data into complex orchestral textures.[8] It does all of this using clear, repetitive, massive musical gestures in its introduction. Perhaps the most audacious element of *Partiels* is the sheer repetitiveness of its introductory four minutes. The listener is hammered by its forceful, insistent opening gesture (reproduced in example 1): a loud, sustained low E2 in the trombone, the open E1 string of the contrabass attacked *sforzando* and *sul ponticello* three times, played with such weight that the woody sound of the string slapping against the fingerboard is audible; together they form a call, mysterious and ominous. That call is met by the staggered entry of the cello, violins, flutes, clarinets, sounding a microtonal harmony with an otherworldly sheen, uncanny and mystical. And then it happens again, that great and yawning low E rippling into the brightest upper reaches of the ensemble. It happens no fewer than 14 times, each repetition revealing a bit more of the fictive world around (or, perhaps, inside) that low E, and each repetition shifting the

[8] Of course, *Partiels* did not appear out of nowhere with regard to Grisey's *oeuvre*. Féron (2010) has traced many of *Partiels'* organizing principles to work begun by Grisey in his composition *Dérives*; and Cagney (2016) traces certain elements all the way back to one of Grisey's first student compositions, *Vagues, Chemins, le Souffle* (1970–72)

rhythmic and harmonic ground on which the structure is built: a theme and variations based on the acoustic imitation of a computer analysis of a time-stretched recording of one note on one instrument.



Example 2.1: Opening gesture of *Partiels*, reproduced from Hasegawa (2011)

The spectral hallmarks on display in *Partiels* are worth exploring as a way in to the generic tropes used by the spectral school in general and by Murail and Grisey in particular. I will begin by explaining some of the concepts of musical acoustics that undergird spectral attitudes toward pitch material, and then I will return to the introduction of *Partiels* to explore

Grisey's fascination with gradual processes (across multiple musical parameters), his use of rhythm and repetition, and his choice of organic, bodily, and zoological metaphors to describe his music.

Western musical practice has cultivated two complementary methods for measuring interval: as the ratio between two frequencies, or as the distance in pitch space (today, 12-tone equal tempered pitch space) between two pitches.[9] A perfect fifth can be thought of as the ratio 3:2, or as the distance of seven semitones in 12-tone equal temperament. Hasegawa (2008) writes: "In broad terms, the ratio model tells us about the sonic quality (the degree of concordance and stability) and the root implications of an interval, while the distance model offers an easy way to measure and compare intervals, but ignores the way that the constituent pitches combine acoustically" (2).[10] When we hear the dyad {C4-Bb4} we might hear it as being a dominant 7th, and/or 10 semitones, and/or that its sound is qualitatively tense, rough, or dissonant. Hasegawa (following the work of James Tenney and others) observes that the first two claims constitute a measure of distance, the latter a measure of frequency ratio. Rather than constituting an abstract artifact of ancient music theory, ratios remain an essential—Hasegawa uses the word "visceral," a felicitous descriptor—component of musical experience. Furthermore, Hasegawa shows how some pieces (in both tonal and post-tonal repertoires) may

[9] Neither of these methods make explicit recourse to tonal hearing of intervals in relation to a tonic pitch (i.e., hearing the major third of scale degrees 1-3 as different from scale degrees 5-7), and this could certainly be considered a third method of interval measure.

[10] Hasegawa traces the lineage of these models through their roots in antiquity through to the work of Helmholtz, James Tenney, and the spectralists themselves. Chapter 1 of Hasegawa 2008 also provides a good account of the history of equal temperament and its relationship to just intonation; a discussion of tuning theory is outside the scope of the current chapter.

draw more on either the interval or ratio-based measures of pitch relationships, and that these varying modes of attending to a piece's pitch structure can shape our experience of the piece.

Speaking physically, sound is vibration, a wave of measurable frequency passing through a state of matter (air, water, et cetera). Speaking psychologically, sound is something we sense when those frequency waves stimulate our hearing organs. The physical conceptualization of sound considers it in terms of frequency and amplitude, the psychological considers sound in terms of pitch and volume. The tension between these two ontologies of sound—of acoustics and psychoacoustics—was of particular fascination for composers in the twentieth century, the spectralists foremost among them. One reason for this accelerated interest likely owes to technological advancements made during the twentieth century—particularly digital audio recording and scientific technologies for studying and measuring sound, both of which built on and expanded our understanding of acoustics. As an object resonates (a musical instrument like a violin string or marimba bar for example, but the principal applies to all physical objects), it vibrates at certain frequencies that are related to the physical nature (size, density, material) of the object as well as the manner in which it has been excited (with a bow or a stick, loud or soft, et cetera). The fundamental frequency is what we typically perceive as the pitch of a sound; the arrangement and amplitude of its overtones (or partials) is a significant part of what we hear as a sound's timbre, though our perception of timbre is just as influenced by aspects of its attack, decay, sustain, and release (ADSR).

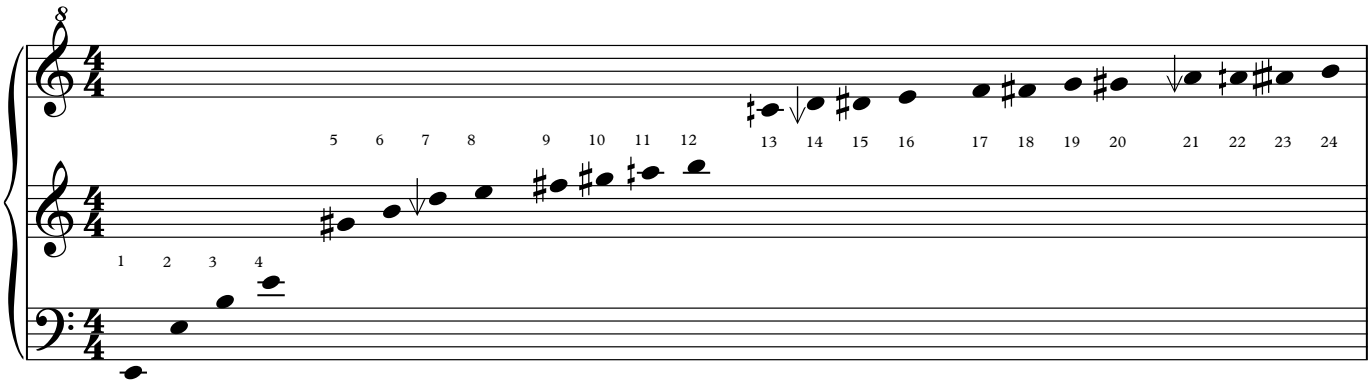
Figure 1 shows a table of the first 15 partials of the harmonic series rooted on a low E1 in hertz:

Partial Rank	Frequency in Hertz
1	41
2	82
3	123
4	164
5	205
6	246
7	287
8	328
9	369
10	410
11	451
12	492
13	533
14	574
15	615

Figure 2.1: Partial rank and frequency

Example 2 notates the first 24 partials (including those 15 frequencies) on the five-line Western musical staff. I will here represent microtonal pitches using quarter and sixth tones, which follows Grisey's practice.

Mathematically, the harmonic series is represented simply by y = n(f) where f is the fundamental frequency in hertz, n is an integer defining partial number in the harmonic series, and y is the sounding frequency. The first elements in the harmonic series of 41.2 hertz, the low



Example 2.2: First 24 partials of E1

E1 of the bass in *Partiels,* are 2*41.2hz = 82.4 hz; 3*41.2hz = 123.6 hz; and so on. We can map these frequencies as notes on a staff, just as we can consider notes as frequencies, but the recognition that notes are often approximations or translations of frequencies into the written medium, rather than precise representations of those frequencies, is one of the most important tenets of the spectral school's approach to pitch. At least in their early compositions, the spectral school's use of microtonal pitches is not rooted in a system of temperament but rather in the use of frequencies.[11] Following from this, the spectralist's use of microtones was best conceptualized as an approximation into the domain of pitch notation of frequencies gleaned through computer analysis of real sounds. Depending on what sound or set of sounds is subjected to computer analysis, the result could be virtually indistinguishable from pitches of the harmonic series or it could be noticeably different.

A sine wave contains only a fundamental frequency and no overtones. Most Western instruments have been cultivated to have relatively "clean" timbres so as to emphasize their

[11] As Murail proclaimed: "We nevertheless need tools that can handle the continuous expanses we have discovered. Pitches, therefore, will be measured by frequency (hertz), not by chromatic degree, and the continuum of frequencies will be controlled by the concept of spectra" (2005, 153).

fundamental pitch more clearly.[12] A more complex sound (like a bell) contains a fundamental frequency and a number of overtones of varying volume or frequency. But any sound is in theory reducible to a number of sine waves of various frequencies, amplitudes, and durations, and so any sound can be recreated by assembling sine waves to the proper specifications. This process is known as additive synthesis and many familiar (and familiarly unbearable) MIDI sounds are produced in this way.

For *Partiels*, Grisey analyzed the low E2 of the trombone using a spectrogram. Consider the following two spectrograms of a trombone E2. (See figures 2.3 and 2.4.) The first thing to note is how much information this *doesn't* tell us. We might like to imagine a composer sitting in front of her computer screen the way that the character Cypher in the science-fiction film *The Matrix* interpreted binary code, staring at pure frequencies and deciphering the exact content of the spectrogram. In fact, the above spectrograms do not tell us with specificity what instrument is playing; if the instrument is a solo instrument or part of a larger ensemble; if the sound is a single note, a chord, or a multiphonic; and so on. This is one of the more radical shifts in the musical epistemology of the spectral school: the written, visual representation of music on the five-line staff, pivotal in the history of Western music for the last 1,000 years, represents some information (pitch, relative duration, instrumentation/orchestration) better than other information (timbre, absolute duration, certain non-equal tempered systems of pitch). The spectrogram more or less inverts this, telling us some important information about the timbral makeup of a sound and displaying it in clock time, but omitting instrumentation, orchestration, and (in most cases) notated pitch.

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[12] Consider the Indonesian gamelan as a familiar example of instruments cultivated with the opposite timbral goal in mind.

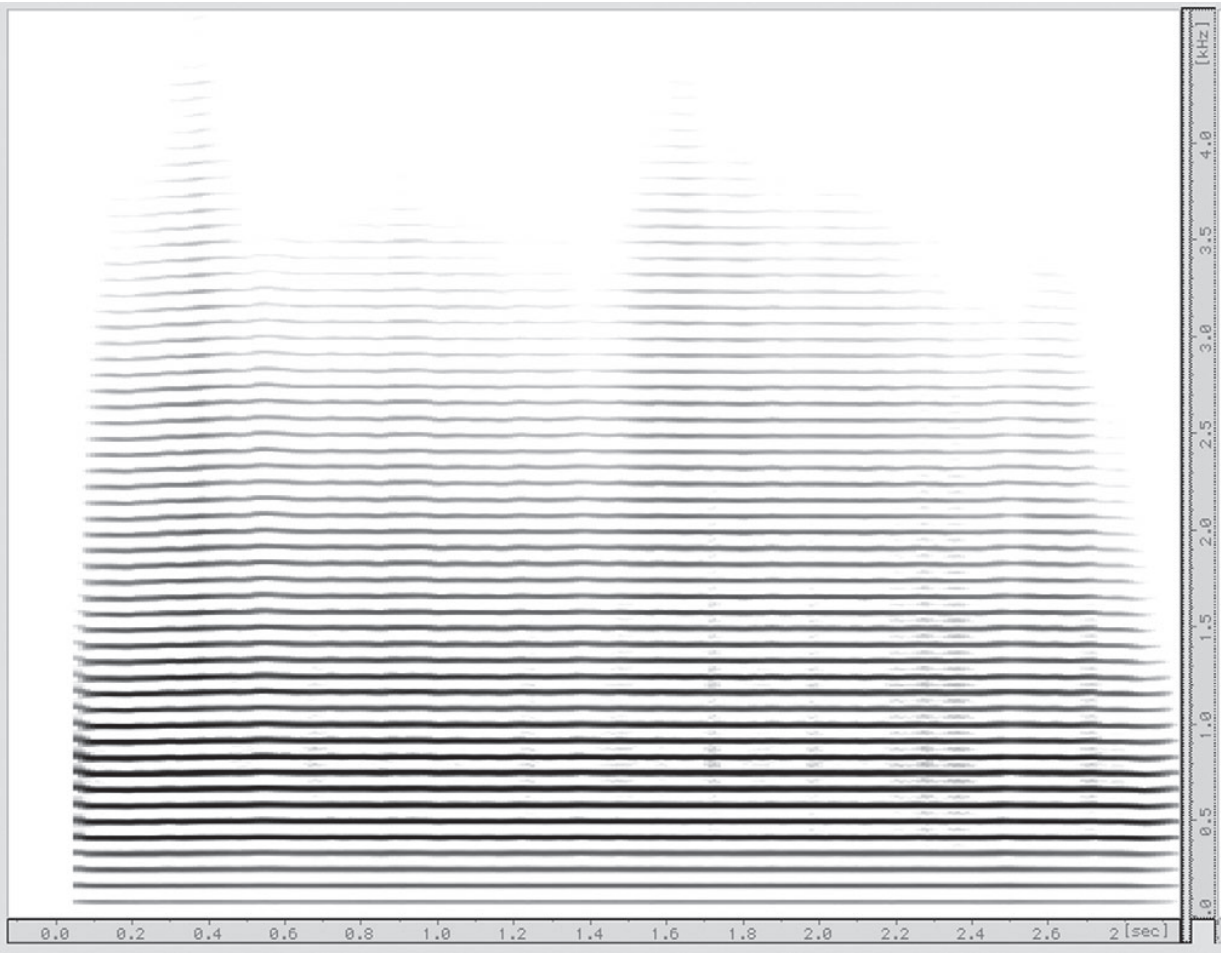


Figure 2.3: Spectrogram of a trombone low E from Hasegawa 2009

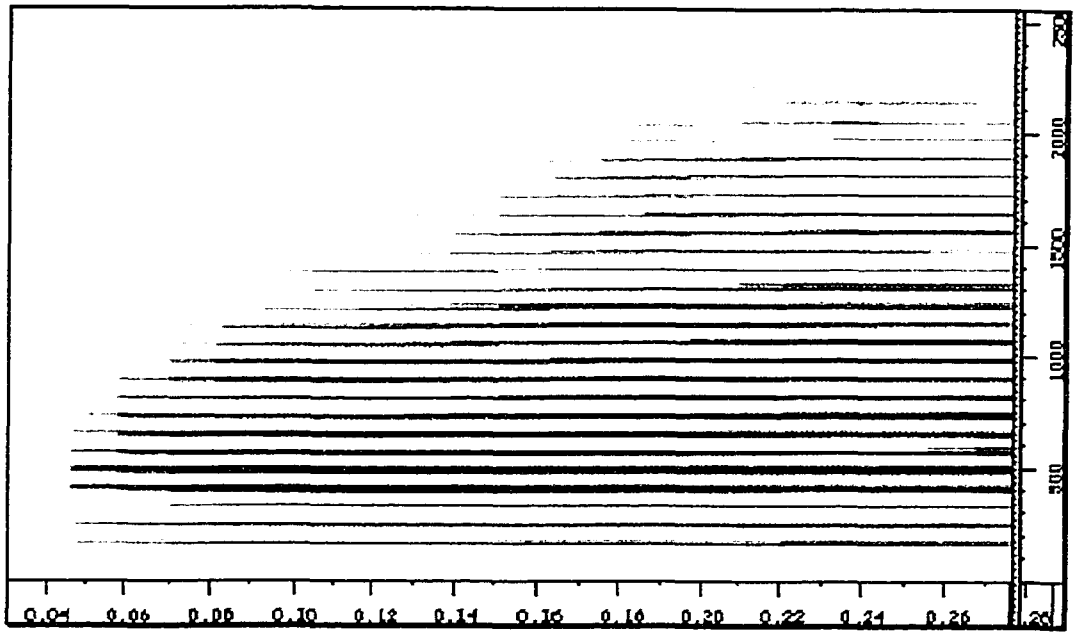


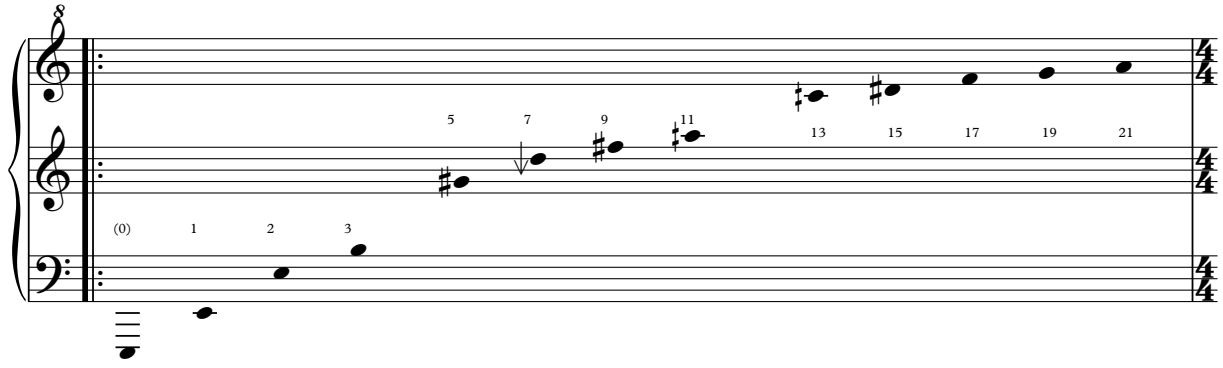
Figure 2.4: Spectrogram of a trombone low E from Fineberg 1999

What do the two spectrograms from figure 2.3 and 2.4 reveal? Each line corresponds to a frequency, indicated on the Y-axis – lower lines are lower frequencies. The duration of each frequency is represented along the X-axis. The darkness of each line corresponds to relative amplitude of the partial. The spectrogram reveals that the trombone sound's upper partials emerge slightly later than the lower frequencies, and that certain partials—in the case of Grisey's spectrogram, the fifth and the ninth—are louder than others. The choice of a time scale becomes important here: the second sonogram (figure 4) has a much smaller unit of time for its x-axis and thus shows in greater relief the behavior of the partials of the low E. By contrast, Hasegawa's spectrogram (figure 3) shows the sound unfold over a longer span of time, which also allows for fluctuations in the volume of various partials to be visible. One of the most important steps in writing a piece of spectral music becomes choosing a sound and recording it to tape; the use of a spectrogram to analyze that sound becomes an interpretive act in itself. All this work finds its ultimate instantiation on the five-line staff. From recording to spectrogram to sheet music, we have had a translation of a translation of a translation.[13] This is a technologically-mediated production of knowledge that has been the subject of research by Ihde (2001) and McLuhan (1995), the latter of whom wrote that "Translation is thus a "spelling-out" of forms of knowing. What we call "mechanization" is a translation of nature, and of our own natures, into amplified and specialized forms" (56).

Recall that additive synthesis is the stacking of sine tones on top of each other to imitate the more complex timbre of real sounds; compare that with the orchestration evidenced in the opening of *Partiels*, reproduced in example 1. Here, Grisey is employing a technique he calls "instrumental synthesis": the stacking of instrumental tones on top of each other to suggest the

[13] For more on spectralism as translation, see Lara (2013).

harmonic series of a particular tone. The ensemble sounds the odd-numbered partials of the trombone E1 (the low E0 in the contrabass serves as a low doubling of the trombone; it cannot be the fundamental because it does not correspond to the registral position of the rest of the ensemble's pitches.) Odd numbered partials are the characteristic tones of a harmonic series. Each odd numbered partial becomes an even numbered one upon its repetition: the third partial is doubled in a higher register as the 6th, the 12th, and so on. This is why the fundamental pitch is so important: we not only hear it as partial rank 1, but as 2, 4, 8, 16, and so forth. Its statistical prominence in a harmonic series is what makes, for example, a violin's low G sound stable or pure. Filtering out the odd-numbered partials leaves us with the same pitch content transposed an octave higher (the 5th partial of E1, G#3, becomes the 10th partial G#4; see figure 6). This filtering has the effect of weakening some of the pungency of the sound, because the more "dissonant" tones emerge at the upper end of our auditory perception and thus take on a different character. Filtering out the even-numbered partials, as Grisey does, weakens the presence of the fundamental pitch. Example 3 shows the pitches found in the introductory phrase of *Partiels*[14].



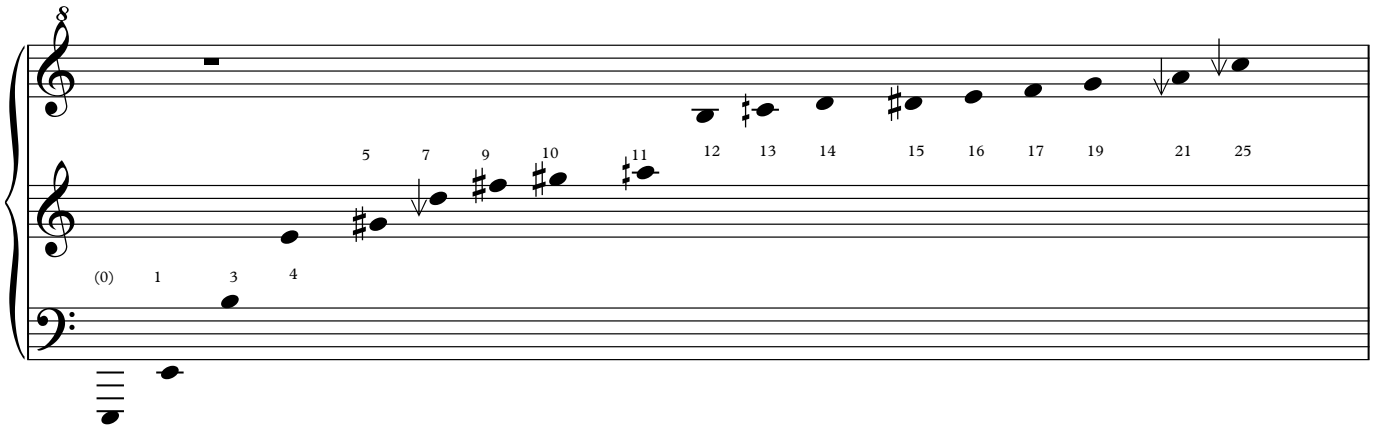
Example 2.3: Pitch collection from first phrase in Partiels

[14] Strictly speaking, partial 21 should be A5 -1/6 tone; above the 13th partial Grisey seems to only use equal tempered accidentals, likely a concession to performance and to the very fine-grained nature of those differences in pitch at a high register. I will represent his accidentals in my reductions and label the partial ranks.

Recall the two timescales of the spectrograms in figure 3 and 4: the closer we zoom in to the sound (the smaller units of time in the x-axis of figure 4), the easier it is to see the staggered entry of the different partials of the trombone recording. The opening gesture of *Partiels* is based on a recording of a trombone roughly one second in length, and in the piece it takes approximately 12 seconds to perform. This is an instance of time stretching, a recording technique in which recordings are slowed down without affecting their pitch (as opposed to slowing down an LP, which transposes the pitch up or down as the speed increases or decreases). It is also a didactic move: the entry of the partials is slow enough for us to consider each pitch as a distinct entity and as part of a fused whole. The goal of instrumental synthesis here is not verisimilitude; it is precisely the point that the music exists in a murky and liminal space between an orchestrated harmony and a fused timbre.

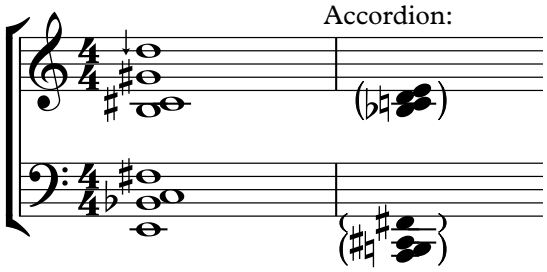
From rehearsal 1 to 3 Grisey adds more and more upper partials of the low E1, thickening the texture. Because the different timbral profiles of the instruments are interacting with the cumulative timbre of the passage, a development that we might expect to become more consonant—given the increased number of appearances of low-rank even-number partials—in fact begins to grow more dissonant and unsteady. By rehearsal 4, almost every harmonic partial from 1 to 25 is sounding (example 4).

This marks the turning point in this introduction from a sound mass assigned the function of stability (the introductory phrase) to a sound mass that grows increasingly unstable. This is achieved by altering the pitches of the harmonic series into an inharmonic mass, and by adding extended techniques in individual instruments to divert attention to particular corners of that sound mass. I experience the first four gestures as a relatively stable group, and with

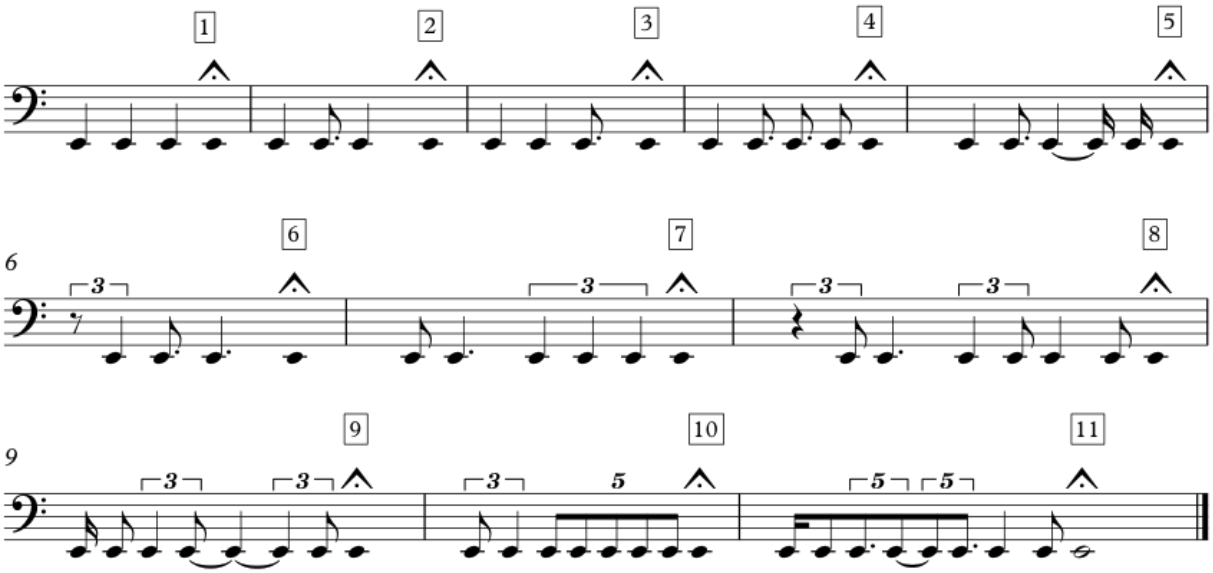


Example 2.4: Pitches in *Partiels* rehearsal 4, with partial rank labeled

each repetition I find that I toggle (either deliberately or not) between hearing the individual instruments of the ensemble or hearing the sound as a fused sonority. This fusion, and the liminal boundary between fused timbres and distinct harmonies, is undercut as the sonority grows more stridently dissonant and the instrumental texture moves away from its blend. At rehearsal 4, the cello sounds a sharp and unstable *molto sul ponticello* trill; at rehearsal 6, the trombone uses a plunger mute; at rehearsal 7, the bass clarinet uses flutter tongue; at rehearsal 10, the cello and viola perform harmonics glissandi on their D and G strings. All of these are like little cracks in the resonance of the ensemble harmony, timbral fissures that draw attention to a particular voice in the ensemble and away from the overarching sonority. The original chord, meanwhile, has deviated significantly from the harmonic partials of the overtone series; while the low E and the 3, 4, 5, and 7th partials of the overtone series remain, Grisey also inserts pitches that cloud the sonority, adding low end murk via a Bb2, C3, and a loud accordion cluster (example 5). Tampering with the low end of this chord is significant as a way of diminishing the fusion of the ensemble. At higher registers the distinction between pitches that are or are not in the harmonic series is relatively small; there is, for example, only an equal-tempered semitone separating a D#6 (the 15th partial) and a D6 (the 14th partial) and as partial rank increases the



Example 2.5: Reduction of pitches at rehearsal 7



Example 2.6: Bass attack rhythms in opening section of *Partiels*

space separating partials becomes very small. But there is no easy way to reconcile the low Bb2 at rehearsal 11 with anything related to the E1 overtone series.

As the pitch content morphs from stable to instable, the rhythmic content of the upright bass becomes irregular as well. Example 6 shows the bass attacks for each section of the opening of *Partiels*. From the initial three even quarter notes, Grisey begins to add and subtract 16th note values to render the spacing slightly more unpredictable: a slightly truncated second attack in rehearsal 2, a slightly truncated third attack in rehearsal 3, and so on. The number of attacks expands as well, from 3 up to 7 in the final instance.

"Spectral music," writes Grisey, "offered a formal organization and sonic material that came directly from the physics of sound, as discovered through science and microphonic access" (2000, 1). I believe my short discussion of *Partiels* shows that this is somewhat fanciful — there is nothing direct about the process of orchestrating the data of a spectrogram into an instrumental texture, but rather the entire process is mediated by, among other things, Grisey himself. The spectrogram is one actor of many in the assemblage of tools and techniques that yield the piece *Partiels.*

Partiels does demonstrate a number of musical features that Grisey has described in rich metaphorical language. In his essay *"Tempus Ex Machina:* A Composer's Reflections on Musical Time," Grisey outlines three levels of thinking about the time of music: the skeleton of time (duration, measured in terms of chronometric time), the flesh of time (time as felt; in particular, the way that periodicity can impact our perception of time passing), and the skin of time (time as impacted by a listener's subjectivity, including their memory, mood, and so on; in general, Grisey considers "flesh" to be something the composer can control and "skin" to be something the composer cannot control). Grisey's metaphorical language has extended past human characteristics: In his program notes to his piece *Le Temps et l'Écume* (1988/1989), Grisey claims to have been inspired by considerations of the phenomenal time experiences of insects, humans, and whales. In *Partiels*, the constant destabilization of the rhythmic ground, coupled with the increasing dissonance of the harmonic content (manifest both in the compression of the harmonic series and the addition of extended string techniques like sul ponticello bowing) creates a sense of goal directed motion without suggesting what the goal might actually be; rhythmic and harmonic density suggest the quality of an acceleration, of a departure from something static (the initial harmonic/timbral sonority in rehearsal 1 reprinted in example 1) to

something full of motion. This, too, finds a physiological metaphor in Grisey's writings: he conceives of the form of *Partiels* at both a large- and small-scale level as tripartite, following a pattern of inhalation - exhalation - stasis.

My analysis of this opening gesture has focused on what I attend to when I listen: sound source/causality (which instruments might be sounding), segmentation (where a gesture starts and ends), schematic models of pitch (a sound conforms to my extant knowledge of the harmonic series). *Partiels* challenges my ability to determine causality even while acts of segmentation and pitch identification remain relatively easy. This seems to be part of its appeal: the clarity of its repeating gesture allows me to focus more intently on the foregrounded variable of timbre — the line between timbre and harmony, the timbres of individual instruments, and the chimerical timbre those instruments form. When I first heard this piece it was as part of a mixtape someone gave me; I lacked knowledge of the stylistic aims of spectral music or even the ensemble make-up in *Partiels*. That lack, and the awestruck experience it precipitated, left an indelible mark on my hearing of this piece. What struck me then, and what I have tried to hold on to in subsequent years, was the impenetrability of the sound mass. There is joy in the remystification of instrumental music, in the strange sensation of time slowing down during the build-up of overtones following the upright bass's low E, and in the feeling of hugeness that accompanied hearing a massive gesture that grew more massive, more bright, with each repetition. It was the enjoyment of that introductory hearing that led me to investigate spectral music, and explanations of the music that made recourse (as in the writings of the composers) to the harmonic series and to acoustical knowledge felt incomplete. In that first, naive hearing, I was trying to parse the sound of that gesture by imagining how it was made, and that imaginative act was in part one of empathetic decoding: of trying to invent the

means by which I might match this strange aural percept. Though not a part of the received discursive tradition of spectral music, I do think that such experiences of a listener—of remystification, of inexorable movement toward an unknowable goal, of heightened challenges trying to make sense of something multifaceted, new, nameless—are in line with musical modernism's exploration of the outer reaches of expression. Such a view is not anti-listener, but rather is one in which great trust is placed in the listener to listen deeply and engage with something new. This, too, springs from empathy: composing entails an imaginative listening, the creation of a field of experiences that include but are not limited to the ones experienced by the composer. Considering the psychological mechanisms of engagement with music, particularly electronic music that might challenge conventional expressive markers, will be the subject of the next chapter.

Chapter 3: Body, Tool, and World in Acousmatic Musical Experience

3.1 Introduction

The twenty-first century listener is confronted with an overwhelming variety (and quantity) of music involves sounds that have either been synthesized electronically or processed using electronics. Examples of the former might include a digital software synthesizer in Garage Band or a Moog analog synthesizer; examples of the latter might include a distorted electric guitar, or a saxophone recorded and processed with compression. One might talk about synthesized sounds as being "like" a more familiar instrument (a warm synth pad might sound like the string section of an orchestra, for instance); or else for being strange and unrecognizable (as in some of the sounds in Stockhausen's *Studie I);* or for summoning surprising extra-musical associations (as when a field recording of waves crashing on a beach is piped in to a piece of chamber music).

Furthermore, music is routinely experienced acousmatically — that is, without visual confirmation of a sound's source. People might listen to music on the radio while driving, in iPod earbuds while walking to work, or on a high quality sound system while sitting at home, rather than at a concert or in a ceremonial setting. In the case of some instruments, such as an electronic synthesizer, there may be no visually obvious causal source for the sound. In the case of others, like the electric guitar, the instrument itself makes almost no sound but relies on amplification and, often, processing via pedals in order to sound like "itself"—what Wolfgang Schivelbusch (2004) would call a "machine ensemble," each component of which participates in the holistic electric guitar sound.

My aim in this chapter is to consider ways listeners use embodied knowledge to make sense of these so-called strange sounds produced by both synthesis and sampling, and to

suggest that these sense-making strategies are productive focal points for music analysis. Listeners rely on a wide range of perceptual information about actions, sound sources, and sound spaces, even if they don't always consciously attend to them. These learned and natural tendencies are manipulated in the illusory sound worlds of electronic music. This manipulation is manifest at both the level of creation and of reception, and composers faced with the real-time feedback of electronic music toggle between the subject position of listener and creator. It is analytically productive to consider how any one group of composers, producers, and sound designers thought about the relationship between sounds and objects, and how they cultivated listener's attention to those details. But such a consideration needs to take into account how the machine ensemble at their disposal asserts agency in those decision-making processes. Finally, turning to poietic experience, what inheres in a listener's perceptual faculties that might enable someone to have an illusory aural experience? What sort of compositional devices or narrative/conceptual priming, if any, might need to be in place to allow a listener to hear these aural environments as such?

These questions are motivated by my experiences as a composer and performer of electronic music, and I will offer an example from my own practice that demonstrates the kinds of analytic problems I want to delve into. I often search for ideas by choosing software instruments and improvising. In one such session in Ableton Live, I begin by selecting a basic analog modeling synthesizer with a default preset (figure 1). I start recording while I test a few sounds.[1] I find that I like the beating that results from the semitone F4-E4, which I play on my laptop keyboard by pressing "F" and "D". But the brightness of the default setting is a bit harsh and grating: it sounds very "machinic," and if I were to make those sounds with my voice, it

[1] The recording can be streamed at soundcloud.com/will-mason/dissertation-synthesizer-example.

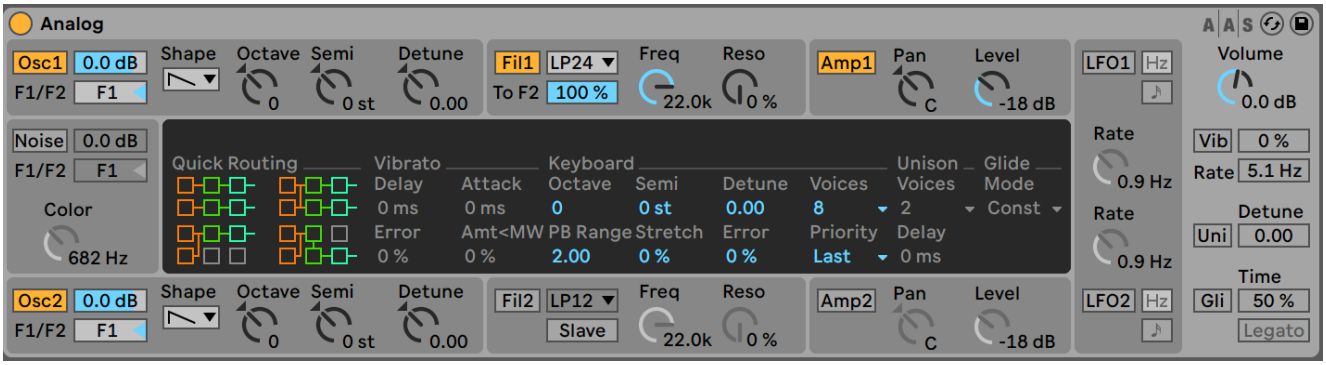


Figure 3.1: Analog modeling synthesizer with default settings in Ableton Live 10

Figure 3.2: Reverb plug-in in Ableton Live 10

would involve tight and constricted vocalizing. To mitigate this, at 0:15 I turn on a reverb plug-in to cut the high frequencies (figure 3.2).

Reverb typically creates a perception of a widening aural space, and I find that happens here: I've not just cut off high frequencies and added reverb but I've pushed the sound source (the synthesizer) back from the listener (which, right now, is me). I want to minimize this distance, so I increase the reflections gain and turn the dry/wet ratio down slightly from 0:35-0:40. I find that moving the synth closer has made it feel ominous, like a fast-approaching fog cloud. I didn't plan for the sound to become ominous, but I now want to capitalize on it, so I increase the decay time to start minimizing the attacks of the minor second dyad E4-F4. The reverb patch's reflections mean that aspects of the timbre of the E4 and F4 are getting amplified,

creating a wider frequency range than those two pitch labels would suggest. At 0:54 I freeze the reverb, which makes it sound either like a sustaining chord or, to my ears, like an ambient environment. Particularly, it sounds like something that had been an object has gradually become an environment: the synth moved from small and distant to engulfing and omnipresent. Lastly, at 0:58 I turn on and increase the reverb's in-built "chorus" effect, which furthers the atmospheric feel of the frozen reverb patch by obliterating any sense of discrete pitch: there's nothing that I could imagine emulating with my voice or with an instrument, and so I am left imagining myself within the sound rather than creating the sound.

This example shows several things. Despite being the composer of this example I did not set out with a plan but rather improvised in response to the sounds I was making. I had a rough sense of what the parameters I controlled would sound like, but it was rarely matched by the result. I would like to suggest that a listener's experience with the piece may parallel my experience in shaping this piece. I conceptualized the timbre of the synthesizer as rough, which I evaluated by comparison to other objects (loud machines, like a weed whacker or a motor) and, ultimately, by comparison to my own voice. I heard the sounds undergo a transformation that would be almost impossible in the real world, from an object (the clearly pitched synthesizer instrument) to an atmosphere or an environment (the frozen and chorused reverb, like a massive gust of wind or rush of water). Were I to try and convey salient aspects of this composition, pitch labels and a transcription of what I played on a Western 5-line staff would be woefully inadequate to describe the sounds that resulted.

This example also demonstrates how the human body-in-the-world acts as the frame for sense-making when we listen both to the strange and the familiar sounds found in electronic and electroacoustic music. Listeners can ascribe intentional physical actions to the cause of

sounds; or imagine the actions that we would make to produce certain sounds using certain materials in a certain space; or can toggle between several distinct modes of listening and even try to inhabit several simultaneously. Exploring different modes of listening can be something that we do unconsciously, or it can be something we develop as a kind of narrative experience with prior priming, and it can be something that certain pieces invite more than others.

Furthermore, technological developments (in both the production and reproduction of sound) in the twentieth century revealed and re-focused these aspects of listening, which cultural practices of listening cultivated in Western art music's common practice era had de-emphasized. Electronic sounds, the techniques of the recording studio, and the music that has been made with those tools have forced us to confront seemingly basic or inviolable premises underlying musical experience which turn out to be neither basic nor inviolable. Just as abstract painting draws a viewer's attention to questions of material and gesture and color by eschewing obviously figurative subjects, novel types and arrangements of sounds lacking obvious tonal or formal frameworks can draw our attention to basic constituents of sound like material, space, gesture, and affect.

In asserting these claims I am drawing from scholarship in three different areas: acousmatic listening in electronic and electroacoustic music; the imbrication of human perception with technologies and technics; and the embodied and corporeal (or gestural) nature of perception and cognition, in both musical and everyday experience. In exploring the intersection of these fields, my work joins De Souza (2017), Tomlinson (2015), Krueger (2014), Godøy (2006), and Cox (2016). There is much more work to be done considering the particular ways in which technology can both create and function within the sonic worlds created by music. For example, Krueger (2014) takes music as itself a technology—of affect regulation, of

altered-state induction, etc.—and thus presents a theoretical framework that is musically undifferentiated, ambivalent about the particular musical content or genre of a song because such a context is not necessary to support his claims about how people use music to regulate affect. I am interested in the experience of reasonably enculturated composers and listeners coming into contact with specific musical works: an audience for whom the difference between the sound of a violin and a piano, or the difference between the interval of a perfect fifth and a minor ninth, are laden with culturally accrued meanings.

These concerns are relevant to French spectralism (particularly their electroacoustic works), but they neither start or end with those composers. An important early thinker of these issues was Pierre Schaeffer, whose work in *musique concréte* and writings on what he called reduced listening will be discussed later. Schaeffer's influence on the spectralists is oblique: on the one hand, but in their stated aim to consider properties of sound itself (as manifest in, for instance, the spectrogram) they reveal an affinity with Schaeffer's ideas about the object of reduced listening, which he called the sonorous object. Murail wrote of the "very essential idea that the musical 'atom' is not the notehead written on staff paper. The musical atom is the perceptual atom, tantamount, perhaps, to Pierre Schaeffer's 'sonic object.'" (Murail 2005, 123). At the same time, the spectralists were interested in the nature of human perception, of acts of listening and musicking which are causal and ecological in nature: in the creation of real and surreal musical objects using physical modeling synthesis, in the imitation of technological sonic phenomena using acoustic instruments, and so on. This suggests affinities with the writings of a composer often placed in opposition to Schaeffer, R. Murray Schafer. Schafer opposed the idea that composers should disregard the real, material dimensions of sounds: sounds used in acousmatic music can and should refer to the real world. Rather than adhere

strictly to one aesthetic dogma or another, composers of electroacoustic music (including the spectralists) have embraced the malleability of listening, veering between causal, ecological, and reduced listening.

These preoccupations were not limited to composers in the art music tradition: the Beatles were exploring manipulations of aural representations of space in their famously adventurous 1967 album *Sgt. Pepper's Lonely Hearts Club Band,* a decade before Grisey and Murail began tinkering with imaginary aural objects. Indeed, the spectralists were more attuned to pop and rock music than their modernist leanings might suggest. "The spectacular development of synthesizers, of electronic sound, owes considerably more to Pink Floyd than to Stockhausen," wrote Murail (2005a, 123). Illusory and manipulative electronic sounds are so common today as to be unremarkable—indeed, the construction of a fictional acoustic space may be an a priori feature of recorded sound—and this nondescript experience is why it's interesting to consider a historical moment when this phenomenon was emergent, as well as the tools and techniques that allowed it to emerge. In the case of the spectralists, it also entails a consideration of some extreme cases to which these techniques were put. For the spectralists, I've argued in chapter 1 that these "extreme cases" were in service of what Metzer (2009) calls late modernism's interest in the nature and limits of expression. From an analytic perspective, considering extreme musical cases (which, it should be noted, are today as likely to occur in in Timbaland's studio as they are the lab at IRCAM) can help shed light on the more subtle ways that these aural practices have infiltrated a wide range of musics.[2]

In using words like "illusory" or "manipulative" I do not mean to suggest that the sonic phenomena or sound-producing objects under consideration exist in some absolute, knowable,

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[2] Timothy Taylor's aptly titled book on music technology, *Strange Sounds*, makes a similar point; see Taylor 2001, 9.

noumenal state. As authors ranging from Jacques Derrida (1967) to Naomi Cumming (2001) have argued, as soon as something is perceived it is interpreted. I suspect that for many listeners, the "enhanced" sound of a voice singing (often softly, or more softly than an unamplified vocalist would typically sing) into a microphone and processed with compression and reverb (a standard recording technique) is the primary way that they come into contact with a sung voice. That augmented sound becomes normative for those listeners, even though it is a result of a dense assemblage of tools and social/historical practices. This helps demystify a common fiction of recorded sound, which is the notion that certain recording techniques might convey a more "true" or "accurate" sense of a performance. The idea of verisimilitude or fidelity is itself a construction, a positional stance within a particular auditory culture.[3]

There is an analytic tension between on the one hand describing a set of technologies and techniques that are used to create or modify sounds on a recording (suggesting a default or standard sound that has been modified) and on the other hand describing the way those sounds might be experienced (which need not rely on any kind of knowledge about what a thing is or how it was altered). My analytic method for the latter is built on the idea that people relate sounds to the skilled actions and action potentials available to their bodies-in-the-world, but also that they can learn to re-map those available actions or to learn new ones. For music theorists interested in changing how people listen to music, the intersubjective sharing of these experiences of source-cause identification should be as much a part of music theory as the intersubjective relating of pitch-class sets or formal boundaries. I find the tensions and resonances between the material affordances of musical instruments and artifacts, the kinds of knowledge demonstrated in production, and the kinds of knowledge demonstrated in reception

[3] In-depth explorations of the concept of hi-fi can be found in Dolan (2010) and Newton (2016)

to be extremely productive for considering a culturally and historically situated relationship to sounds, tools, others, and ourselves.

3.2. Embodied Music Cognition

If, as I argued in my second chapter, modernism in the twentieth century ought not to be understood merely as a negation of romanticism and classicism, what attributes might positively define modernist music? I find in spectralism, as in early twentieth century modernism, a development of musical attitudes analogous to the gradual move away from the criterion of verisimilitude in figurative visual art and towards a more explicit emphasis on method and on material (and on a self-conscious consideration of what musical material might even be). There are certainly more points of worthwhile divergence between twentieth century modernism and its precursors in the larger history of modernity; the political upheavals of the twentieth century and the gradual enfranchisement of traditionally marginalized demographics, for example.[4] This scholarly work into the pluralism of twentieth-century musical modernism opens the door for further analytic work into the diversity and variation of musical expression employed by these communities. This means not only examining differences in technical practice and aesthetic orientation on the part of different composers of abstract modernist music, but in considering some of the ways that listeners might respond to these differing practices. I want to construct a framework that helps elucidate how the historically malleable and ambiguous notion of "musical abstraction" is contextual and contingent. It

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[4] Eric Drott has written several compelling accounts of music, politics, and modernist music; see, for instance, Drott 2011. Brigid Cohen's account of modernism and migration in the music of Stefan Wolpe offers another point of departure for considering the political and identity concerns surrounding certain modernist communities in the twentieth century; see Cohen (2012). And Ellie Hisama (2001) explores the work of three women modernist composers, exploring intersections between gender, institutional structures, and modernist music in the early and mid-twentieth century.

correlates with musical activity which approaches or exceeds individual listeners' readily available conceptual knowledge, a knowledge that is premised in part on the nature of their physical selves and their movements in space. My aim is to oppose the idea that abstraction entails an absence or erasure of humanity—that the stretching of extant conceptual knowledge is not tantamount to total perceptual incomprehensibility, and that in foregrounding the various material constituents of music, composers are also drawing attention to physical, material, and psychological aspects of performance and listening. In music listening, our body remains the frame through which aesthetic objects are felt and evaluated.[5]

An example may help show how this embodied knowledge can be brought to bear on music analysis. Many music theoretic articles about spectralism are content exclusively tracing pre-compositional procedures; a smaller number suggest an interpretive hermeneutics oriented around perception and identification of those compositional processes. For instance, Julian Anderson's discussion of Tristan Murail's *Ethers* (1978) describes the opening as follows: "The flute proposes a series of 'acoustic models' which the quintet attempts to simulate; in so doing, the models are progressively deformed into a new texture which provides the pretext for a new acoustic model from the flute, and so the process continues" (1993, 321). Murail's own performance notes for the opening of Ethers, scored for flute, trombone, violin, viola, cello, and contrabass, plus a steady churn of maracas, show as much (Figure 3.3). How these models, and their deformations and transitions, are experienced is dependent on compositional maneuvers Murail makes but could stand more explication.

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[5] The idea of our body as a frame is a recurring theme in this dissertation and I will take great pains not to adopt a monolithic account of the body as some naturally-given "fact." When I refer to the body I consider it a product of culture as well as of biology, a complex assemblage of objects and forces in regular flux. If the account in this chapter seems insufficiently sensitive to this observation, it is by way of introduction only and will be complicated later on.

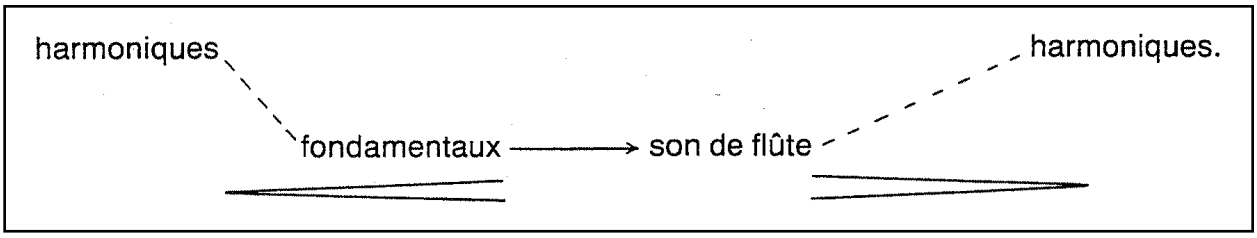
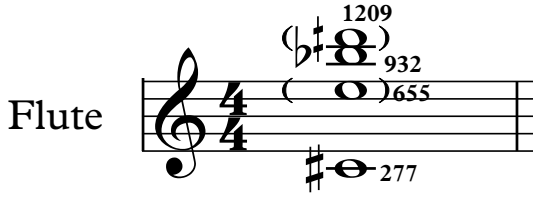


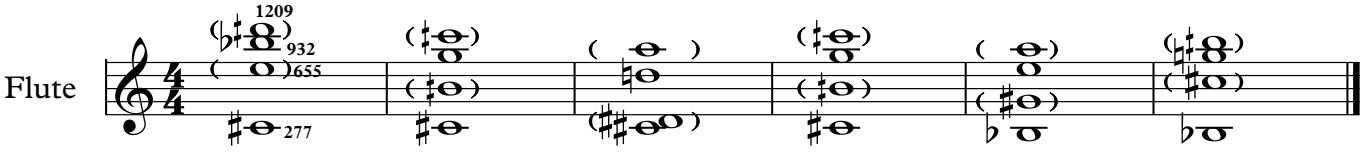
Figure 3.3: Opening gestural process of Murail's *Ethers* reproduced from score

The strings sound a dense cluster of high harmonics; gradually, a fundamental corresponding to those harmonics is introduced (usually by the cello or the bass). The flutist sings the fundamental (in the first instance, a C#4) and plays a Bb(5) (example 3.1). The intended effect is sum and difference tones, which have traditionally been understood as psychoacoustic phenomena arising from nonlinear distortion in the inner ear. (They can also



Example 3.1: First flute sonority in *Ethers* (bottom pitch sung, top pitch played)

arise physically, as the result of ring modulation in an audio circuit.) Following the flute sonority, the strings sound new harmonics comprised of pitches that include the four pitches of the flute, as well as other pitches, yielding the deformation Anderson references. Example 2 gives a reduction of the four sounding pitches in the first flute sonority of *Ethers*, with their frequency values in hertz notated.



Example 3.2: All six flute combination tone sonorities in *Ethers* opening

I find the flute's Bb5 a bit odd at first glance. The score allows for microtonal notation, so if Murail were trying to have the two performed pitches correspond to the characteristic natural 7th (the 7th partial of the overtone series), he could have asked as much. More likely, the Bb was chosen precisely because it creates a more complex sound. At 960 hertz, the natural 7th of C# would result in a sum tone of 1237 hertz (D#, the 9th partial) and a difference tone of 683, the natural 3rd (or the 5th partial of the overtone series, 14 cents lower than the equal tempered third, F natural at 697 hertz). Because the resulting tones would align with the harmonic series, they would be less identifiable as pitches and easier to understand as timbre. Indeed, all of the sonorities of the first section of *Ethers* feature equal tempered sung and played pitches; the played pitch never comes close to a triadic relationship (that is, partials 2-6) with the sung fundamental. Note too that when the fundamental shifts to Bb in the fifth chord it is a T_{P-3} transposition of the fourth chord, and the sixth chord is a T_{P-3} transposition of the first. Thinking in terms of frequency rather than pitch offers a theoretically limitless number of combination tones, but Murail only uses four intervallically distinct sonorities. The complex sound of the flute draws our awareness to the combination tone process itself: it is easier to hear the sum and difference tones when they are not subsumed by the harmonic series of the fundamental pitch; they do not fuse as easily and the timbre/pitch line is blurrier. The distinction (or lack thereof) between pitch and timbre has been a hallmark of spectral thought since the beginning. As Murail writes: "There is a harmony – timbre continuum. A timbre can be defined as an addition of basic elements, pure frequencies, sometimes white noise bands; a harmony is created by adding timbres together, which is to say the addition of additions of basic sonic components. In other words, there is theoretically no difference between the two concepts; it is all a question of perception, of habits of perception" (2005, 138). Alternative perceptual modes are encouraged

by the harmonic and orchestration decisions Murail made. The string harmonics, blending with the steady white noise of the maracas, are both pitch and timbre: the harmonics are white noise, too, an ambient backdrop into which the flute (the star of the show in this section) emerges and recedes. At the same time, the pitches from the flute generate the pitches of the string harmonics, and this connection makes it impossible to ignore the permeable boundary between timbre and pitch. This is my becoming aware of a habit of perception, as Murail wrote.

The music of *Ethers* is a technology of phenomenological awareness in the same way that the spectrogram or the other tools of the laboratory co-opted by the spectralists are technologies of conceptual awareness. What gives me this awareness, which is so critical to my particular experience of this piece, is my own lived and embodied experience. My ability to measure the sound of the flute in relation to my own body's sound-producing capabilities, or to my knowledge of musical instruments, or to my experience being in a space all depend on the nature, structure, and history of my body. These kinds of observations about music can feel deflating to analysts accustomed to marking cadence types or formal regions, since it's subjective, qualitative, and inherently unverifiable. But a great deal of music has proven resistant to the kinds of analytic claims that have traditionally been the aim of music theory; this music calls out for a new approach. In what follows I will review sources whose work provides psychological, philosophical, and evolutionary support for the idea that listeners can deploy their bodily knowledge to empathize with imagined objects, and to use that faculty to imagine experiences that stretch the bounds of that very same body. The second half of my claim—that technologies of music production constitute an apparatus that produces and modulates these experiences—is the subject of chapter 4.

Embodiment is a malleable term, and the body itself—easily taken as an unexamined and universal given—is not so clearly demarcated a concept as might be assumed. Becker (2004) outlines three ways of thinking about embodied experience: first, the body is the physical structure where emotion and cognition happen (a viewpoint Becker associates with mainstream music cognition); second is the notion of the body as the site of our phenomenal experiences, our inner selves; third is the body "as involved with other bodies in the phenomenal world, that is, as being-in-the-world" (8). Embodied cognition describes a wide set of views which hold that the nature and construction of a person's physical self, a person's developmental maturation from infancy to adulthood, and a person's sensorimotor experience of moving with a body, all play a causal or even constitutive role in their understanding of the world. This view is in contrast with standard theories of cognition (often called cognitivist), which share what Shapiro (2011) calls an "ontological commitment" to the idea that "cognition involves algorithmic processes upon symbolic representations" (2). One paradigmatic example of traditional cognitive science would be Chomskian linguistics, with its rule-based approach to language acquisition and manipulation. This view of cognition has been traced back to the dualism Descartes drew between *res cogitans* and *res extensa*, in which the immaterial mind was the seat of thought and the physical body little more than a vessel for the mind. This view permeates much foundational work on human cognition, which was indebted to an information-processing view of the mind in which a perceptual modality like vision, for instance, was conceptualized in computational terms: inputs are received from the eyes, the mind assembles them into representations, and then decides what conclusions to draw or behaviors to output.[6]

[6] There are innumerable authors who have discussed both the pitfalls of mid-twentieth century cognitive science and its links to Cartesian dualism; see for instance Shapiro (2011), Cusick (1994), and Pickering (2010).

As Shapiro writes, "the guiding idea is that vision is a computational task, involving the collection and algorithmic processing of information" (25). Instead, embodied cognition holds that mind and body are inseparable, growing together from birth in accordance with the environment in which a subject is embedded. Returning to the example of vision, information is not received but rather sought out through movement and action. We direct our perceptual attention toward exploring certain invariant features of our environment. This view of perception was pioneered by James Gibson, founder of ecological psychology. "Each perceptual system," he wrote, "orients itself in appropriate ways for the pickup of environmental information, and depends on the general orienting system of the whole body" (Gibson 1966, 58; quoted in Shapiro 2011, 35-36).

But it must be emphasized that embodied cognition is a comparatively new framework and there is no one unifying theory of embodiment and cognition. Shapiro identifies three themes as suffusing various work on embodied cognition, and these themes are not necessarily incompatible with one another. They are:

1) **Conceptualization**; where the properties of an organism's body serve as a boundary limit for the kinds of concepts an organism can acquire;
2) **Replacement**; where traditional representational processes (algorithms performed on symbols) supposed to be central to cognition are replaced by an organism's body in interaction with its environment. Important here, Shapiro observes, is the concomitant claim that cognition can take place "in systems that do not include representational states, and can be explained without appeal to computational processes or representational states" (2011, 4);
3) **Constitution**; cognitive processing as we know it is constituted by the body and the world.

In *Action in Perception*, Alva Noë (2004) advances an action-oriented ontology for considering perception. He argues that sense perception and motor processes work in tandem to ground perceptual and conceptual knowledge of the world around us. Walking towards a tree makes the tree grow in our visual field; moving near a stereo makes the sound grow louder; and the fact that over time we know these to be causally related forms the foundation of our perception and our formation of concepts. In Noë's account, which he calls the enactive approach, perception is *constituted* by the sensory knowledge possessed by the perceiver — Shapiro's third theme. Movement, as in the examples just cited, gives rise to changes in stimulation. But Noë argues that stimulation alone is not sufficient for perceptual awareness. "For perceptual sensation to constitute experience—that is, for it to have genuine representational content—the perceiver must possess and make use of sensorimotor knowledge" (Noë 2004, 17).

One of Noë's examples is Merleau-Ponty's famous formulation of a blind man sensing with his cane. There is no feeling in the cane, and yet the man is certainly perceiving with it, judging objects in the world as he moves through it. The blind man with the cane is *enacting* perceptual content because he is using sensorimotor knowledge to engage with the world. In enactivist terms, a blind man who has walked around a scene with aid of his cane has possibly perceived more about it than a sighted and inert observer who has explored it with fixed vision alone. Where so much of modern culture and modern science is visualist in nature—often relying on visual translations of data from other modalities like smell or hearing, and in general equating "seeing" with "believing"—one consequence of the turn to embodiment is to interrogate the extent to which Western epistemology is fundamentally sight-oriented, and what

might be left out in that sensory bias. Music theory as a discipline relies on translating aural phenomena into visual form, be it text or music notation.

Music is a paradigmatic example of an active, kinesthetic art form: we tap, nod, or dance to music; we see music performed in all of its skillful physical complexity; we use our bodies and instrumental artifacts to produce sounds, and we bring that knowledge to bear in imagining how someone else might have made a sound. Performing music need not be the only realm of creation: the seemingly passive activity of sitting and listening is itself an active and creative activity, implicating a range of faculties from sensorimotor knowledge to mental imagery. Creation is fundamentally social, implicating performers, composers, dancers, and listeners in a shared (and thus historically and culturally situated) expressive moment. As my account of my hearing of Murail's *Ethers* demonstrated, one way that music is rendered meaningful is by grounding our perceptual observations about performance in our embodied ecological knowledge. A familiar way that sounds are produced is through expressive physical gestures: clapping hands together, shouting, striking an object. First-person knowledge of how these gestures are performed allows for decoding information about their possible intention: there is value in understanding that a loud, aggressive sound required great exertion to make and likely signals some manner of threat. Robert Hatten defines a gesture as "any energetic shaping through time that may be interpreted as significant" (2006, 1, my emphasis). Leman and Godøy (2010) define a gesture as "a movement of part of the body, for example a hand or the head, to express an idea or meaning" (3). The two definitions are complementary: Hatten's gesture implicates an interpreter, whereas Leman and Godøy suggest authorial expression.

A listener interpreting a musical gesture first and foremost compares it to a physical gesture deemed analogous, be it the gesture that elicited the sound or one that reminds of the

sound or both. For instance, grief is often manifest in musical gestures with falling pitches, which might suggest a kind of weightiness, or which could nearly imitate a wailing sound.[7] A surprising musical event might be accompanied by opening the eyes wide and raising the eyebrows, facial gestures generally accompanying surprise.[8] Naomi Cumming likewise argues for the importance of physical gestures in musical meaning formation. She writes that "paying attention to a performer's physical activity is important also in counteracting the sense of sound as disembodied, a sense that can come from listening to 'piped' music without a knowledge of its physical source, or to CDs whose technically altered perfection has removed the sounds of a performer's breath or of the obtrusive scraping of a bow on the strings" (2000, 21).

It is critically important that Cumming implicates an object—the bow on strings—in her account. It's not simply that we gesture, but that we regularly gesture purposefully with instruments. Knowledge of instrumental gesture becomes linked to our sense of a gesture's effort or intensity. If I didn't know about a hammer or hammering, I would see nails driven into a board as the result of immense strength. If I didn't know about a fretted guitar, I might be amazed at the ability to play angular melodies with accurate intonation. Gary Tomlinson's sweeping account of music's evolutionary origins, *A Million Years of Music* (2015), begins by declaring musical activity's inseparability from tools and from social communication: he writes that "musicking was always technological" and "musicking was always social" (48). The notion of musicking, coupled with Tomlinson's long view on the development of music and the development of early humans, gives us a framework for considering how tool use has been imbricated with human thought and expression and thus in the making of music. Tomlinson

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[7] "When I am laid in earth," Dido's lament from Henry Purcell's opera *Dido and Aeneas*, is an oft-cited example of this correlation.

[8] For discussion see Huron (2006), especially chapter 2.

demonstrates that Acheulean tools produced in the Lower Paleolithic era "functioned as material extensions of the body that altered the selective landscape and its pressures. As the toolmakers were advantageously selected, so were the capacities that enabled their industries: self-initiated motor sequences, mimesis of others, rehearsal loops" (2015, 82). A feedback loop emerges between material objects and functional physical gestures within the taskscape, and because of its mimetic dimension—I observe you cracking a crab shell with a rock to obtain meat, and I perform the same task in hope of the same result—this feedback loop is fundamentally social. Furthermore, this feedback loop led to the production of referential gestures and sounds. "The imitation and conventionalization of action gestures and iconic pantomines," writes Tomlinson, "resulted in meaningful gestures" (109). Our capacity for both expressing and understanding the expressions of others begins in this Acheulean taskscape, amidst the earliest stone tools and the earliest human formations.

All of this is important because whatever music expresses, it does so with a combination of tools and gestures whose protolinguistic significance is easier to grasp when set at a remove from both its very recent musical manifestations as well as the concomitant development of language. Music has important divergences from language, particularly because language fixes semantic meanings and music generally doesn't; and yet comparisons between music and language are an enduring part of music scholarship.[9] Many of the gestures and vocal utterances of early hominins were communicative but lacked the combinatorial elements of language: "a laugh or a sigh cannot be broken down into smaller, discrete parts that might be recomposed into other signals" (Tomlinson 2015, 110). But we can express gradations of these core utterances: big and little laughs, whose gesturing may be grander or smaller depending on what

[9] For more discussion of music's relation to language's semantic content see Agawu 2009, especially pages 20-29.

general idea is to be expressed. These core aspects of human sociality that Tomlinson traces—gesturing, tool use, referential social communication, and most importantly mimesis—provide necessary evolutionary background to an embodied account of music making. They are especially relevant in contemporary "abstract" music, which has often sought to strip away accumulated musical meanings to arrive at something composers might have deemed as originary or else to envision trajectories of musical organization other than those received from tonal music.

Arnie Cox has formulated what he calls his "mimetic hypothesis" for musical experience, which is predicated on the principle that "part of how we comprehend music is by imitating, covertly or overtly, the observed sound-producing actions of performers" (2016, 12) and that this faculty is simply a subset of how we comprehend the human behavior of others in general. Cox distinguishes between mimetic motor action (MMA), which is overt mimetic behavior (as when a piano teacher demonstrates to a student how to finger a certain passage at the keyboard), and mimetic motor imagery (MMI), which is covert mimesis rooted in mental imagery, as when I see someone jump across a small stream and imagine what it would be like to do the same (Cox 2016, 12).[10] Both of the examples I listed are goal-directed actions, which Cox says more strongly activate MMI and MMA; and both of them implicate motor imagery, which is one component of musical imagery (13). In the case of watching a performance, we might understand the piece by imagining ourselves performing the observed sound-producing actions (which Cox calls intra-modal mimetic motor imagery); and/or we imagine analogous sound-producing actions (singing a melody that we hear on violin, for instance, which Cox calls

[10] An example of motor imagery without mimesis would be if I saw a stream and imagined jumping across it.

cross-modal mimetic motor imagery); and/or we imagine other analogous exertions (like dancing to the music, which, for Cox, is also cross-modal mimetic motor imagery).

For example, as a percussionist I know that there are a number of very fast patterns that are nevertheless quite easy to perform because they're produced by bouncing a drumstick a certain way. They sound effortful to lay listeners because there are a lot of attacks, and most listeners imagine each individual attack being the result of an excitation. Lots of attacks must mean lots of effort. A trained percussionist would instead hear something like a double-stroke roll and experience it differently: as less effortful, and perhaps even comfortable and relaxing. Both listeners are responding mimetically; but one is misidentifying effort and construing a musical experience accordingly. That might be what I as the performer want them to experience —it's nice to do something effortless that impresses a crowd—and so even though they've misread the difficulty of the gesture they may still be receiving its intended meaning.

So far these examples have dealt with observed performance, which is generally absent or impossible in the largely acousmatic world of electronic music. Cox (2016) extends his mimetic hypothesis to claims that are especially important some electronic and electroacoustic music that I want to consider. First, mimetic behavior can be conscious or unconscious—we can hear a pianist and imagine manipulating piano keys without attending to that imaginative act (13). Second, mimetic motor action and imagery can be intramodal (the example of matching a pianist's finger movements with our own), cross-modal (hearing a melody played on a piano and imagining how we would sing it), or amodal (imagining certain muscle exertions that would underlie limb movements) (13). Cox considers an array of empirical evidence in support of these claims but I want to highlight two studies in particular. Haueisen and Knösche (2001) compared motor activiation in pianists and non-pianists when presented with recordings of

piano pieces. Pianists demonstrated a significant increase of involuntary motor activity in the contralateral motor cortex compared with non-pianists; their sensorimotor knowledge of the production of piano sounds was activated by the auditory stimulus. If we are accustomed to performing an action on or with an object (musical or otherwise) and hearing a particular sound result, we are in general very good at reverse-engineering this process when given a sound: we imagine what we or someone else would have done to produce this sound in this way. This is a fundamental component of the history of musicking that Tomlinson describes: that music developed alongside the faculty for empathetic mind-reading (inferring what might be driving an organism to do something) and that this faculty can implicate tools and objects. Humans needed not only to be able to use a stone hammer, but to watch someone else use a stone hammer and mimic their actions. This is intramodal mimetic motor imagery: an auditory stimulus elicited a response in a listener with a particular skill set that was different from the response elicited in a listener without those skills.

Margulis et al. (2009) examined the effect of a listener's biography—"an individual's long term experience with a particular type of auditory input" (267)—on their perception of music. They found that when listeners heard music played on their instrument of expertise, they had dramatically increased sensitivity to nuances of timbre, syntax, and sound-motor interactions. The experiment's subjects, all of whom were either highly trained violinists or flutists, were presented with two similar pieces: J. S. Bach's Partita in A Minor for solo flute and Partita in D minor for solo violin. fMRI analysis revealed that skilled performers experienced greater activation of parts of the brain devoted to parsing auditory information, like the left medial frontal gyrus, when presented with their own instrument's excerpt. This is not the only study to suggest that learning an instrument forges new audio/visuomotor associations.

Proverbio et al. (2015) found a correlation between the number of years of formal training on an instrument and the ability to detect an incongruence between pitches performed on an instrument and pitches heard; more advanced musicians were better able to tell that the audio and video were mismatched, suggesting a correlation between perceptual sensitivity and instrumental knowledge.

Margulis et al. (2009) note that "activation in the inferior frontal region can be attributed to the involvement of the mirror neuron network" (274). Mirror neurons have been directly observed in some primate species; they are neurons that fire both when an animal performs a task and when the animal observes the task performed by another animal.[11] I do not wish to overstate the explanatory value of mirror neurons, and Hickok (2014) provides a thorough critique of some studies which have placed too much explanatory value on mirror neurons. Cox, too, sounds a note of caution: in listening to a flute performance, it is not clear which aspects of performance an auditor might mirror, be they finger movement or breathing or mouth and tongue movements, etc.[12] Nevertheless, I do think that they suggest that some sort of physical mimetic relationship between artifacts, learning, and cognition inheres in our experience of music. Intramodal MMI responds to auditory cues with which a listener is especially familiar: the timbre of a particular instrument implicates an object (flute, violin, etc.) with which we might have skilled sensorimotor knowledge.

It may seem as though this theory of mind-reading (of mental simulation) is contrary to the action-oriented and anti-cognitivist approach evoked by philosophers of embodied cognition. I would point to the distinction made by Currie (2011) between two views of

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[11] Mirror neurons were first documented in Di Pelligrino et al. 1992.

[12] See Cox 2016, 23 for discussion.

simulation. The first he terms the philosophical and developmental psychological understanding, in which simulation "names a theory about how it is we come to understand people's reasons, the idea being that we imagine ourselves in their position and then reproduce the reasoning which led to their own decision or conclusion" (2011, 85). This would be a kind of cognitivist approach to simulation and it is not the one that finds its roots in Tomlinson's account. A second kind of simulation Currie defines as "a theory about ways in which certain aspects of human performance are implemented in systems that operate within the person, are not directly under personal control, and the workings of which may be inaccessible to consciousness, though they may give rise to conscious experiences" (85). Currie cites judgments about the production of simulated movements, as when a test subject rotates their hands as part of the process of figuring out how they might grip an object depicted on a screen. When I see a violinist perform and imagine performing the same gestures, it's not that I am reproducing a "reasoning" because the reasoning behind a musical gesture is usually diffuse and highly subjective. (Consider my example of the percussionist performing an easy but fast drum roll.)

It is important to emphasize that experiential contexts will likely elicit different forms of mimetic behavior: at a live concert, where I am watching (for example) a cellist perform, the strongest pull will be toward imagining actions performed by the cellist. In an acousmatic context, as when listening to a recording, there will be more potential for cross-modal MMI given the absence of a visual reference. Experimental evidence for cross-modal MMI is not abundant, but Cox points to one study on timbre imagery as evidence of the specific cross-modal phenomenon of subvocalization. Halpern et al. (2004) asked participants to judge the similarity and difference in the timbre of different instruments heard in recordings, and then to perform the same assessment based only on the name and image of that instrument—that is, by

imagining the sound. Cox writes that "one premise of the study was that timbre imagery likely does not involve subvocalization" (31). However, fMRI scans found activation of the supplementary motor area of the brain, which Cox says is consistent with a theory "that understood recall as a combination of *rehearing* and *reenacting"* (29). Cox speculates that we subvocalize not just for pitch but for timbre. "Despite the limitations of the human voice, we *do* intentionally and overtly imitate timbres, to some degree of fidelity, as children and as adults… What matters is the attempt to emulate the sounds, to feel something of what it would be like to make such sounds, and to thereby feel something of what it would be like to be an entity capable of making such sounds" (32).

In acousmatic music, it is absolutely conceivable that mimetic motor imagery would, for some listeners, be activated by a clear electronic gesture more than, say, a fast *sul ponticello* arpeggio from a violist. Indeed, the seemingly paradoxical role of the human-like machine and inhuman performer is one expressive resource that electronic musicians have mined. We don't just interrogate other humans mimetically; Cox writes "when we take an aesthetic interest (a disinterested interest, as it were) in some entity, in effect part of what we are doing is wondering what it is like, or would be like, to do what that entity is doing and to be that entity…in principle the hypothesis extends to inanimate entities like rivers, trees, mountains, sculptures, and architecture" (2011, 4).

Another way to think about this is that we can adopt first- and second-person subjectivities in perceiving the world (including music). As Cox (2012) writes, performance is corporeally a first-person activity (I am performing) and listening a second-person activity (you are performing). But "a listener's subjectivity combines something of all three of these positions, roughly simultaneously, in a continuously changing blend" (2012, 2). For example, enjoying the

sound of a metal singer screaming could originate in a masochistic desire to be screamed at in an aesthetic context (second person: you are screaming at me), or in a desire to be able to scream at someone (adopting a first-person subject position through mimesis: you are screaming but I am imagining what it would be like to scream like you). Music gives us a safe environment in which to act out either or both of these desires, which may be taboo in our daily life.

3.3 Acousmatic representations

It's a truism to state that different media represent phenomena differently (often with varying degrees of verisimilitude): a film of a man walking represents his gait better than a painting would, even if the act of walking is still conveyed by the fixity of the painting. To a particular viewer, the feeling of awe in the Grand Canyon might best be conveyed through painting even though in reality our aural and proprioceptive experience of being in the canyon (which are absent from painting) contribute to the sense of awe the landscape inspires. In writing about the sublime, Edmund Burke argued that poetry was a superlative medium for conveying that which might otherwise be considered "unrepresentable," citing passages from Milton about the figure of death and of Satan as two examples and deriding painting for being mere mimetic representation (Burke 2015, 129-130, 138). Total accuracy should, by definition, not be something we look for in representations in any medium: a representation is a step removed from that which it represents. As Jen Webb writes, representation is an epistemological process: "it is productive of what we know, and how we know it: that is to say, it is constitutive — it makes us" (2009, 5). In sum, representation is mediation between our conscious selves and the world around us.

Music can be understood as a representation of action: it conveys information about how an action might have been performed, mediated by the various tools of musical creation. Listeners extract information from music to govern a variety of aesthetic and gestural responses. With repeated exposure these actions become laden with meaning and accrue into concepts, tropes, or symbols (tonality being one such symbolic system). By representing music as action, our body and its physical capacities acts as a fundamental mediator of musical sound.[13] I see an analogy between the materials of music and visual art: timbre, gesture, and acoustic space are like color, line, and depth of field. Those basic elements can congeal into something that we represent as a tree, or they can remain abstract, or they can straddle various experiential thresholds between abstraction and verisimilitude. Style and medium necessarily impact our representational experience in art: Titian's trees are not like Wolf Kahn's but in both cases the majority of observers assign them the category of "tree" and then make subjective judgments as to the character of the tree based on their color, shape, and other medium-specific attributes. In abstract painting, we have shapes (lines, squares) that a viewer struggles to place in categories about real-world objects or scenes (taking a square to be a theoretic concept abstracted from aspects of the real, physical world). And in some art (such as Duchamp's *Nude Descending a Staircase*) we begin to straddle the line between objects whose conceptual roots are clear (as in Titian's trees) and objects that are abstract (Mondrian's lines, Rothko's rectangles.) Synthesis, as in the "instrumental synthesis" of Grisey's composition *Partiels* (1975) analyzed in chapter 2, exists in limbo between the suggestion of a concrete category (in the Grisey example, a trombone sound, or a dominant 7th or 9th chord) and an "abstract" one (a strange and novel composite timbre, an unfamiliar chord, an impossible composite gesture). Murail's flute in the

[13] Authors who have made similar arguments include Leman (2007, 2016) and Godøy (2003).

opening of *Ethers* uses novel playing techniques (gesture—in this case, singing and playing) to occlude the traditional timbre of the flute such that it occupies a greater frequency space due to the combination tones.

Are these moments of abstraction—moments when we know we're listening to a computer algorithm generate music, or are unable to hear human presence in music, or struggle to bring a particular concept or skillful knowledge to bear on a percept—necessarily *inhuman*? Disembodied? The embodied framework that I have pointed to so far leads me to answer "no." This has been the subject of work by Peters (2012b), who writes, "What we hear becomes *expressive presence* only via our bodily experience in listening…Electronic music becomes an interrogation of human presence or absence by the very difficulty that composing this presence in fact entails." (18-19). A listener imbues sounds with agency and with intentionality through mimetic comprehension of the sound.

Listeners might wish to escape the mimetic foundations of human experience that Tomlinson and Cox outline; for example, Roger Scruton has expressed a Romantic view of musical experience, writing that "music is heard as though breathed into the ear of the listener from another and higher sphere…Music fulfills itself as an art by reaching into this realm of pure abstraction and reconstituting there the movements of the human soul" (Scruton 1998 489, quoted in Bicknell 2002). In other words, music ought to transcend its fleshy provenance in order to reach a higher plane of experience: we escape *res extensa* for *res cogitans*, to invoke Descartes again. And what better way to enact this experience than to use a computer and do away with the fleshy sound-makers altogether? But such an account is problematic for a variety of reasons: it risks obscuring the human and material and social relationships that gave rise to music and continue to be a critical part of its meaning; and it obscures aspects of embodied

cognition which increasingly appear essential and inescapable to our experience of music. I would suggest that such "transcendental" listening is in fact learned, and culturally specific. Building on Peters' idea of interrogating bodily presence in electronic music, I claim that digital technologies may in fact render the plastic and embodied nature of perception *more* obvious or apparent because of their virtual nature, and that this is part of their aesthetic appeal. Or, as Joanna Demers has written, "All electronic music is a meditation on the act of listening to sounds both old and new" (2010, 22).

Finally, I want to consider what it means for the preceding description of music as an active, gestural, and embodied practice to be treated as normative or totalizing. We might think about how certain musical practices have deviated from these norms, or augmented them, or subverted them, or hacked them; and how these practices might come to be normative themselves within the bounds of a particular culture. At what point is this account erasing the real dimension that social constructions of race, gender, sexual orientation, disability, and class have in music perception and creation? Innumerable authors have critiqued the study of cognition for applying a veneer of universalism that in fact simply covers the centering of a particular kind of (usually white and male and Western) experience. Becker (2008) cites one critic, Elizabeth Tolbert, who writes: "Can one determine anything about musical meaning by reducing musical experience to an explanation of perceptual and cognitive processes? From the point of view of most ethnomusicologists, the nature of musical meaning is considered to be inapproachable by empirical studies, especially in light of ethnomusicological work that demonstrates the close relationship of musical meaning to its cultural and historical contexts" (Tolbert 1992, 7 quoted in Becker 2008, 3). But, as Becker eloquently discusses, culture has a material impact on the mind—consider the study by Margulis (2009) discussed earlier,

about the plastic nature of the brain and the way that training impacts perception. "What neuroscience can do is help understand some of the underlying mechanisms of the central nervous system that contribute to, or that make possible…the transcendental pleasure we may experience when entranced by music" (Becker 2008, 10). Becker's account reframes cognition away from its Chomskian roots as a theory of information reception and toward a murkier study of human-environment interaction. The concept of embodiment—that the mind and the body are inseparable—is at the center of this effort. Its explanatory value is not toward a universal theory of mind or of information, but rather in bolstering a holistic and relational picture of a human subject embedded within a specific ecological, physical, and cultural milieu.

And so it is not that the embodied cognition work just discussed is a normative account of music, but rather that it is usefully underdetermined. I want to take great pains to avoid conflating embodiment and aesthetic value, or to merely invert the maligned Cartesian dualism that placed the mind on a pedestal with one that grants the body supremacy. Returning to Georgina Born's account of musical modernism in and around IRCAM, she contrasts the "cerebral, complex" nature of modernism with the "physical, performative, simple" world of postmodernism (Born 1995, 63). Modernism's abstraction from the body (which Born accepts as a given, but which I question) is in contrast to the more embodied postmodern music, and the latter is aesthetically more desirable than the former. What such an account lacks is a relational or positional stance. One virtue of embodied cognition is that it provides ample room for scholars to ask: "For whom?" Which communities regard a particular music as complex, and why might they think that? For example, Heidemann (2016) proposes a system for describing vocal timbre that is rooted in embodied cognition and that places listener subjectivity and singer

identity at the forefront of analysis: what does it feel like when I imagine singing like the performer I'm hearing?

A second virtue of embodied cognition, one that is especially relevant to music theory, is that it draws attention to the plastic nature of the mind and to the capacity for cultivating unusual or peak experiences. One of the functions of music analysis is to direct attention: imparting concepts to apply to percepts, asking questions that prompt new angles on familiar aural experiences, and so on. Where much work in music cognition attends to the quotidian experiences that non-professional musicians have with music, the merging of music theory and embodied cognition allows for the consideration of heightened musical experiences that may be fleeting or ephemeral rather than durable aspects of everyday experience.

3.4. The problem of timbre and Chion's three modes of listening

Musical traits like gesture, material, and space are transmitted to listeners principally through timbre, and so an account of how composers construct and manipulate perceptions of those three features must necessarily also be an account of timbral manipulation. Western popular and art music in the latter part of the twentieth century has been preoccupied with explorations of musical timbre, and the music of the French spectral school has in particular been focused on timbre. But defining timbre is problematic. The *Encyclopedia of Perception* begins its entry on timbre by defining timbre by what it is not: "Timbre is that characteristic of sound that distinguishes between the perception of two sounds with identical loudness, duration, and pitch" (Terasawa 2010). Leonard Meyer considered timbre a secondary parameter in music: timbre "cannot be segmented into perceptually proportional relationships" like pitch and rhythm, so it is "the presence of syntactic constraints that distinguishes primary from secondary

parameters" (1989, 14). There is some irony here, in that perceptually speaking timbre is foundational in a way that pitch isn't: humans are very good at hearing differences in timbre and our perception of timbre is more refined than our perception of discrete pitches.[14] And, as Fales (2002) observes, Meyer's view evinces a kind of timbral deafness, "a perceptual proclivity on the part of western listeners, including ethnomusicologists, to focus on melody in music where the dominant parameter is timbre" (56). Still, Meyer is correct that timbre does not parse into discrete categories with any ease and thus taxonomies of sounding timbres are difficult.

Timbre is multidimensional; it is a complex combination of individual elements. Timbre, space, and material are inextricably linked — hearing timbre is hearing a sound source and locating it in an space, even if that sound source is imagined or misapplied. This source/sound discrepancy can occur in the absence of visual information; or it can occur when our eyes and ears seem to disagree, as when a pianist plays a prepared piano or an oboist performs multiphonics. Timbre can be described in terms of the material one perceives as being at its sound source: this could take the form of an instrumental description — saying that violin harmonics sound flute-like, for instance, though this claim also assumes a familiarity with normative sounds produced on both of those instruments (of hearing the flute *through* the physical structure of the violin). Timbre is also described in terms of raw materials (like wooden or metallic) or of vocal qualities (nasal, hoarse, pinched) or in emotional terms (lovely, irritating); furthermore, timbre and space are connected, as when a reverberant timbre suggests a large space.

Analysts have struggled to account for timbre by virtue of its multidimensional nature. There are interesting methodological divisions which relate to older debates about acoustics and

[14] See Moore, Glasberg, and Proctor 1992 and Pitt 1994.

psychoacoustics: whether to measure timbre in terms of its physical properties or its perceived attributes, and what the relationships between the two can fairly be said to be. Sethares (2004) asserts that "physical attributes of a signal such as frequency and amplitude must be kept distinct from perceptual correlates such as pitch and loudness" (12). All physical objects resonate with characteristic frequencies which diverge in both frequency and amplitude from the harmonic series (in which overtones are integer multiples of a fundamental frequency). These divergences are the physical, acoustical features that contribute to the characteristic sound of those objects. Western musical instruments have been designed with a particular set of scales and intervals in mind and have emphasized timbres which hew relatively closely to the overtone series and thus render intervallic relationships between fundamental frequencies more clearly (Sethares 2005, 3).

But as Fales (2004) observes, there can be significant discrepancies between physical characteristics of a sound and the features a listener perceives. The human auditory system "perceives sources according to its own expectations, sources that are consistent with similar sources identified in the past, or that have characteristics typical to an environment, though digital analysis might show them to be completely anomalous by any measurable standard" (58). The explanatory value of physical measurements of sound must be tempered in light of these perceptual features. Lay listeners, Fales explains, can "more easily describe the production of the sound than the perceived features of the sound that allow them knowledge of its production" (59). Gaver (1993a and 1993b) cites an array of evidence showing that listeners are skilled at hearing the material of a struck bar and the hardness of the mallet used to strike it, or hearing the shape of hands as they clap: this is information conveyed by the sound's timbre. Adaptive advantages of our refined ear for timbre are easy to imagine: for instance, judging the

size and location of potential predators — ideally before they become visible. Our timbral sensitivity is also part of our capacity to distinguish different speakers, and to separate speech sounds in a crowded room.

Wallmark (2014) offers a definition of timbre that is rooted in embodied experience: "Timbre is the sonic result of material engagement, imbued with the audible traces of bodies in motion" (8). Like Cox (2016) and Heidemann (2016), Wallmark roots his argument in theories of mimetic engagement, especially concerning the voice. He argues that we relate noisy timbres to the human voice and specifically to the imagined feeling of exerting with our voice: of clenching our throat, tensing our muscles, expending energy. I would add that timbral understanding can't only be rooted in our capacities of (vocal) exertion, but needs to implicate space and material as well. If I scream and it's heard by someone else at great distance, this gives information to them about my scream—for I must have put a lot of exertion into it for it to be heard—but also about the sounding space. If I hear the sound of a rock thrown against the ground, I learn about its size and infer information about the size and strength of whatever threw it. This is important because these physical phenomena rooted in human exertion in a physical world are, in a sense, "hacked" by acousmatic music and by the imagery that listeners can conjure in an acousmatic listening context.

The invocation of imagery in acousmatic listening is not uncontroversial, and points to enduring aesthetic questions in the creation of acousmatic music. Chion (1994) outlines three modes of hearing, indebted to the writings of Pierre Schaeffer: causal, semantic, and reduced.[15] Semantic listening refers to the way we listen to speech for semantic meaning. Patel (2007) offers

[15] Schaeffer's four modes of listening—*écouter* (intentional listening), *ouïr* (physiological perception of sound), *entendre* (attention to spectromorphological features of sound, the heart of Schaeffer's notion of reduced listening) and *comprendre* (engaging with sound's external or semiotic referentiality)—are the subject of several extensive critical treatments, especially Demers (2010) and Kane (2015).

a range of evidence for this mode of listening. One study presented speech-like sounds made of sine waves to listeners before and after priming them to hear the sounds as speech.[16] Participants first reported hearing the sine waves as amorphous nonsense but after being primed to hear them as speech experienced a radical shift in perception of the stimulus. Causal listening refers explicitly to much of what this chapter has discussed: listening to a sound to determine its location, material, and so on. While walking down the street, I might hear a scream and turn my head to see if it's a person in distress. In music, causal listening might include picking out different instruments of the orchestra, or waiting for the entrance of a singer.

Chion (2011) critiques the very concept of timbre for being rooted in causation, which electronic music has complicated. "With the fixing of sounds by recording, their manipulation, sampling, synthesis," Chion writes, "this initial causation and the role that it plays in the determination of sound have completely changed in nature" (240). Chion argues that his third mode of listening, Schaeffer's reduced listening, is in part a response to the changes technology has wrought on causal listening. Reduced listening, Chion writes, is a "mode of listening that deliberately and artificially abstracts from causes — and I would add from effects — and from meaning in order to attend to sound considered for itself and not only with regard to its sensible aspects of pitch and rhythm also of grain, matter, shape, mass, and volume" (2016, 267). For Schaeffer, reduced listening stems directly from the capacity to record and replay sound. The sounds of the wheels of a train, like the ones used in Schaeffer's early *musique concrète* composition *Etude aux chemins de fer* (1948), become rhythmic on repetition: as Kane (2015) writes, "repetition musicalizes the sound fragment by removing the dramatic and anecdotal

[16] Remez et al. 1981, quoted in Patel (2007, 76)

traces of its original causal content" (16).[17] Chion's definition of reduced listening is broad enough to apply to all sounds: it is a positional stance adopted by a listener as much as it is a fact of technological reproduction. But it's also a compositional attitude, and an orientation that composers can seek to cultivate or suggest in a particular piece. It can also exist on a continuum: one of the joys of listening to Schaeffer's *Etude aux chemins de fer* is the experience of willfully aspect-shifting, of hearing a sound as a train and hearing the sound of a train *as being rhythmic*, for instance. Kane's definition of acousmatic listening calls it "a shared, intersubjective practice of attending to musical and non-musical sounds, a way of listening to the soundscape that is cultivated when the source of sounds is beyond the horizon of visibility, uncertain, underdetermined, bracketed, or willfully and imaginatively suspended" (2015, 7).

I can listen to *Ethers* in ways that accentuate or attenuate each of these modes. I could imagine making the flute's combination tone sonority with my voice. To me, this sound feels sickly, like a pneumonic groan: airy and pinched and hoarse. Because I do not play the flute I have no sense of how easy or hard it is to sing and play at the same time. Were I to try to listen to the sound stripped of its causal properties, I find that it's easier for me to hear the transition from the four pitches sounded by the flute into their doublings in the strings, like the complex flute sonority has turned to dust and risen into the airier string timbres.

Many practitioners and theorists of acousmatic and electronic music have commented on Schaeffer's four modes of listening or on Chion's extension of Schaeffer. Denis Smalley (1996) evidences some of the contradictions and omissions that emerge from Schaeffer's thinking.

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[17] Diana Deutsch's well-known speech-to-song illusion, in which the spoken sentence fragment "… sometimes behave so strangely" seems to become pitched and musical on incessant repetition is one example of this same phenomenon. Margulis (2014) says of this and similar experiments: "What's remarkable in this example is that in shifting this way, we have the sensation that we're approaching the stimulus not in a slightly different manner, but rather as if it were a completely different stimulus altogether—as if speech had magically been transformed into music" (18).

Smalley discusses Schaeffer's third mode of hearing, *entendre,* which deals with spectromorphological features of sound like brightness, loudness, and so forth. (Schaeffer describes it as "I hear, as a function of what interests me, from what I already know and what I seek to understand" (quoted in Demers 2010, 27).) Smalley writes that this mode "is a selective process where some sounds are preferred at the expense of others. These preferences are based on certain spectromorphological criteria which appear to the listener to be more attractive, interesting or significant than others" (1996, 79). He goes on: "If we then ignore the context of events and consider only the sound, for example its dynamic shape, the intonation of acceleration, the changes in the timbre and grain of the sound, then our listening focus and attention intentionally shift to a selective perusal (and enjoyment) of attributes in mode three" (1996, 79). Smalley, echoing Schaeffer, emphasizes that we can shift between these modes or inhabit multiple modes at the same time. But I feel that Smalley leaves his invocation of listener preference and interest while practicing reduced listening under-considered. Sound comes to be objectified in this account, as if significations could be stripped away like coats of paint to reveal some objective truth beneath. What, in a world of listening that is supposedly free from extraneous causal representations or significations, would dictate listener preference? What would govern enjoyment? Schaeffer's description of *entendre* as coming "from what I already know" seems suggestive of both the problem and the solution: even when stripped of residual significations listeners are left with some degree of causality inherent in a timbral signal because timbre is itself an information-bearing percept. Even artificial, chimerical, or otherwise impossible synthesized timbres are captive to the bounds of embodied human perception. Godøy (2006) links Schaeffer's notions of reduced listening to underlying perceptual schemata relating to gesture, and suggests that even in reduced listening Schaeffer does not intend for the

schemata to be ignored (2006, 152). Godøy terms the interrelation of gesture and sound a "gestural-sonorous object" and argues that "there is a gesture component embedded in Schaeffer's conceptual apparatus which is on a more general and basic level than that of everyday causal listening, i.e. not on a level that the principle of reduced listening is supposed to lead us away from" (2006, 154). Godøy writes:

> The gestural categories have a certain degree of abstraction in the sense that they are transferable from one setting to another, both with regard to effectors (i.e. hand, fist, finger) and instrument (drum, string, metal sheet, computer), hence in fact be what we could call reduced gestures'…or in more general terms become image schemata (Johnson 1987) which we use in our perception of known as well as unknown, previously heard as well as unheard (155).

Though the cause may not be precisely known, is the implication that a listener would imagine a gesture in the abstract without subbing in these effectors and instruments? Can someone imagine a fist traveling through the air toward a drum, and then remove the fist and the drum from their mental image? I return to Cox's account of cross-modal mimetic motor imagery: absent the mental imagery (or perhaps more broadly the sense) of a fist hitting a drum, listeners appeal to other modalities to make sense of what they hear. This could be with their voice, or by making recourse to knowledge of another instrument. This raises a different problem: could an electronic apparatus itself come to be instrumental? Is there a "feeling" associated with truncating the attack off of a waveform in ProTools, which someone skilled in that activity may come to associate with attack-less sounds? I would suggest that, for this hypothetical listener, the sound would be perceived on multiple levels: knowledge of its mode of production would work in tandem with that listener's personal embodied sense of somatic effort and exertion (vocal, muscular, gestural, etc.).

3.5 Chapter summation

Listening entails mimetic consideration of sound causality, and this consideration can be overt or covert. In acousmatic musical contexts, listeners toggle constantly between different modes of listening. These include first person (I am performing) and second person (you are performing) subject positions; and they also include Schaeffer and Chion's modes of listening: semantic, causal, and reduced. Timbral features of music index sound causality (material, gesture, acoustic space). Reduced listening can never fully overcome the fingerprints of bodily causality because our bodily knowledge is brought to bear even on seemingly abstract traits of a sound like "brightness."

In the next chapter, I will suggest that the tools of the recording studio participate in listeners' mimetic experience of musical sound and can even augment that experience. Technologies of sound synthesis entail constructing new timbres, and this can result in chimeric or impossible timbres. The mimetic and imaginative capacities considered in this chapter are the necessary foundation on which extraordinary extensions of feeling can be produced.

Chapter 4: Constructing Sonic Worlds

4.1 Introduction

Iverson (2015) analyzes Björk's song "There's more to life than this," discussing the sound world that the song both represents and creates: the sounds of people talking in a club and glasses clinking together stand as diegetic sounds and represent an aural image of the club space: of walking through a club, hearing Björk sing, hearing dance beats and synth bass lines ebb and recede based on the impression of moving closer to or farther from a loudspeaker. There is an intermingling of subject positions, with Björk at times seeming as if she is addressing us as the listener and leading us through the space, while other times she becomes the lead singer, seemingly standing on stage performing. Iverson concludes: "What is remarkable about the track is the way it creates the impression of space. Listeners are immediately invited into an environment, and not just a musical one" (156). This invitation into a space implies a listening body, Iverson says, one with experience deciphering sounds in a space — a causal approach to listening that recalls the ecological psychology research described in the previous chapter.

Listening to music live immerses us in a particular environment: for example, of the concert hall, seated with a stage in front of us populated by performers. The technology of the recording studio is no different in its creation of an immersive environment, but it is not bound by the same physical laws. The sound of a violin could rush from the back of the soundscape to the front; a voice could sing quietly but sound louder than a fortissimo drum beat. These effects are illusions insofar as they trick listeners into hearing and believing an arrangement of real objects and real performers that would nevertheless be impossible in physical reality. They are also augmentations or enhancements: a multi-tracked guitar (that is, overlaying multiple

recordings of a single guitar passage) can create a thicker, richer sound: its source is still recognizably a guitar, but it is an idealized and fictional composite of multiple guitars, amps, microphones, and processing techniques.[1] And lastly, these effects entail empathy: both in the first-person mimetic sense of what it would be like for me to perform a heard action in a heard space, and in the second-person imagined exertions of an imagined performer and imagined instruments.

Using the recording studio to create a sense of real space and movement, as in Björk's song, is today fairly common. But this was not always so, and while there are a wide range of attitudes toward the studio (such as "minimalist" approaches that appeal to ideas of fidelity and verisimilitude that, I would argue, are just as constructed as any other approach to sound recording[2]), the development of attitudes of recording rooted in illusions, augmentations, and other surreal auditory phenomena is worth examining. I am particularly interested in how the technological workings of digital synthesis suggested these kinds of illusions to composers. Digital sound production is uncoupled from the physical actions that produced it (even if interfaces strive to recreate this coupling, as with a MIDI keyboard). With a traditional acoustic instrumental performance technique like a bow being dragged across a string, the sound correlates closely with the action that produced it. Identifying sound causes holds true for many non-traditional instrumental techniques as well, like knocking on the body of a violin. But the relationship between actions and sounding results in digital synthesis can range from tenuous (i.e., lightly depressing a key on a Moog synth could yield a massive and thick-sounding square

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[1] Such enhancements are not restricted to the recording studio. The use of three strings per pitch in the middle register of the grand piano is a similar effect as multitracking a guitar: the timbre of the instrument becomes thicker and mellower, not to mention louder.

[2] Sterne (2003) provides an excellent history of ideas of verisimilitude in recording, especially chapter 5.

wave) to unrecognizable (i.e., pressing a computer space bar to commence an algorithm that sends off frantic-sounding bleeps and bloops, or triggering complex instrumental samples with the push of one button). The sounds themselves can also vary widely in terms of timbral content, presenting conceptual problems for composers finding it necessary to rein in the possible options.

Studying particular moments in the history of the development of electronic sound synthesis may yield insights into the conceptual touchstones composers and engineers used to organize their work. These insights, in turn, might bear out on the works they produced, which can be treated as contemporary accounts of the perceptual experimentations of its creators. I will focus on the writings of two composers, Hugues Dufourt and Jean-Claude Risset, before turning to some of the music of Kaija Saariaho. Dufourt and Risset both felt that digital synthesis software and studio manipulations could create surreal listening environments. Furthermore, they expressed perceptual concerns about existing methods of synthesis: that the prophesied world of unlimited sound was in fact not coming to fruition. Risset felt that analog synthesis techniques yielded relatively flat sounds and did a poor job of imitating real instruments. In trying to "solve" the problem of synthetic sounds, Risset turned (as with many other composers) to psychoacoustic concerns. But where Murail and Grisey's writings about psychoacoustics tended to focus on parametric aspects of sound like harmonic and inharmonic partials, Risset made explicit appeals to ecological psychology and to the ways in which embodied and embedded perceptual tendencies guide listeners when confronted with new and strange sound worlds.

Dufourt is a founding member of the spectral school of composition and was a founding member of the French new music ensemble *l'Itineraire*, alongside Tristan Murail, Gérard Grisey,

Michaël Lévinas, and Roger Tessier. Risset is not generally considered a spectral composer, though conceptually he is very closely aligned to them. *l'Itineraire* performed works by Risset, including premiering his 1981 electroacoustic work *Aventure de lignes*. Risset wrote of the ensemble: "*l'Itineraire* was the first group that took into account the 'electric revolution,' as Hugues Dufourt calls it, and that wanted to implant it in the mainstream of instrumental music, and to avoid having electroacoustics remain a separate branch" (2014, 37).[3] Saariaho began working at IRCAM in 1982 and is generally considered part of the second wave of French spectral music, following the composers affiliated with *l'Itineraire*. Her music adeptly intermingles acoustic and electronic elements and, like *l'Itineraire*, she aimed for the creation of a unified sound world rather than leaving electronics as a distinct element.

Risset and Dufourt outline aesthetic prerogatives in spectral music that were generally not discussed by Murail and Grisey and so, given the outsize influence of those two composers in anglophone discussions of spectral music, are not generally part of the narrative about spectral music. This is not to suggest that the prerogatives Dufourt and Risset discuss are not present in their works, or that I am "reading against" the writings of these figures. I am less trying to offer a counter-narrative than I am trying to show that a set of conceptual orientations surrounding acousmatic music—about referentiality, causation, and abstraction, all of which I conceive as both compositional and listening strategies—also apply to electroacoustic music in general and the work of some spectral composers in particular. And these discourses can be in service of analytic strategies: of explaining certain compositional choices, and of giving listeners deeper and broader pathways through a work.

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[3] l'Itineraire apparaît comme le premier groupe qui ait pris en compte la "révolution électrique," comme la'ppelle Hugues Dufourt, et qui ait voulu l'implanter dans le grand courant de la musique instrumentale, en évitant que l'électroacoustique ne reste une branche séparée.

4.2 Hearing and constructing virtual worlds

Risset wrote at length about the potential for technologies of sound synthesis to build illusory, virtual sound objects and sound worlds. He points to several early examples, such as John Chowning's work producing the illusion of fast-moving sound sources from stationary loudspeakers, and Risset's own work with Shepard on the Shepard-Risset glissando, an MC Escher-esque illusion in which a tone seems to rise indefinitely without ever moving, like a barbershop pole (Risset 2014, 42). Risset's long career in the world of computer audio and synthesis began in part with some frustration about the state of early synthetic sounds. "Electronic music [prior to 1967] had failed to imitate musical instruments, and it was not as simple as one thought to achieve acceptable imitations with the computer" (2014, 42). The reason for this has to do with different methods of synthesizing sounds. Early digital synthesis algorithms tended to be subtractive (Keislar 2009, 20). Subtractive synthesis starts with a complex wave form and filters out certain frequencies. Additive synthesis, by contrast, constructs complex spectra by stacking individual sine waves of varying amplitudes, which gives a more realistic sound but is much more processor-intensive and so was unpopular during the early days of computer music. In 1973 Chowning discovered frequency modulation (FM) synthesis, in which a small number of wave oscillators are modulated to yield complex aggregate sounds (Keislar 2009). FM was processor-efficient and produced more musically satisfying (if still relatively static) tones; it is perhaps best associated with the Yamaha DX7 synthesizer.[4]

Risset describes an aesthetic problem with additive, subtractive, and FM synthesis: "the ear is good at detecting the origins of sounds generated in a mechanical world, but it is far from

[4] Lavengood (2017) presents an in-depth discussion of the DX7 as it relates to the analysis of timbre.

being as discriminative with most synthetic sounds. Hence it is of interest to generate sounds by modeling physical vibrations, since such sounds are well differentiated by the ear" (Risset 2004 43). This can be as simple as studying (for instance, via spectrograms) real world sounds and carving out waveforms that resemble them, and Risset has worked with these methods. There can still be problems: for instance, the waveform of a trumpet playing softly and loudly will need to be quite different in order to reflect the timbral changes of that instrument at different amplitudes. But Risset is also making reference to another synthesis algorithm: physical modeling synthesis. Physical modeling represents a major conceptual shift in sound synthesis, with far-reaching implications for the idea of music as constructing a virtual (that is, non-physical) world. Physical models stipulate and modulate parameters related to real objects and modes of playing: plucked strings, bowed strings, struck objects, etc. Where subtractive and additive synthesis focus on sculpting the waveform itself, physical modeling establishes a set of rules and parameters for sound impulses rather than attending to the resulting waveforms. "Such modeling," Risset writes, "can replace not the subject, but the surrounding world, as observed by the subject through the windows of the various senses" (2004, 202).

Risset was a keen reader of the ecological psychologist James J. Gibson, whose work informed Risset's own thoughts about how to use digital technology to construct sound. "Attempting in 1972 to compile a general article on musical acoustics, I came across an article by psychologist James Gibson that criticized the excessive recourse made to perceptual parameters such as height and intensity," Risset writes. "Are these parameters really attributes of perception? Or simply the sensible counterpart of the physical parameters - frequency, amplitude - which are obvious in the representation of acoustic waves? According to Gibson, the study of these parameters is not significant: it would be more interesting to study how

hearing distinguishes events in the real world" (2004, 116).[5] Risset turned to ecological psychology as a way around an aesthetic problem presented by the methods of digital synthesis: the tools available to him generated sounds that his ear found (intuitively, he might say) lacking, or bland. Familiar means of producing sound were absent from the sound source, but Risset's ear longed for them still. "Gibson points out that large families of musical instruments correspond to distinct mechanical actions — hitting, scrubbing, blowing — that the ear spots very well," Risset writes (121). The means of generating a sound retain their meaning in audition, and thus provided one category for Risset to consider. This perspective was for Risset not just ecological but necessarily embodied; he quotes Bergson: "to recognize a common object is to know how to use it" (123).[6] It also implies, in its reference to hitting scrubbing and blowing actions, musical mental imagery (not just mimetic motor imagery, of the kind described in chapter 2): the way that the mind conjures images to accompany or fill in for perceptual gaps. It is this faculty for mental imagery that leads to the surreal experiences conjured by certain synthesis tools. And, as Cox (2016) argues, "musical imagery is partly motor imagery" (41): if musical imagery is imagined music, and music is (at least originally) the result of sounding actions, our capacity for musical imagery relies on a capacity for motor imagery.

Risset wants to be able to make sounds that the ear can easily parse: to have tools in his composition toolkit that can build naturalistic sounds. At the same time, he is focusing on modes of production more than particular instruments: his aim is not to build the sound of a

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[5] Tentant en 1972 de compiler un article général sur l'acoustique musicale, je rencontrai un article du psychologue James Gibson qui critiquait le recours abusif à des paramètres perceptifs tels que hauteur et intensité. Ces paramètres sont-ils vraiment des attributs de la perception? Ou simplement la contrepartie sensible des paramètres physiques -- fréquence, amplitude -- qui sautent aux yeux dans la représentation des ondes acoustiques? Selon Gibson, l'étude de ces paramètres n'est guère significative: il serait plus intéressant d'étudier comment l'audition distingue les événements du monde réel.

[6] Reconnaître un object usuel consiste surtout à savoir s'en servir.

clarinet so much as to build a sound that suggests blowing into a tube. I see this as an important distinction, simultaneously a desire to offer the listener familiar footholds while harkening to a modernist impulse (described in chapter 2) to push expressive resources precisely by stripping away accrued meanings — which certainly included familiar musical instruments. In this way Risset's consideration of source/cause mechanisms in synthesis is of a piece with the spectralist interest in preserving consonance and dissonance while redefining them in terms of acoustic features rather than tonal function.

In his 2010 essay "The Principles of Music and the Rationalization of Theory" Dufourt makes a useful analogy: "Just as chemistry became a science of non-existent bodies, as Auguste Laurent said in 1854, electroacoustics has now become a science and a technique of non-existent sounds" (28). In *La Musique Sur Ordinateur* he initially sets out to discuss how computer music has refigured the relationship between music and the sciences: "The creation of music on the computer," he writes, "provides a field of proofs for the theoretical advances in artificial intelligence, particularly in relation to the representation of knowledge or relationships, the modeling of human reasoning, or the determination of behavioral strategies" (2014, 256).[7]

Dufourt's invocation of science is not of the sort associated with Milton Babbitt, who felt that art music ought to aspire to the same set of discursive and methodological tools as empirical science and ought to be conferred cultural prestige and institutional support as a result.[8] Dufourt, rather, seems interested in the ways in which music and science are different modes of experimental inquiry into human experience. I mean experimental in the sense

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[7] La création musicale sur ordinateur fournit un champ d'épreuves aux avancées théoriques de l'intelligence artificielle, notamment en ce qui concerne la représentation des connaissances ou des relations, la modélisation du raisonnement human ou la détermination des stratégies de comportement.

[8] For discussion see Brody (1993).

associated with John Cage and discussed in Piekut (2011): of the testing of a hypothesis the outcome of which is unknown. This is also a context in which the tools of science—the tools of the laboratory—have an epistemic function, of the sort considered in studies by Latour and Woolgar (1979) and Steege (2003). Though there are significant differences between the high-art modernism of spectralism in the '70s and '80s and the (mostly American) experimental contexts Piekut considers, some kindred lines of thought remain. "Like any avant-garde," Piekut writes, "experimentalism performs not simply a return to daily life but an intensification of it…It is the everyday world around us, as well as the possibility that this world might be otherwise" (2). Attention to the quotidian can look like Cage's attention to silence, but it can also be a renewed focus on material, on the mechanisms of gesture, and on the residue that these leave on the sounds listeners parse.

In another essay, "Computer music: A semantics without a subject?" (*La musique sur ordinateur: un sémantique sans sujet?* Dufourt 2014), Dufourt's opening considerations of experiment and experience lead him to consider questions of aesthetics in computer music, which in turn lead him to questions of perception. He writes: "The implicit aesthetics of computer music is part of this intellectual tradition for which perception is a particular form of knowing [intellection]. In this perspective, aesthetic appreciation and aesthetic emotion are possible only because the intellect and perception obey the same basic rules" (2014, 259).[9] Especially in light of the claims Dufourt goes on to endorse, I read this passage as pushing against the typical separation of perception from cognition: perception is a *form* of cognition, not prior to it or subservient to it. And the basic rules that cognition and perception obey Dufourt

[9] "L'esthétique implicite de la musique sur ordinateur s'inscrit dans cette tradition intellectualiste pour laquelle la perception est une forme particulière d'intellection. Dans cette perspective, l'appréciation esthétique, l'émotion esthétique ne sont possibles que parce que l'intellect et la perception obéissent aux mêmes règles fondamentales."

explains in his next sentence: "According to the psychologist of perception James J. Gibson, the sensory equipment is perfectly adapted to the information available to each individual under natural conditions. The neural mechanisms are adequate for understanding and representing events in a three-dimensional world." The rules obeyed are rooted in the relationship between an organism and its environment, and that statement requires some further background on Gibson's work.

Heft (2013) traces a set of conflicting intellectual heritages on the field of psychology. One school of research in psychology can be said to be focused on the individual (and, implicitly, an enlightenment, humanistic sense of the individual), bracketing off the unitary self from its environment. Gibson, Heft argues, saw his ecological approach to perception as a response to and a refutation of this traditional cognitivist view of perception, in which aspects of our environment are represented in the Cartesian theater of the mind via our senses. Rather than considering the bounded individual, Gibson takes the individuals' relationship to the world as his subject of inquiry. His approach has strong intellectual precedents in the work of William James and other pragmatist thinkers. Gibson drew a distinction between a physicalist understanding of the world as it exists independent of a perceiver, and what he called the *econiche,* which is specified in relation to an animal. What animals perceive in their econiche are not objects but affordances, which are relational features between an organism and an environment. A chair affords sitting for a human, perching for a bird; a doorknob affords grasping and twisting for a human hand, but it may be essentially invisible to a dog; those action potentials are the true object of perception, and they have a gestural, embodied, and corporeal essence. Gibson writes, "An affordance…is equally a fact of the environment and a

fact of behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and the observer" (quoted in Heft 2013, 164).

Gibson's work was principally focused on visual affordances, but they can be communicated aurally, too: size and sound are communicated aurally, as when an organism determines that a sound they heard is threatening—consider the call of a hawk, which means something very different for a mouse as it does for a birdwatcher. Music, as a special class of sounds, has been said to have its own affordances: these include movement (Windsor and de Bezenac 2012 and Kozak 2015), affect regulation (DeNora 2000), and affective synchrony (Krueger 2014). Kozak invokes the work of Merleau-Ponty to extend the idea that music affords movement toward an account of imagined movements, because listeners possess a motor-intentional stance toward musical sounds. "Not only does each listener constitute 'objects' of experience anew, but these very objects show up as Gestalts with different kinds of depth, depending on the bodily capabilities of the gesturer" (2015, 3.15). Crucially for music analysis, Kozak argues that listener's motor-intentionality "turns sounds into musical objects, rather than those objects being given in advance" (3.16). In chapter 3 I considered how composers working with tools of electronic music are closer in subject position to a listener than to a performer even if they're nominally performing a sound. I believe that Dufourt and Risset's discussion of Gibson and ecological perception indicates as much, and it suggests that the boundary between creator and receiver (or poiesis and esthesis), which is always porous, is even moreso in the world of electronic sound. Dufourt and Risset are deploying their own motor-intentionality and their own embodied knowledge on the sounds they're making. The drive to create more flexible digital sounds is not necessarily coming from a desire for realism but from a more basic desire

for sounds with timbral features that denote corporeal, causal, and material cues familiar from lived experience.

In an essay from 1988 Risset writes: "Is not the prospect of being able to confront our perceptual mechanisms with a simulated world with different physical laws fascinating?… Purely illusory, anchored not in the sonorous body but in the body of the listener, in the flesh of the perceptive organization, it can be more pregnant than the real world, insofar as it makes full use of our perceptual, sensitive and cerebral operations at the same time, likely to involve our most current preoccupations as well as archaic, originary mechanisms" (quoted in Dufourt 2014, 264). In music listening, be it acoustic or electronic, listeners are capable of fabricating and being immersed in a virtual environment, one in which musical sounds convey information about size, shape, material, intensity, affect, and space. The capacity for this imaginative immersion plays on evolutionary, ethological, and developmental capacities specific to an organism. In the world of digital music, these sounds and spaces can be stretched to take on impossible physical characters: a soft, quiet, violin-like sound with reverb applied so that it sounds like it's filling up a giant room; a breathy voice that resonates like a gong; the sound of bowing a 40-foot-long iron cable. Listeners are confronted with categories of sound that they cannot recognize, or that they attribute to constructed and possibly impossible causal phenomena and experience as aural illusions.

In Risset's music, such illusions are quite strong. In his 1985 tape piece "Sud," field recordings of sounds associated with the sea and with the forest intermingle with synthesized sounds that often resemble the sounds heard in the field recording.[10] To my hearing, the piece opens with bird calls, and a gradual entry of the sound of lapping waves. The waves are tinged

[10] A recording is available at https://www.youtube.com/watch?v=Fhj2O4jToKI

with the sound of digital clipping, such that the tail end of their sound takes on a brightness that sounds artificial. (Waves, interestingly, are among the best natural sources of "white noise," a characteristically digital sound with equal intensity across the auditory frequency range.) Small chirps enter around 1:00, suggesting insects in a field. The insect noises subtly morph into percussive, fast, and staccato synthesized tones beginning at 1:50. I am aware that they are synthesized but I'm also primed, by their proximity to real-world sounds, to evaluate them in terms of insects. Eventually I start to hear the sounds in terms of other objects—particularly, key clicks on a saxophone or clarinet—and experience the freneticism of the insects calming down as it becomes the rapping of fingers against keys. I am in this moment performing an aspect-shift between two ways of conceiving of the same object: in terms of gestures suggested by its sonic features and in terms of its real-world significance, or in terms of the Schaefferian *écouter* and *entendre*.

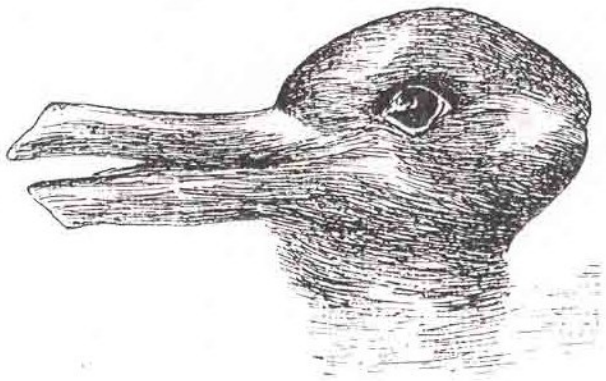

Figure 4.1: the duck-rabbit

Figure 4.2: the Rubin vase

Aspect-shifting of the kind associated with Wittgenstein's "seeing-as" has often been associated with optical illusions like the duck-rabbit (figure 1) or the Rubin vase (figure 2), in which the same image can foster two competing interpretations. This has been extended into

musical experience in recent work by Guck (2017). Guck contrasts the pairing of perception (hearing) and impression (hearing-as); perceiving-as (instead of merely perceiving) is perception "about which one is aware that one is making a choice about how one sees what one sees among possibilities" (245). Smalley (2007) observes that "when we recognize that a sound has been created by human gesture we can identify in detail the type of physical energy and touch that instigated and propagated the sound, and in acousmatic music we connect spontaneously with any vestiges of gesture we may detect, even when the sound (either the source, or the aspects of the cause) is not 'real' or does not seem entirely plausible" (39). These associations can constitute a path through a musical work; I find that clear formal boundaries in Risset's *Sud* exist between the sections that are obviously field recordings and the ones that are obviously synthetic, and that the blurring of those aural entities at times constitutes a blurring of formal boundaries.

But the duck/rabbit is a binary illusion: either you see a duck, or you see a rabbit. By contrast, listening to acousmatic music effects a perceptual continuum between poles of (relative) referentiality and abstraction. Field (2000) discusses strategies composers have used to exploit our auditory listening strategies in the reasonably controlled environment of a through-composed work. "The representation of reality is now a compositional parameter that can be found at the heart of many contemporary electroacoustic approaches, be they *acousmatic, soundscape/ecological,* or even *musique concrète"* (37, emphasis in original). Field describes a range of listening environments from "*hyper-real environments* where it is not possible for the listener to tell the difference between a recording of reality and a simulation of reality" (37) and "*virtual* (environments that appear overtly simulated in some way)" (37). Field argues that the clearer the causal source of a sound, the more likely a listener is to determine it as "real." And,

following Wishart (1986), Field outlines a continuum of aural reality: hyper-real, real, virtual, and non-real (45). "Hyper-reality" refers to music that sounds "more real than real" (45): where digital simulation is undeniably present but in service of heightening what Field calls "the gestures and signs of reality" (45). "Real" refers to an environment that has not been simulated but simply represented from recordings without interference. I would argue that this notion of the "real" occludes the constructedness of recording — from choice of microphone, to the position of the recorder in relation to the subject, to the space in which it is recorded. I suspect Field would agree, as he hastens to add that "this definition simply enables a distinction to be made between simulated virtual or hyper-real environments where the composer has changed a representation of reality and those that have not been manipulated" (46). Sounds in non-real environments "have no discernible connection with the real world" (47).

Field does not state clearly whether a category like "virtual" applies only to the referentiality of an object (for example, a synthetic gong sound) or if it applies to traits like musical gesture (for example, a note sung for longer than any human could breathe). I want to deploy the embodiment framework described in chapter 3 to describe issues of expressivity in these various degrees of "real" aural environments. Even Field's "non-real" environments can be measured by recourse to real expressive phenomena, and indeed I believe this is one source of their expressivity and meaning. A piece like Ligeti's *Artikulation* (1958), which would seem a paragon of the non-real given its plainly synthetic timbres and gestural content, nevertheless is understandable in terms of timbral roughness, gestural activity, and imaginative speculation about causation. In the opening ten seconds of *Artikulation* I find that I listen for causation by default: I hear the sound of an intake of breath, possible voices murmuring in the distance, water droplets in a large space, and reverberant footfalls. This rather literal hearing places me in

an environment (which I imagine is large, because of the reverb, and dank, because of the water droplet sounds) and has me regarding the sounds as "other" — not made by me. If I try to engage with the opening breath-inhalation noise by imagining myself make it, I find that the gesture feels tense, as though I'm poised for action. Were I to try to listen adopting a more performative, first-person stance, I might consider how I would make the raindrop and footfall sounds with my mouth, or with a percussion object: in both cases, it feels relatively relaxed compared to the tension I feel listening to the sounds as environmental noises. Were I to try and listen without regard to causality, I might think of the sounds as being relatively clean: I do not hear them as particularly complex or noisy in terms of timbre. But this attribute of cleanness reveals the problems with reduced listening discussed in chapter 3, because the observation still hinges on a relational measurement: in this case, what I hear as cleanness maps to my vocal production of similar sounds, which I would do with minimal distortion via constricting my vocal cords.

No single hearing of this opening is correct: all are plausible, all could be made intersubjectively meaningful through description, and all make recourse to my feeling moving body. Following Cox (2016), assuming that a listener has consented to engage with this music, they will deploy whatever mimetic motor imagery is available in light of their background in service of parsing the aural information they receive. And the account of timbre in Wallmark (2015) suggests that even abstract timbral elements can be related to concrete vocal phenomena: the timbral roughness and low overall pitch register of a sound being relatable to a high-exertion growl, and broadcasting similar information: of tension, or of threat. I will turn now to the opening of Saariaho's *Verblendungen* (1984), which nicely intersects with Risset + Dufourt's consideration of ecological perception, as well as Field's discussion of real and hyperreal

sounds. The piece is, like many spectral pieces, built around a slow and inexorable progression between poles: in this case, noise and pure sound.

4.3. Artificial objects in Kaija Saariaho's *Verblendungen* (1984)

Kaija Saariaho's *Verblendungen* (1984) is one of her earliest works and her first to combine a live orchestra with electronics recorded to tape. In her program note she writes that "in spite of their different, sometimes opposite materials, the orchestra and the tape should build a common, inseparable sound world." In the piece, the orchestra and the tape move in opposite directions across a pure sound <—> noise continuum. The tape starts as a noisy hissing mass and moving toward stable, readily identifiable pitched material, while the orchestra begins with clear pitches and moves toward noisier playing techniques. The piece begins with a bang — a loud, forceful orchestral tutti on a dense chord, competing (and at times drowned out by) a loud hissing tape part. The tape sounds somewhere between white noise and the escaping of steam, or perhaps the sound of brushes dragged on a snare drum; at times it also sounds like the distortion that results from analog tape clipping. There are two competing global parameters Saariaho is balancing: she envisions a pure tone—noise continuum and wants for the orchestra to traverse from tone to noise across the duration of the piece while the tape component traverses from noise to tone. The global form of the piece is broadly modeled on an image of two paintbrush strokes (figure 3), which were suggestive to Saariaho of a spectrogram, with darkness referring to amplitude and the lines of the brush bristles representing various harmonic spectra (Saariaho 1987). Like the image, her piece begins with strong dynamics and a thick texture before receding — and then it does this again to effect the second brush stroke.

Figure 4.3: Paintbrush gesture that forms the structuring formal metaphor for *Verblendungen,* from Saariaho (1987)

At the beginning of the piece the orchestra sounds a thick and dissonant chord, a sonority dominated by ic 1, often expressed as minor 2nds. Saariaho's reduction of the opening pitch progression (from Saariaho 1987) is shown in figure 4. As the reduction makes clear, the opening is characterized by relatively parsimonious voice-leading: in general, only one or two pitches move or are added/subtracted between chord onsets, and they typically do so by one or two semitones at most. The low E0 is less present in the orchestrational texture than it appears from the reduction, and the section doesn't feel as though there's a pedal tone throughout in part because of the prominence of brass in the middle register. Durations in seconds are listed above each sonority, showing the unpredictable and aperiodic nature of these chord onsets. Of interest is that Saariaho conceives of these chords as being as far on the "pure tone" continuum as possible: the orchestra is only going to get noisier from here in terms of timbre, though the

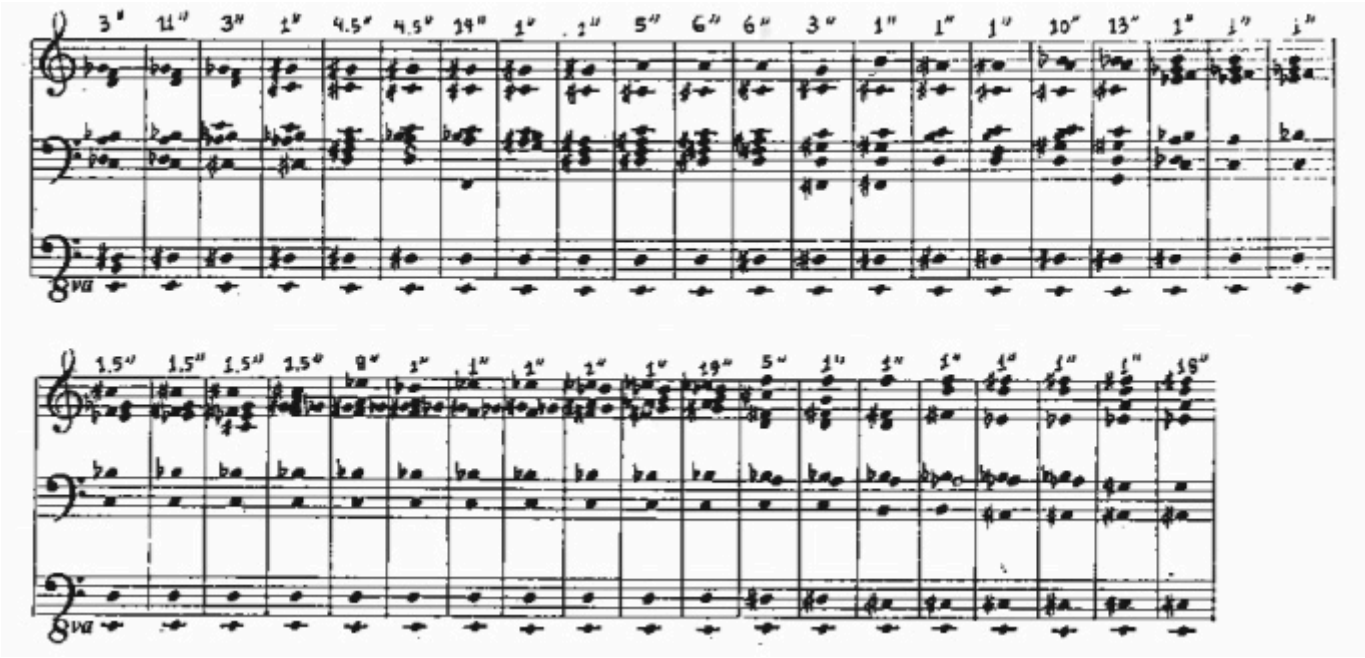

Figure 4.4: Opening pitch progression in *Verblendungen* from Saariaho (1987)

pitch content of the piece gradually thins out and becomes relatively static and consonant. Thus, noisiness of tone and harmonic dissonance are decoupled.

The tape component, startling and inescapable at the outset of the piece, begins to recede into the background after about four minutes. When it gradually reappears, it bears much closer resemblance to its source material, the two violin strokes, and is far less noisy. After seven and a half minutes, the piece begins the "second brush stroke," or second major dynamic peak, using only the tape component. The single violin sample has been transposed to effect an entire string orchestra, but it has an unearthly sheen, and the timbral world signifies (at least to this listener) the retro atmosphere of 1980s movie soundtracks. I imagine that some of the otherworldliness of the strings in this section comes from the speeding up and slowing down of her starting sample to produce different pitches.[11] This, in turn, speeds up the sound of the bow stroke (effecting the attack onset). Given the electroacoustic context, in which the predominant sound thus far has

[11] Saariaho has not to my knowledge commented in detail about her working method for creating this section of *Verblendungen,* although since I am only recounting my hearing it is not necessary that I correctly glean the manipulations used.

been acoustic string instruments, the synthetic strings at first sound "othered," or enter the so-called uncanny valley: by failing to be perfectly accurate they are rendered all the more inaccurate. But they also sound bright and glassy, and thinner; my imagined sense of both the playing method and string material is altered. Or, given their synthetic sound, I imagine the pitches performed by one person at a keyboard rather than by an ensemble of individuals. In sum, *Verblendungen* as experienced on recording complicates my sense of object/material perception, and invites me to introspect on that complication. My experience of the piece is impacted by aspects of the sound that are rooted in technological features—in the speeding up of a sample to change its pitch, and the concomitant change in timbral attack characteristics that this technique causes—but which are also rooted in my motor imagery and in my experience with various instruments. These technological and perceptual features intersect as part of my affective response to the piece.

Stepping back even further, I find that there is joy to be had in not knowing what produced a sound, because it effects my predictions of what might come next. If I've been hearing something that I thought was a violin harmonic only to learn that it's a cymbal, I have had a musical expectation subverted (which could be positively or negatively valenced) but it's possible that I've also, for a brief moment, imagined an object doing something impossible. That imaginative experience is coupled with a sense of exertion—a feeling of wondering, mimetically, how I would make the sounds I'm hearing—and when the interpretation of the sounds on which those feelings of exertion are built changes, rather than shattering my sense of immersion I am instead left feeling like I've undergone a non-real gestural transformation (if I am imagining sounds from a largely first-person perspective) or that someone or something else has undergone that transformation (if I'm imagining from a largely second-person perspective).

Saariaho was working at IRCAM during this time, though the tape component of *Verblendungen* was primarily made at the GRM. Barrière (1991) writes: "From her collaboration with (Stephen) McAdams between 1983 and 1985 emerged an innovative conception of timbre as a form-bearing musical element…Together they strove to combine psychoacoustic concepts, such as auditory image, with compositional ideas aided by computer music tools that were then becoming available" (96). In her program note for the piece, Saariaho writes: "The tape part has been worked out with GRM's digital tools for manipulating and transforming concrete sound material. The basic material for the tape consists of two violin sounds, a sforzando stroke and a pizzicato. From these two sounds I have built a quasi-string orchestra with a very wide pitch range" (Saariaho 1984). She sketched curves outlining the prominence of different parameters (figure 5), including the relative prevalence of the orchestra and the tape part, the use of polyphony, the rate of harmonic progression, and dynamics. Moisala (2009) describes Saariaho's interest in dazzling bright lights as a metaphor for the piece (the title of which can be translated as "Dazzlings"). Moisala (2009) writes: "*Verblendungen* has its roots in Saariaho's childhood experience of feeling the warmth of sunlight on her skin; "When I listen to music and when I imagine my music, there are also coloristic aspects [involved]—I am not looking for these relationships between images and sounds but they exist in me." (56).

In *Verblendungen*, as in Risset's *Sud*, I am struck not just by the electronic sounds themselves but by the way in which they intermingle with the putatively "natural" acoustic instruments (or, in *Sud,* field recordings). As the orchestra pulses and shimmers in the opening of Saariaho's piece, the pre-recorded tape gradually sounds less like a distinct instrument and instead colors the orchestral sonorities. They are orchestrated into the texture just as much as

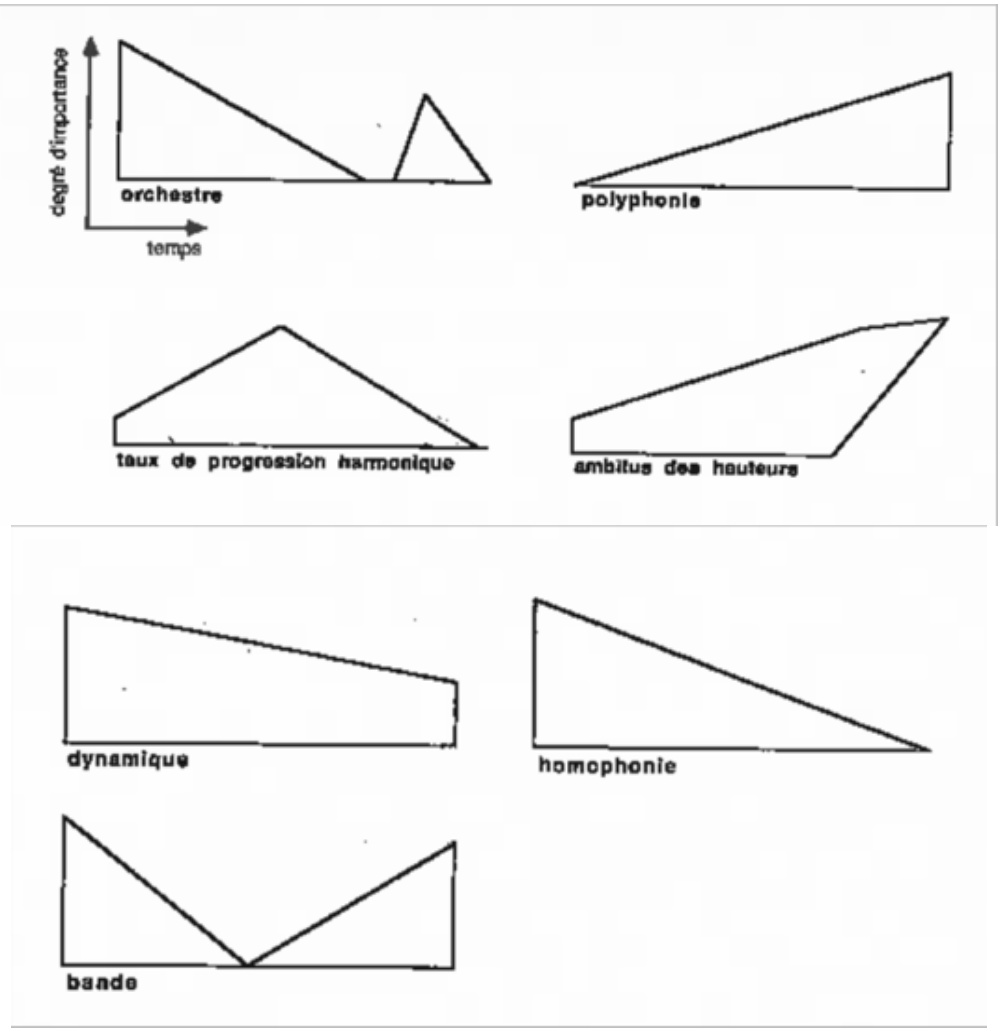

Figure 4.5: Parameter curve sketches of *Verblendungen*, from Saariaho (1987)

the brass section or the woodwind section, with an ear toward their effect on the sum total sound.

4.4. The Volition of Sounds

It is a truism for composers to observe, often with some frustration, the seemingly limitless world of sound presented by electronic music. Risset's critique of subtractive synthesis

is in part a response to this; there is a way in which the material of the sound can be ascribed volition, a path of least resistance that may be seen as working against the preferences of the human auditory system. Missives by composers on this subject are abundant; Babbitt wrote that "it is not a matter of merely simulating a specific, conventional instrumental timbre, but of endowing any electronically synthesized timbre with the same high degree of dimensionality possessed by, say, a string timbre, if only to eliminate the genuine 'steady-state' of electronic sound, and the resultant sense of 'sameness' and fatigue" (Babbitt 1964, 262, also quoted in De Souza 2018). Or consider Boulez's observations in his essay "Technology and the composer":

> Oscillators, amplifiers, and computers were not invented in order to create music…So rich in possibilities are [electronic music tools] that sometimes mental categories have yet to be created in order to use them. To musicians accustomed to a precise demarcation, to a controlled hierarchy and to the codes of a convention consolidated over the centuries, the new material has proposed a mass of unclassified solutions, and offered us every kind of structure without any perspective (1978, 60).

The new sonic "material" that electronics have provided was a salutary development as long as composers find meaningful ways to structure these sounds. For Boulez, the question of referentiality might seem at odds with his Adornian aesthetic of autonomy and an imperative toward the "progress" represented by these novel musical materials. But later in the essay he seems to write approvingly, if also warily, of the recourse to the familiar: "The quite natural temptation is to approach this new field with our tried and tested methods and to apply the grid of familiar categories to an unexplored domain" (61). Boulez continues by suggesting that in making recourse to familiar concepts as a way of structuring new sounds, the concepts are likely in turn to morph in response to the material in ways that could not be foreseen.

> The existing categories could, it is true, be helpful at first in mapping out virgin territory and enabling us, by reconstitution and synthesis, better to know the natural world which we think we know so well and which, the nearer we get to it, seems to elude the precision of our investigation. It is not only the question 'what is a sound made of?' that we have to answer, but the much harder one of 'how do we perceive this sound in

> relation to its constituent elements?' So by juxtaposing what is known with what is not known, and what is possible with what will be possible, we shall establish a geography of the sound universe. (Boulez 1978: 61-62)

Boulez' unfortunate colonial metaphors here point (among other things) to a belief that there may be finite limits (and discoverable ones) in our world of sounds. What precisely that might mean is hard to discern, and it also seems contradicted by more nuanced observations he makes later in the essay about the symbiotic relationship between sonic material and method. Boulez continues: "The reasoned extension of the material will inspire new modes of thought: between thought and material a very complex game of mirrors is set up, by which images are relayed continuously from one to the other…We might compare this with architecture, where structural limitations have been radically changed by the use of new materials such as concrete, glass, and steel" (62). The sonic material, Boulez argues, has an agency of its own, and the agency of the composer is in dialogue (if not outright tension) with material constantly. And the source of this tension, Boulez and Risset both argue, is psychoacoustics: not just perceptibility but comprehensibility. Goldman (2010) has outlined how Boulez and the spectral composers shared a number of aesthetic objectives. Their interest in psychoacoustics, and specifically as a response to the tendencies (or volition) of their electronic tools, is an important unifying point. Techniques associated with spectral music like instrumental synthesis—the imitation of additive synthesis using the rich timbral resources of acoustic instruments—are in some respects a response to the aesthetic impasse Risset observes.

Boulez' comment about new architectural materials suggests a link to Siegfried Giedion's historical account of the impact of iron and ferroconcrete on architecture in France. Giedion invokes the notion of airspace: "through the condensation of [iron] to a few points, there appears an unknown transparency, a suspended relation to other objects, a creation of the

airspace…This sensation of being enveloped by a floating airspace while walking through tall structures [like the Eiffel Tower] advanced the concept of flight before it had been realized" (1995, 102). The feeling of walking into a new architectural space enabled by the structural possibilities of iron and concrete, while commonplace today, must have elicited at the turn of the twentieth century (and may still elicit today) feelings of awe, wonder, immensity — aesthetic emotions like the ones experienced when listening to new musical sounds that connote particular experiences. In the case of Giedion, the technology (iron) is new; the design of the structure is new; and our bodily response to the environment is new. We may feel that entering a large building and entering a large cave have similar feelings of airspace, but the knowledge that one is man-made and one is natural might lead to different evaluations of the experience. We have all felt awe or wonder before, but there is a more specific feeling of awe that being in a large building can create, and this is because such a technological feat is outside the domain of everyday experience and so is outside the common domain of embodied experience, and yet can still be subsumed within our embodied perception. We can become inured to their aesthetic force with repeated exposure—or we can come to appreciate them more—but the potential for these experiences is technologically dependent.

Rehding (2016) has explored the epistemological significance of instruments for the field of music theory: how the monochord, for example, participates in and conditions knowledge of pitch ratios. De Souza (2018) has extended this argument to the synthesizer, which he argues has epistemic significance for understanding musical timbre and its relationship to materiality and performativity. "Perceptual limits," De Souza writes, "are revealed by the synthesizer's apparent limitlessness" (18). Babbitt echoes this in his essay on the RCA synthesizer: "the composer who approaches responsibly the composition of music for electronic media must find

himself engaged in what can be termed in all justice and accuracy, 'basic research.'…The constant self-question of the composer of the past: 'Does what I have written exceed the capacities of the performer?' is now replaced by: 'Does what I have produced exceed the perceptual capacities of the trained listener?'" (1964, 263) Electronic tools for synthesis, including the computer, gave epistemological knowledge not just of timbre but of particular modes of listening: ecological modes of the kind outlined by Gibson and Gaver, "reduced" modes outlined by Schaeffer and Chion, and not only the spectrum between them but the ways in which these two modes (often set at odds) may in fact overlap. And the pieces composed with these tools come to perform this epistemic function by proxy, as in a piece like Grisey's *Partiels* (discussed in chapter 2), which didactically makes the listener aware of the fuzzy relationship between timbre and harmony.

The broader intellectual context for these observations today is the field of media theory, which deals with the ways in which materials mediate or otherwise condition thought and experience. "Media determine our situation" (Kittler 1999, 1) and "The medium is the message" (McLuhan 1964, 7) are two well-known media-theoretic declarations, though they also represent stronger positions on the issue of technological determinism than other authors might suggest. Hansen (2006) describes media theory as concerned with "an ineliminable oscillation between the materiality and the phenomenality of media" (297), which I would suggest expands older questions of poiesis and esthesis — creation and reception — to encompass the agency of non-human actors whose role had hitherto been considered neutral or passive. Hansen stresses the role that embodiment, and our embodied perceptual systems, play in our media ecosystem. "The medium, and mediation as such, necessarily involves the operation of the living, the operation of human embodiment…Humans have always evolved in

recursive correlation with the evolution of technics" (300). Tomlinson (2015), discussed in chapter 3, is a complementary account of this same observation: that "musicking was always technological" and that our mimetic relationship to objects constituted one node in an evolutionary feedback loop between objects, physical gestures, mimesis, and the taskscape.

There is a chronological media hierarchy in musical creation. Across the lifecycle of a hypothetical piece of composed music, the pen and paper used in composition is a layer of mediation, the software used to engrave that composition is a second layer, the instrument(s) used is a layer, be they acoustic or electronic, the recording devices used (if any) are a layer, and so forth. These layers are generally applied, like coats of paint, in a particular order, but there is a way in which they also feed back onto each other. For example, a particular passage scored for a violin might be re-written once the mixing phase has begun, perhaps in order to accommodate a certain kind of filtering or compression applied to the total mix. Certain instruments do better being processed in real-time than others (for example, a snare drum turns out to be a relatively limited instrument for processing) and this can effect scoring choices either at the outset or once the trouble is encountered. Learning that a snare drum is hard to process electronically in turn reveals aspects of the physical quality of the sound of a snare drum — that its sharpness and rapid decay give relatively little material to play with. This is an epistemic function performed by the technology of the recording studio. How these layers of mediation "act" upon a musical composition is to some extent premised on what they afford by design, and to which composer/compositional agenda.

The idea that technology sometimes performs an epistemological revealing helps navigate around rhetoric of newness: how new is new media? Is the technological assemblage of the recording studio revolutionary or evolutionary? Are the virtual worlds Risset and

Dufourt discuss so dependent on technologies of audio inscription and synthesis and analysis, or are they simply an intensification, another step in a process of perceptual play and illusion that has been present in all of the arts? After all, our sensory apparatus isn't changing, exactly, but rather our attention and sensory knowledge are being redirected or attenuated constantly in a process that is both technological and cultural. Hansen (2004) invokes the work of Henri Bergson to consider technology's impact on perception. Of particular use for Hansen is the way in which affect and memory render perception impure: "the world is composed of an aggregate of images, and perception demarcates the selection of a subset of this aggregate by a 'center of indetermination'" (Hansen 2004, 3). For Bergson and for Hansen perception is also inherently bodily (this being the source of its "impurity"): "Bergson places his emphasis on the body as a source of action; it is the action of the body that subtracts the relevant image from the universal flux of images" (Hansen 2004, 3-4). It follows from this that the body has a creative agency, and that our bodies and our motion through our environment literally creates our perception.

Different media platforms have different capabilities, different things that they afford, different actions and thoughts which they constrain. Already here there is a way in which environmental perception involves the consideration of technical objects (doors, chairs), a line of thinking that continues through to digital technology. Hansen explains: "The capacity of the 'embodied mind' to adapt quickly to new virtual realities demonstrates the plasticity of the nervous system and the operative role of bodily motility in the production of perception" (39). One implication of this idea, which is one of Hansen's central arguments, is that digital technologies may in fact render the plastic and embodied nature of perception *more* obvious or apparent because of their virtual nature. Musical compositions that employ digital technology may cast certain embodied experiential dependencies that hold across all musical practices into

greater relief: if I find that listening to the electronic sounds in Saariaho's *Verblendungen* is given affective meaning by imagining them produced by bowed strings, I might be led to consider how source/cause imaginings translate affective content in more familiar musical contexts.

Hansen coins the term "affectivity" to describe "the capacity of the body to experience itself as 'more than itself' and thus to deploy its sensorimotor power to create the unpredictable, the experimental, the new" (2004, 7). While I find the word "affectivity" unhelpfully vague, the notion that our bodies can feel "more than" themselves is strongly suggestive. When Risset writes "the challenge for the artist is not merely to create an illusion of our world, which is the usual goal of virtual reality, but rather to create appealing new virtual worlds" (2004, 203), this creative act is as much an act of listening as of composition. It invokes the listener's sensorimotor skills, imagination, and sense of *what it would be like* to do something. The drive to activate the imagination more strongly, rather than to risk breaking the mimetic invitation of the music with too many incomprehensible sounds, led composers like Risset and Saariaho to search for new tools to better achieve these appealing new worlds. One such tool was the CHANT physical modeling synthesis software, which emerges from the perceptual impasses described in this section. The workings of that software, and its use in a composition by Grisey, are the subject of the next chapter.

Chapter 5: Grisey and/at the Limits of the Voice

5.1 Introduction

When Gérard Grisey set out, beginning in 1981 at IRCAM, to write a piece employing the capabilities of the CHANT vocal synthesis software, he began with a relatively simple idea: he envisioned a large complex of vocal polyphonies, enveloped by an uninterrupted vocal tone acting as a pedal point or fundamental pitch (Grisey 1984).[1] Even though this sketch of an idea would three years later become just one part of the 37-minute electroacoustic piece *Les Chants de l'Amour*, it immediately connects to several of the larger themes of the piece. There is the characteristically spectral idea of a fundamental tone and polyphonic activity above it, perhaps suggestive of the harmonic series. There also is the notion of a binary—the fundamental voice and the polyphonic voices on top—and gradations between it. Binaries and gradations tend to be central in early exemplars of spectral music: harmonicity and inharmonicity, stasis and motion, tone and noise. Much in that same spirit, *Les Chants de l'Amour* is in part a piece about the binary pairing of the human and digital choirs: their opposition, their blending, their interactions. Grisey's fantasy of an uninterrupted vocal tone is fundamental to the themes of the piece: Grisey was not envisioning the kind of "choral breathing" familiar from centuries of vocal performance, but rather the idea of one entity singing a note without interruption for vast lengths of time — for inhuman lengths of time.

To achieve this effect, Grisey had to consider the voice at a granular, microscopic level, a level of awareness that the CHANT software's team of creators were likewise attuned to. I find

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[1] "The first sketch of *Les Chants de l'Amour*, actually the formal setting, dates from the summer of 1981. I then conceived the idea of great vocal polyphonies enveloped and supported by a powerful fundamental." (Grisey, 1984)
"La première esquisse des *Chants de l'Amour*, en réalité la mise en place formelle, date de l'été 1981. Je conçus alors l'idée de grandes polyphonies vocales enveloppées et soutenues par un fondamental puissant."

it a useful point of entry into the piece to imagine the sorts of questions Grisey likely had to consider in order to write the passage he described: How to make something sound like a human voice, and even sound like it's breathing, without having it stop producing noise? How to encourage listeners to imagine this sound as a voice, or as a human voice? Grisey's motivation to write a piece heavily featuring synthesized voice and saturating it with references to love, an emotion deeply associated with human (or at least organic) life, merits similar scrutiny.

This chapter will analyze the genesis, narrative, and compositional organization of *Les Chants de l'Amour* and search for points of overlap between those elements and my embodied listening experience. I consider the piece an ideal case study of the aspects of acousmatic listening discussed in this dissertation. The synthesized voice undergoes rapid transformations, is at times quite distinct timbrally from the human choir and at other times blends in. The two imitate each other: for instance, when the human singers perform the machine-like sounds of a vinyl LP slowing down and thus decreasing in pitch; or when the tape voice performs in a smooth bel canto. These are strategies of compositional organization (they allow for sections to feel distinct); and they are strategies for structuring a narrative for the piece (albeit a fragmentary one). But they are also strategies for inviting me as a listener to engage and empathize with the musical actors in the piece. Following Cox (2016), my mimetic engagement with sound might be always present but it can be stronger or weaker depending on what kinds of cues I'm responding to, and how readily I am able to map those cues onto my motor imagery. My analysis will focus on the moments in *Les Chants de l'Amour* that most strongly activate my first-person mimetic engagement, and which lead me to imagine doing things that are well outside the normal means by which I express myself or exert myself.

The narrative elements of *Les Chants de l'Amour* engage with both familiar and novel ideas about non-human expression and agency which were made realizable through then-cutting-edge advances in computing technology and vocal synthesis software. At the same time, Grisey's compositional choices are both informed and constrained by the capabilities of the software he used to realize his synthetic voice. In this sense, both the piece and the compositional process illustrate aspects of technology's impact on creative decisions and perceptual experience, and elevate those aspects to the level of conscious awareness by dramatizing or aestheticizing them in a work of art. This manner of not only exploring but revealing facets of perception through music is a marker of the spectralist's particular cultural and historical moment — sitting at the nexus of technological advances in digital computing technology, reactions against (and continuations of) high modernism, and developments and refinements in psychology. Grisey's piece stages the porous relationship between human and machine at the level of programmatic narrative—which is certainly not unique to this piece and taps into older narrative tropes[2]—but also evidences it on a technical level, particularly regarding Grisey's uses of the CHANT synthesis software.

Jérôme Baillet notes that *Les Chants de l'Amour* is "an isolated attempt in the evolution of Grisey" (24), with his next composition incorporating voice (*L'icône paradoxale)* being composed ten years later and reflecting several significant changes in aesthetic. There is little secondary literature in English on *Les Chants de l'Amour,* and it is not performed often. It is a sprawling 37-minute work for voice and tape, and the tape component requires that the conductor be

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[2] Consider Philip K. Dick's 1968 novel *Do Androids Dream of Electric Sheep?* which became the *Blade Runner* (1982) film. Even earlier examples exist: Carlo Collodi's 1883 story of *Pinocchio*, the toy that desires to become human; or the large literature on the fascination with automatons in the 19th century (for instance, E.T.A. Hoffman's 1816 story *Der Sandmann).* Riskin (2016) places such stories in a larger narrative of science's refusal to attribute agency to nature or to non-human objects.

synchronized with a click track, which presents challenges for crafting an expressive performance. Barrière (2015) described the scope of the work as "a mistake," suggesting that the piece would have been more effective in miniature. Grisey has written at length about the piece, including in a 1500-word program note and an accompanying published presentation from the 1985 International Computer Music Conference. Because of the referential nature of writing for voice, its use as a model for the CHANT synthesis software Grisey used, as well as the variously abstract and figurative compositional maneuvers Grisey deploys in the piece, *Les Chants de l'Amour* provides an excellent vehicle for considering conceptual touchstones in spectralism that are more oblique in other works and which are not a part of the overarching narrative about their music. Spectralism's objects are never simply timbre but the sensations and images those timbres might conjure in a given a listener. Grisey's belabored emphasis on perception and on listening was not simply about didactic compositional processes and psychoacoustic phenomena but about the stretching of the listening subject. Grisey spoke in a program note for his 1988/1989 work *Le Temps et l'Écume* of the time of whales and the time of insects: of the way that different perceptions of time scales could provide an organizing metaphor for time in Grisey's work.

A number of the compositional techniques in *Les Chants de l'Amour* reveal the influence of total serialism on spectral thinking. This piece presents a tension between a set of aesthetic values rooted in perceptible processes, and a desire to use a compact idea or seed to yield an entire composition. That desire connects spectral music to an older set of aesthetic values about musical composition, typically associated with nineteenth-century Austro-German music in the wake of critics like E.T.A. Hoffman and Heinrich Schenker: that a composition should be traceable to an initial kernel of an idea, the working out of which ultimately comprises the

piece. Watkins (1988) has observed this tendency in the music of American minimalists like Steve Reich: "[minimalism's] devotion to the idea of process from germinal sources suggested a link with classical repertoires whose formal foundation resided in the potential for working out musical ideas of an organic nature" (275). Spectralism's connection to minimalism is thus not simply a shared interest in audible and gradually unfolding processes, but in a shared commitment to a defining aesthetic value in the tradition of classical music (especially in the Austro-German tradition): of the working-out of a concise initial idea. This affinity may have been apparent to those working at IRCAM: *Les Chants de l'Amour* was premiered alongside a new work by Reich, *Mein Name Ist,* which played with similar conceptual touchstones (of vocal sounds transitioning between sense and nonsense, referentiality and abstraction) as Grisey's piece.

5.2. CHANT

In an important respect, the genesis of *Les Chants de l'Amour* begins in 1979 with the development of the CHANT software at IRCAM. Initially written by Xavier Rodet, Yves Potard, and Conrad Cummings, the software was also developed by John Chowning and John Gordon at Stanford and was refined extensively by Jean-Baptiste Barrière. CHANT was a physical modeling synthesis software, which the programmers call synthesis-by-rule. It was initially coded in the SAIL language and was then rewritten in C and in FORTRAN (Rodet, Potard, Barrière 1984). As its name suggests, it began as a tool for the synthesis of vocal sounds, but it proved a far more flexible program and was used to synthesize all manner of familiar and novel timbres. Analog synthesis and manipulation of vocal signals had been around since at least the 1930s, and speech synthesis can be traced much farther back: Schroeder (1993) details a speech

machine invented by the Hungarian nobleman Wolfgang Ritter von Kempelen in 1791, which produced vowel sounds and was modeled on the shape of the vocal tract — including "a hinged tongue and movable lips" (232). In 1929, Homer Dudley began developing what would become the Voder ("voice decoder)", a device that synthesized the human voice as a means of saving bandwidth while transmitting the voice over radio (Schroeder 1993, 234). Robert Moog's vocoder was developed beginning in 1968.

But CHANT's developers—Xavier Rodet, Yves Potard, and Jean-Baptiste Barrière—felt that digital technology had reached a level of sophistication that analog could not match (Rodet, Potard, Barrière 1984, 15). The complexity of the human voice was precisely what made it an appropriate subject: "because of its extreme richness…the voice inspires a more general and fertile approach than the study of any other instrument" (16-17). The first step for synthesis was an understanding of the physiological production of vocal sound—as the developers note, "synthesis [meant generally] is the proof of both our understanding of sound phenomena, and of the music itself" (1984, 15). The physiological production of a vocal sound can be summarized as follows: lungs exhale a stream of air that travels into the vocal tract, through the larynx, and into the mouth and nasal cavity. Along the way, that airstream is disturbed: by the vocal chords, which modulate the stream of air; and by the narrowing of the mouth via the lips, tongue palate, and glottis. The vocal tract acts as a set of resonators, filtering frequencies to various extents to form vowel sounds. Consonants are simply the introduction of noise elements (using the teeth and tongue) into this steady stream of air. This description of vocal function is highly suggestive of signal processing in general: a fundamental tone and its filtering at various stages.

CHANT could theoretically have used any number of sounding objects as a model. Why did the software developers choose to focus on the voice? I believe there was something peculiarly attractive about the voice given the aesthetic aims of late modernist music in and around IRCAM in the 1970s and 1980s. Because of its intimacy, its familiarity, its multiplicity of significations, its Barthesian "grain," working with the voice (and with synthetic vocal sounds) presented challenges and opportunities for composers desperate to explore new expressive terrain. Barrière writes:

> What justifies recourse to vocal material in this context is the need to create afresh a mimetic process…The choice of vocal material becomes an important one, because of a parallel resolve to move towards even more abstraction, by making play of a paradoxical perception which hovers between a "disembodied" sound synthesis and an abstract presence which is never grasped, always assumed, endlessly sought, ever non-existent. There is a "voice" but no singer. There is only a corpus of material which is terribly abstract, but which retains an inevitable physical link with every listener (1984, 182).

I read Barrière as appealing to the same mechanisms of listening as Cox (2016): that vocality has a privileged place in encouraging and even producing empathy in a listener, and that this production of empathy allows composers to push farther into abstract domains of pitch, gesture, timbre, and narrative.

CHANT's developers also had concerns about the user-friendliness of their software. "Analog devices have often been simpler to use than many programs," they write, and there was a drive to make something that was both user-friendly and provided instant or near-instant feedback: something with real-time music-making capabilities (1984, 15). Barrière describes an aesthetic and conceptual "war" at IRCAM in the early 1980s about real-time music making with computers. "You could work in real time but sacrifice sound quality, or have a high level of control and better sound quality. And real time won" (Barrière 2015). Because CHANT's variables dealt with physical aspects of sound production—with the excitation of a source and

with the ways in which that source resonates—it opened the door for somewhat more intuitive uses. Creating a bel canto singing voice that sings the note A4 for three seconds would, using the tools of additive or subtractive synthesis, be immensely laborious, both conceptually abstract and necessitating a great deal of trial and error.

While still complicated by 2018's standards, in 1980 physical modelling tools like CHANT were much faster in part because of the way in which their capabilities were laid out for users. As discussed in Rodet, Potard, & Barrière (1984), the parameters that users could control in CHANT included:

- Frequency of a fundamental pitch
- Random variations of that fundamental pitch
- Vibrato
- Random variations of that vibrato
- Spectrum: formants and amplitudes
- Slope of the spectrum
- Amplitude envelope of the formants

These parameters roughly divide into controls dealing with the attack of a sound (its pitch, and its amplitude envelope) and the resonance of the sound (vibrato, formants). That division meshes well with extant aspects of the spectral aesthetic. In both Grisey's *Partiels* (discussed in chapter 2) and Murail's *Ethers* (discussed in chapter 3), a sound's attack and resonance are decoupled, allowing for an impressionistic coloring, shading, and stretching of the resonance of the low E of a trombone (in *Partiels*) or the combination tones produced by singing and playing a flute simultaneously (in *Ethers).*

5.3. Pre-compositional genesis and structure of *Les Chants de l'Amour*

It may seem unnecessary, in a project about listening, to consider pre-compositional design at all. But I am not entirely split from one traditional aim of music theory, which is to

develop an ability to hear a piece's "structure." There are two reasons for this. First, there are elements of the piece's design which point to spots in the piece that are especially mimetic, for instance in Grisey's use of different types of compositional rhetoric for transitions (by excess, by silence, etc). But more broadly, I believe the pre-compositional plan of the piece shows that Grisey is imaginatively empathizing with the synthesized voice. This belief is not offered as a statement of provable fact; rather, I find when listening that I can't help but wonder about Grisey's own thoughts while experimenting with the CHANT software. This act of placing myself in Grisey's subject position, fictional though it may be, has become integral to my experience of the synthetic voice part in *Les Chants de l'Amour* and in its cultivation of imaginative listening experiences. And it intersects meaningfully with pre-compositional concerns, especially concerning Grisey's schematic

Grisey (1985) states that during the summer of 1981 he was briefly neighbor to the Dagar brothers, who were Indian carnatic singers. He cites that experience as an important influence on his compositional thinking in *Les Chants de l'Amour*, alongside music by Ockeghem, Dufay, and the Lituri Forest Pygmees. He regularly met with Rodet in the fall of 1981, and made a few trips to IRCAM, where he acquainted himself with the workings of the CHANT software (Grisey 1981).

The piece is divided into 28 sections (plus an introduction), each based on one phoneme found in a recording, made at IRCAM, of the sentence "I love you" (**figure 1**). Grisey scrutinized the recording using spectral analysis to glean the content of its formants, the prominent overtones which render recognizable the various vowel sounds in speech (as well as all manner of other sounds). Grisey is using sound as a model, with an emphasis on the microscopic level: the molecular components of the voice. Another of Grisey's predilections, the stretched or

"inhumane" time that Baillet referenced, is present in the stretching of "I love you" to 37 minutes in length. Grisey's interest in tripartite divisions of musical material (prevalent through the six-movement *Les Espaces Acoustique* cycle) is a hallmark of *Les chants de l'Amour*, and one reason why Grisey picked "I love you" as the germinal phrase for the piece may be its three word structure. (Figure 1 reveals that its phoneme content partitions fairly evenly into thirds.)

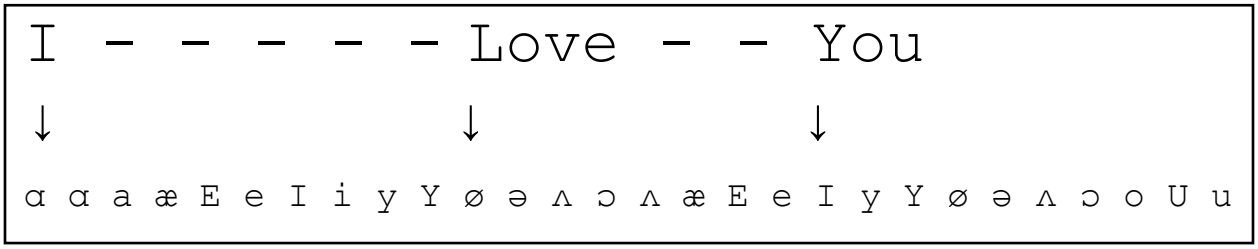


Figure 5.1: Grisey's list of the 28 phonemes of "I Love You"

The extreme stretching of "I love you" could be read as a winking and sly maneuver, since it strips that expression of meaning and renders it impossible to discern except in its vestigial traces. Several sections of the piece are texted, typically containing one-word fragments like "love" or the names of famous lovers (for instance, "Romeo" and "Juliet"). Additionally, in several moments Grisey shades the phonemes such that they have a clear connotation, for instance with erotic panting or frightened declamations. The very act of writing a high-modernist love song could be seen as subversive, a recourse to a mundane and low-brow topic. Yet Grisey seems to have viewed it as in line with musical modernism's push against the boundaries of representation, and the ineffability of love seems to be what attracted Grisey to the subject. In the program note he writes: "In a recent interview, I was asked this question:

"Why love songs? I could not answer because if the love song, like the love poem, is a difficult genre, it is even more difficult to talk about it" (Grisey 1984).[3]

Grisey's sketches for *Les Chants de l'Amour* suggest that Grisey was looking to write a piece for choir that explored tropes familiar both to modernist works of that era and to spectral music: continuums between nonsense and sense, phonemes and complete text, and timbre and harmony. **Figure 5.2** reproduces a scratch sheet of thematic material in the piece. Not all of the ideas on this scratch sheet are borne out in the final piece, but Grisey's efforts at grappling with how to handle semantic and referential content in tandem with spectral aesthetic hallmarks is evident. He sees continuums between nonsense and sense, with the former being characterized by atomic elements of speech like vowels and consonants and the latter being characterized by text.

The formant frequencies of "I love you" are used to govern much of the pitch material in the piece. Grisey et al (1985) reproduces the global pitch and formal chart of the piece, here printed as **figure 3.** The top line lists each of the 28 phonemes of "I love you" using the international phonetic alphabet; below that are two frequencies, which are the frequencies of the two loudest formants for each phoneme. Grisey then mapped these frequencies onto pitches, transposing them down an octave (that is, dividing the frequency in half). Presumably this was to bring the pitches into a more reasonable register for performance. Next, Grisey rounded those frequencies to the nearest partial of a low fundamental (indicated at bottom as H, or hyperfundamental). For instance, the first D and A of the phoneme "a" represent the 6th and 9th partials of the low hyperfundamental G (97.99 hertz). Shifts between hyperfundamentals are

[3] Lors d'un entretien récent, on m'a posé cette question : « Pourquoi des chants d'amour ? » Je n'ai pas su répondre, car si le chant d'amour, comme le poème d'amour, est un genre difficile, il est encore plus difficile d'en parler.

"Piece pour Choeur"
1) *Voyelles = choeur*
2) *consonant/bruit = bande*

Dissocier *- bruits (plosives, sibilants) etc., tape*
- voyelles
↓
Associer *- Texte = choeur*

Apparition du sens vers la fin. (un au debut)

Trouver une phrase unique (richesse du matériau phonétique du sens.)
Non-Sens (dissociative) —> Sens (associative)

Consonances (Bruits) —>
Voyelle (formants) —> morphemes —> phonèmes —> mots —> sens
signifié = signifiant?

Evolution harmonique et mélodique provient des formants du chacune des voyelles utilisées
La forme est donc la projection touts le durée (l'étirement voir computer) de formants contenus dans un mot ou une phrase

"Piece for Choir"
1) Vowels = choir
2) Consants/noises = tape

Dissociation - noises (plosives, sibilinats) etc., tape
- vowels
↓
Association - text = choir

Appearance of meaning toward the end. (One at the beginning).
Find a unique phrase (richnesse in phonetic material and meaning)
Nonsense (dissociative) —> meaning (associative)

Consonants (noises) —>
Vowells (formants) —> morphemes —> phonemes —> words —> meaning
signified = signifier?

Harmonic and melodic evolution comes from the formants of each of the vowels used
The form is the projection of all the durations (stretching out, see computer) of the formants contained in one word or one phrase

Figure 5.2: Excerpts from a pre-compositional sketch of thematic material in *Les Chants de l'Amour* held in the Paul Sacher archive; English translation is mine and is not in original sketch

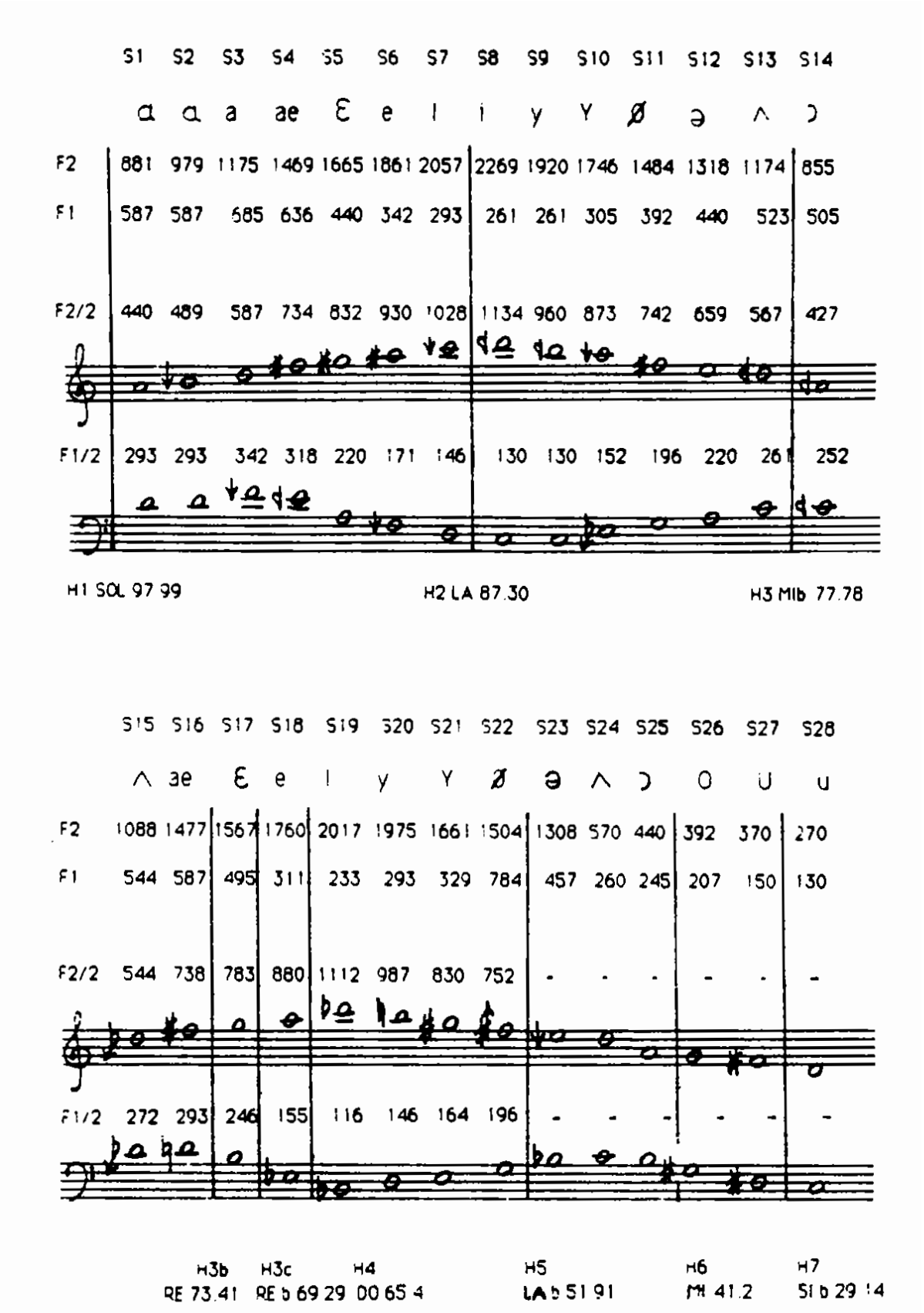
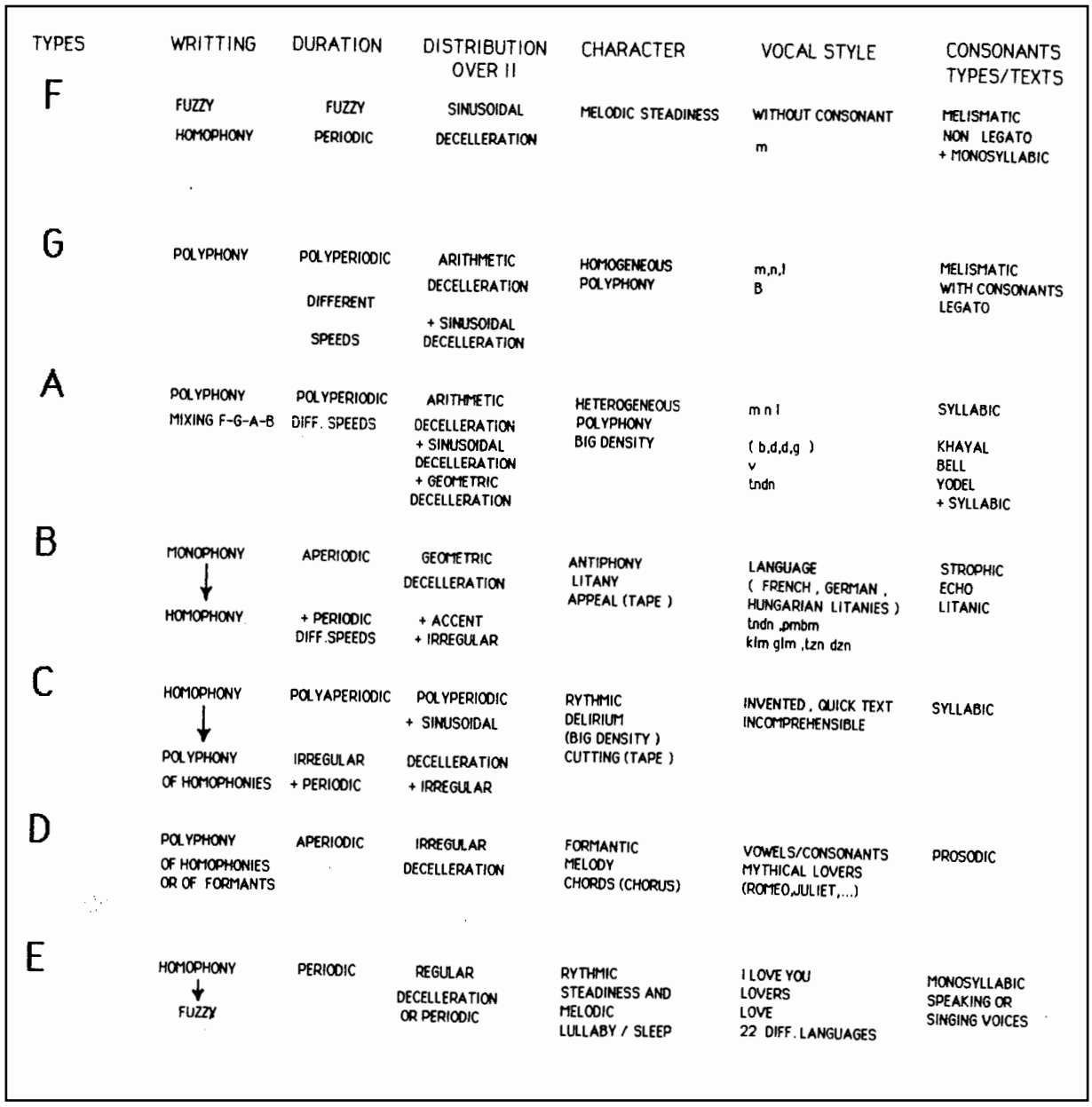


Figure 5.3: Map of formal sections of piece and formant frequencies, from Grisey et al (1985)



TYPES	WRITTING	DURATION	DISTRIBUTION OVER II	CHARACTER	VOCAL STYLE	CONSONANTS TYPES/TEXTS
F	FUZZY HOMOPHONY	FUZZY PERIODIC	SINUSOIDAL DECELLERATION	MELODIC STEADINESS	WITHOUT CONSONANT m	MELISMATIC NON LEGATO + MONOSYLLABIC
G	POLYPHONY	POLYPERIODIC DIFFERENT SPEEDS	ARITHMETIC DECELLERATION + SINUSOIDAL DECELLERATION	HOMOGENEOUS POLYPHONY	m,n,l B	MELISMATIC WITH CONSONANTS LEGATO
A	POLYPHONY MIXING F-G-A-B	POLYPERIODIC DIFF. SPEEDS	ARITHMETIC DECELLERATION + SINUSOIDAL DECELLERATION + GEOMETRIC DECELLERATION	HETEROGENEOUS POLYPHONY BIG DENSITY	m n l (b,d,d,g) v tndn	SYLLABIC KHAYAL BELL YODEL + SYLLABIC
B	MONOPHONY ↓ HOMOPHONY	APERIODIC + PERIODIC DIFF.SPEEDS	GEOMETRIC DECELLERATION + ACCENT + IRREGULAR	ANTIPHONY LITANY APPEAL (TAPE)	LANGUAGE (FRENCH , GERMAN , HUNGARIAN LITANIES) tndn ,pmbm kim glm ,tzn dzn	STROPHIC ECHO LITANIC
C	HOMOPHONY ↓ POLYPHONY OF HOMOPHONIES	POLYAPERIODIC IRREGULAR + PERIODIC	POLYPERIODIC + SINUSOIDAL DECELLERATION + IRREGULAR	RYTHMIC DELIRIUM (BIG DENSITY) CUTTING (TAPE)	INVENTED , QUICK TEXT INCOMPREHENSIBLE	SYLLABIC
D	POLYPHONY OF HOMOPHONIES OR OF FORMANTS	APERIODIC	IRREGULAR DECELLERATION	FORMANTIC MELODY CHORDS (CHORUS)	VOWELS/CONSONANTS MYTHICAL LOVERS (ROMEO,JULIET,...)	PROSODIC
E	HOMOPHONY ↓ FUZZY	PERIODIC	REGULAR DECELLERATION OR PERIODIC	RYTHMIC STEADINESS AND MELODIC LULLABY / SLEEP	I LOVE YOU LOVERS LOVE 22 DIFF. LANGUAGES	MONOSYLLABIC SPEAKING OR SINGING VOICES

Figure 5.4: Types of writing in *Les Chants de l'Amour* (from Grisey 1985)

meant to be moments of heightened drama in the piece, which Grisey calls "transitions by excess" which "causes the current process to deviate from its path for a short moment" (1985, 218).

Grisey's rhetorical resources in each section are relatively tightly constrained by a scheme he outlines in **figure 5.4.** Grisey calls these "extremely simple" (1985, 219) and observes

that though they applied equally to the synthesized voice and the human choir, in practice they were interpreted differently. (For example, writing type "D" focused more on the blocks of homophony and names of famous lovers for the human choir, but in filter-based melodies with a steady pitch in the voice.) Grisey tracked these in a massive chart that I've reproduced in **figures 5.5** and **5.6**. Many parts of the chart were left blank and the most complete and consistent entries deal with the writing style scheme and the transitions between each section. Grisey divides each of the 28 formal sections into three sub-sections, which he describes as being like the phases of breathing: inhalation, exhalation, rest. In the piece's program note he also describes these by analogy to the waveform of a sound, with section one's dynamic climb being like "attack transients," section two being like the "sound body," and section three being like the "transient extinction." Grisey also makes clear that "I / Love / You" correlates to sections 1, 2, and 3. In Grisey's charts (figures 5 and 6), writing styles with a tick mark (') are close to the subsequent style: so, writing style A' would be a mixture of A and B; A'" would be very close to B with a bit of A mixed in; and so forth. As Grisey's formal chart makes clear, the large transitions between each hyperfundamental are always a transition by excess: dramatic moments in which things seem to spiral out of proportion. Furthermore, each of the three subsections of a phoneme has a markedly different writing style to create variation across each of the 28 sections.

The tape voice in *Les Chants de l'Amour* is cobbled together from a mixture of sound synthesized using CHANT and recordings of spoken voices that Grisey processed and filtered using CHANT. The relationship between the tape voice and human choir provides the central drama in the piece. Of this relationship, Grisey wrote: "The [tape] voice, in turn divine, monstrous, threatening, seductive, mirror and projection of all the fantasies of the human

		I	dyn ↗				
Phoneme	**Section and global fundamental**	**Système**	**Repartition**	**Noume Spectre**	**Consonnes**	**Durées**	**Dynamique**
ɑ	S1 (H1)	A’	1 v + tape à 1 voix			16”	pp
ɑ	S2	A’’	1 v			15”	pp
a	S3	A’’’	1—> 2 v			13”	p
æ	S4	B	1—> 3v (1 rev)			10”	mp
E	S5	B’	1—>4v			9”	mf
e	S6	B’’	1—> 5v			8”	f
I	S7	B’’’	1—> 6v			7”	ff
i	S8 (H2)	C	tape à 2 v ; solo tape			6”	fff
y	S9	C’	tape à 2v.; solo; solo tape			7.5”	ff
Y	S10	C’’	1—> 6v ; 5; 1			8.5”	f
ø	S11	C’’’	1—>5v; 4; 1			10"	mf
ə	S12	C’’’’	1—>4v; 2; 1; 1			11.5”	mp
ʌ	S13	D (C’’’’’)	1—>3v; 1; 2			13"	p
ɔ	S14 (H3)	D’	solo tape; tape à 3 voix	i - - - - - - - - ɔ inhumain - - humain		20”	mp
ʌ	S15	D’’	olo tape	euridice		16"	mp
æ	S16	D’’’	6 v (female)	Tristan		13"	mf
E	S17 (H3-flat)	D’’’’	6v (male)	Helena, Pandora, Medea, Jiulietta, Laura		11.5”	f
e	S18 (H3)	E (D’’’’’)	solo tape + superp. A’’’’	Don Quichotte, Dulcinea		10"	ff
I	S19 (H4)	E’	solo tape			9”	fff
y	S20	E’’	1v tape			10"	ff
Y	S21	E’’’	1v			12”	f
ø	S22	E’’’’	1v			13.2”	mf
ə	S23 (H5)	F				15”	mp
ʌ	S24	F’				17”	mf
ɔ	S25	F’’				21”	f
o	S26 (H6)	F’’’		text Cortazar Rayuela		25.5”	p
U	S27	G	tape	respiration —> ronflement		28.716”	pp
u	S28 (H7)	G’ + E’	tape	grande polyphonie parlée / somme des durées		27.76”	ff

Figure 5.5: Grisey’s sketch for each section of *Les Chants de l’Amour*, part I

		II	dyn ↘				III	statique				
Phoneme	**Section (& global fundamental)**	**Système**	**Répartition**	**Neume Spectre**	**Consonnes**	**Durées**	**Système**	**Répartition**	**Neume Spectre**	**Consonnes**	**Durées**	**Transition type**
ɑ	S1 (H1)	F’		2	m	27″	E				14″	silence
ɑ	S2	F’'		2, 2/3; -5, 4	m, n,	27"	E’				12″	silence
a	S3	F’''		2, 3; -4, 3	m, n, ß	23″	E’'				11″	tuilage
æ	S4	G		2, 4	m, n, l, ß	25″	F				11"	analogie
E	S5	G’		3, 5/6	m, n, l, ß, d̨	37″	F’				14"	juxtaposition
e	S6	G’’		4, 7/8	m, n, l, ß, d̨, b, d, v	49″	F’'				13″	rupture
I	S7	G’’'		5, 10	m, n, l, b, d, d̨, v	62″	F’''				13″+20"	excès
i	S8 (H2)	A		6, 13	m, n, l, b, d, d̨, ¨g, v; tndn	72″	G				8.5″	contraste
y	S9	A’			m, n, l, b, d, d̨, ¨g, v; tndn; pmbm	69″	G’				10.5″	fusion
Y	S10	A’’			m, n, l, b, d, d̨, ¨g, v; tndn; pmbm; klm; glm	60″	G’'	4 bruits ≠	Polyphonie		13"	silence
ø	S11	A’’'			m, n, l, b, d, d̨, v; tndn; pmbm; klm; glm; tvn, dvn	42″	G’''	5 bruits ≠	Polyphonie		13.5″	tuilage
ə	S12	A’'''			lœ-rə, pm, bm, klm, glm, tvn, dvn	35″	G’'''	6 bruits ≠	Polyphonie		13"	fusion
ʌ	S13	B (A’’’’)			lʌv tvn, dvn	31″	A	7 bruits ≠	Polyphonie		17″	excès
ɔ	S14 (H3)	B'			Amore	33″	A’		♀ “orpheo!”		11"	silence
ʌ	S15	B’'			Love Dove Above	31.5″	A’'				10.5"	silence
æ	S16	B’''			J’aime…. (Debut de litanie française)	30″	A’''				9″	rupture
E	S17 (H3-flat)	B’'''			Szerepem (litanie hongroise)	35"	A’'''				10.5"	tuilage
e	S18 (H3)	C (B’’’’’)			Liebe… (litanie allemande)	43.5″	B				11″+(3)+13″	excès
I	S19 (H4)	C'		total des voyelles neume 2	p t k pr te ku ps ts kz	52″	B’				6″	fusion
y	S20	C’'		neume 3		49"	B’'				8"	juxtaposition
Y	S21	C’''		neume 4		45″	B’''				9"	silence
ø	S22	C’'''		neume 6		40″	B’'''				35″	tr. par excès et fusion
ə	S23 (H5)	D		2, 5		35"	C				10"	tr. par silence
ʌ	S24	D’		2,4		33″	C’				12"	tr. par rupture et tuilage
ɔ	S25	D’’		2, 3		34″	C’'				40.5″	tr par excès et fusion
o	S26 (H6)	D’''		berceuse		38″	C’''				10"	tr. par fusion
U	S27	E			Bribes, Rêves, Souvenirs	52"					(rest)+8″	tr. par excès et fusion
u	S28 (H7)	E’ + G’				55.377″					123″ total	

Figure 5.6: Grisey’s sketch for each section, part II

voices, doubles and multiplies itself into a crowd. It learns to breathe, to sing, to move, to stammer, and finally to speak 22 languages."[4] Grisey's interest was not in the imitation of the human voice as much as the "deviations of these voices." He continues:

> We discover several fields of perceptions and emotional reactions related to the avatars of the human voice:
> - Sung voice, well imitated, almost too pure, flawless. "What a voice!"
> - Mysterious territories of the human voice put in unheard situations. "What happened to this voice?"
> - Disquieting areas of the "organic" voice. Something or someone lives and breathes to produce that sound. "What is this monster?"
> - Reassuring areas of instrumental or electronic sound. "Ah! It's only a machine…"[5]

Such tropes bring Grisey into dialogue with other twentieth century artists who have engaged with the figure of the cyborg in music. Auner (2003) refers to musical representations of machines-as-human as "ventriloquism," which he argues "can be linked to broader cultural changes associated with the digital technologies that are transforming our sense of reality, subjectivity, and the human" (101). He quotes Donna Haraway's Cyborg Manifesto: "Late twentieth-century machines have made thoroughly ambiguous the difference between natural and artificial, mind and body self-developing and externally designed, and many other distinctions that used to apply to organisms and machines" (quoted in Auner 2003, 101). Auner, like Cox (2016), privileges the voice as a site of humanity and of expression, and suggests that the juxtaposition of the human voice with synthetic voice (and the potential subversion of the

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[4] Cette voix, tour à tour divine, monstrueuse, menaçante, séductrice, miroir et projection de tous les fantasmes des voix humaines, se dédouble et se multiplie jusqu'à la foule. Elle apprend à respirer, à chanter, à émouvoir, à balbutier, enfin à parler 22 langues.

[5] Nous y découvrons plusieurs champs de perceptions et de réactions émotives liées aux avatars de la voix humaine : - voix chantée, bien imitée presque trop pure, sans défaut. « Quelle voix ! », - territoires mystérieux de la voix humaine mise dans des situations inouïes. « Qu'est-il arrivé à cette voix ? », - zones inquiétantes de la voix « biologique ». Quelque chose ou quelqu'un vit et respire pour produire ce son. « Quel est ce monstre ? », - zones rassurantes du son instrumental ou électronique. « Ah ! Il ne s'agit que d'une machine... »

human voice's putative expressivity and the synthetic voice's putative dispassion) is a site of expressive potential in recent music.

I find that the use of thematic material related to love in the piece's narrative fosters my empathetic listening. To my ears, the CHANT-synthesized voice rarely sounds human in *Les Chants de l'Amour*: it either sounds deliberately synthetic, or falls into the so-called uncanny valley of near- (and thus plainly non-) human. Establishing a narrative framework (however loose) around love is a way of composing what Cox (2016) calls a mimetic invitation: an invitation for me as a listener to empathize with the machine and thus to consider what it would be like to express what it expresses. This in turn enables a perceptual broadening, an implicit imagined sense of what it would be like (or feel like) to sing or do something impossible. Rather, I am trying to imagine a particular listening mindset that would reflect certain aesthetic goals surrounding the use of synthesis to plumb the experientially new. However, while I'm not arguing that this experiential broadening *does* happen, I am suggesting that such an experience is *possible* for a listener to have. Examples from film scholarship may help illustrate.

Richmond (2016) scrutinizes the digital cinema techniques in *Avatar* and *How To Train Your Dragon,* which "both elicit from viewers a giddy, as-if sensation of flying through space: the illusion of bodily movement" (254). These illusions rely on immersion; or as Richmond puts it, they "modulate the embodied perception of their viewers to elicit an immersive sense of a world onscreen" (255). In such cinematic experiences, the camera plummets and I, immersed and empathetically engaged in an intersubjective relationship with the perspective of the camera, plummet too: my abdomen tenses and I lean in my seat. (Recall the example in my first chapter, of my experience watching a movie in a large iMax theater.) My perspective shifts from

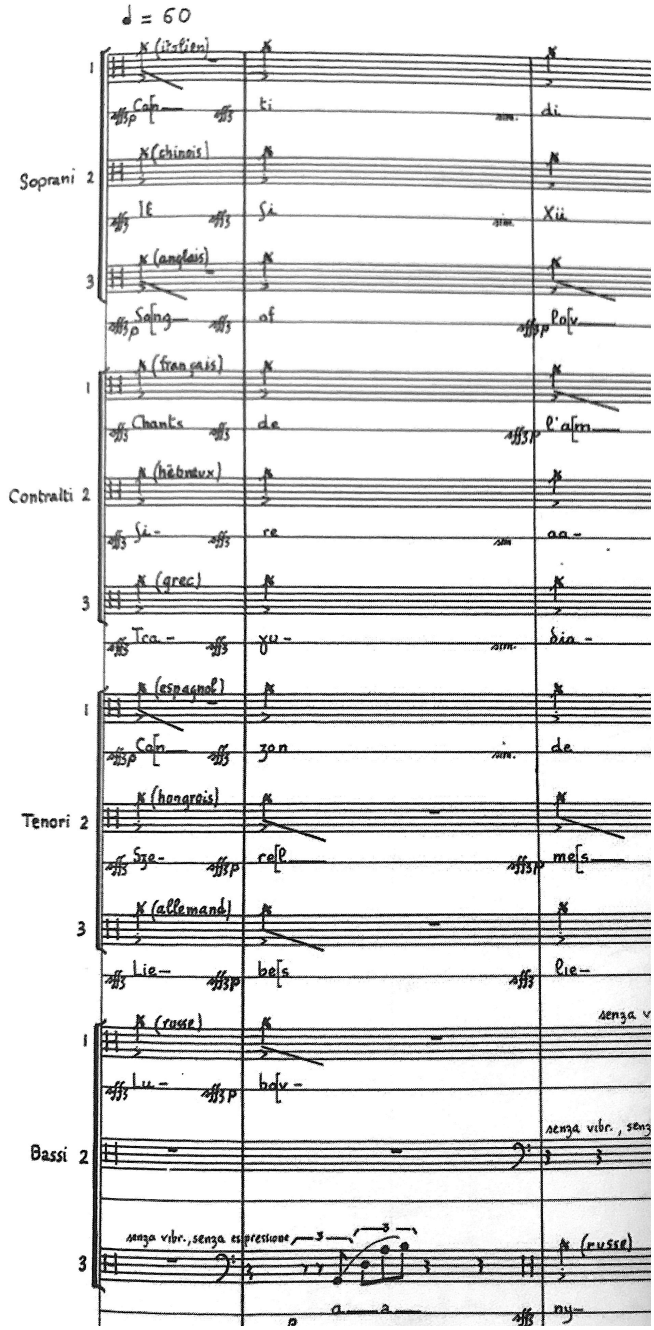
third person (it is flying) to first person (I am flying). Richmond stresses that verisimilitude is not a requirement for this kind of immersion: "their sensation impact stems rather from perceptual effects like the illusion of bodily movement through immersive cinematic space… rather than from verisimilitude, resemblance, or iconicity, categories of likeness that stem from understanding cinematic worlds as grounded in representation" (256-257). Richmond draws from the work of Vivian Sobchack, who describes a viewer's encounter with the cinema as being not one of biological vs mechanical physicality but as no different from the relationship "between any singular embodied consciousness perceived as 'mine' and those 'others' that are understood only by virtue of my own experience of myself in the eyes of others and through my own intentional activity of inference" (Sobchack 1992 329, quoted in Richmond 264). Viewers do not empathize with the camera *as* camera, argues Sobchack, but rather "the viewer and the camera share the same *interest* in the world. They do not share the same *place* in the world, nor the same *body*" (ibid. 329/265, emphasis in original). This distinction has the effect not of saying that we, the human viewer, empathize with an inanimate object, so much as it says that we endow the inanimate object with intentionality, with agency, and empathize with that intentionality.

The same is true in listening to music, though I would argue that because film is more readily multisensory it provides a better illustration of these effects. What is an analogue for the experience of flight in music? Any time a listener has the experience of feeling what it would be like to do something that exceeds their actual bodily knowledge. Returning to the work of Cox (2016) discussed in chapter 2, this experience could be intra-modal: As a percussionist, I can hear a virtuosic pattern executed cleanly and enjoy the imaginative feeling of having played it, or of having the skill required to perform it — this despite quite possibly lacking that finesse. Or

it could be cross-modal: through subvocalization I could imagine the great strain and exertion of singing in the register of a piccolo flute (since I lack embodied knowledge of how to play the flute) even though this strain may be absent entirely from the performer. This approach forms the core of the approach to vocal timbre analysis in Heidemann (2016): the imagined strain and exertion one feels in trying to sing like Aretha Franklin is part of how we both decode and ascribe the affective and expressive intent of her singing. In Richmond's analyses of *Avatar* and *How To Train Your Dragon*, a consideration of the expressive resources of the films (the corporeal and empathetic illusions of flight) was inseparable from both the technical apparatus that created it (the darkened cinema with its giant screen, cloistered off from the outside world; the techniques of digital imagery and sound design) and from the embodied and ecologically-grounded perceptual apparatus that made it legible. By extension, a music analyst interested in explicating the expressive moments in *Les Chants de l'Amour* would profit from considering the nature of the synthesis software used and the ways it might activate certain faculties of listening in a suitably empathetic viewer. I turn now to several moments in *Les Chants de l'Amour* that stage the human/machine tropes that Grisey describes in his program note.

5.4 Analytic scenes

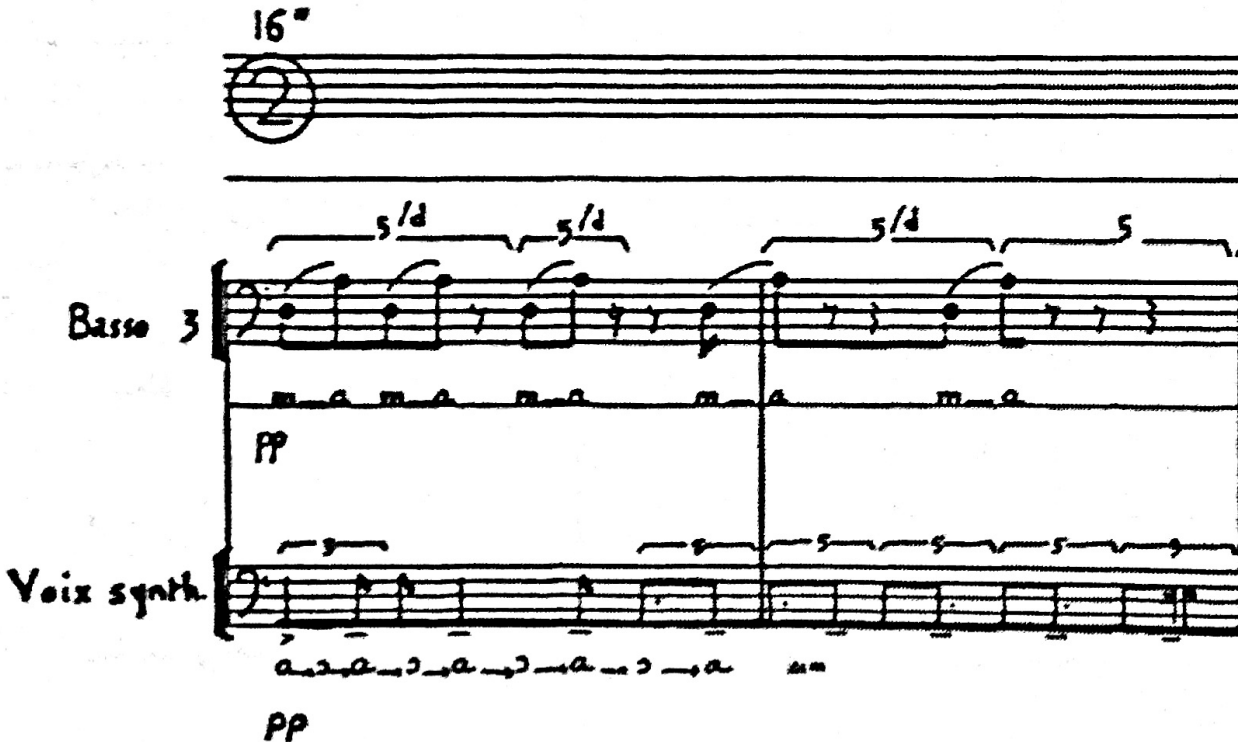
Grisey's sometimes-glib attitude toward intelligibility is well encapsulated by the opening of the piece: 10 of the singers loudly declaim the sentence "Songs of love for all loving lovers of all the world" in 10 different languages, leaving about one second between each syllable. (See example 1.) The result is a powerful and jarring barking sound with barely-recognizable fragments of text peeking through. Grisey's affinity for sounds that lie at the precipice of separation and fusion is also present: several of the singers trail off after declaiming



Example 5.1: measures 1-3 of *Les Chants de l'Amour*

their word, extending consonances in a downward glissando. Gradually, pitches of the harmonic series of the note G (the hyperfundamental of this section) are arpeggiated in upward gestures, first by the bass voices and gradually moving through to the soprani. The plainly stated arpeggiations of the harmonic series has the feeling of emergence and even of nascence,

ushering in the introduction of the tape voice at rehearsal 1 (recording 1:05). The tape voice's first utterance is in some respects remarkably similar to the vocal declamations: a loud, barking attack with a long tail. The noisy and weighty attack is surprising, a timbral world clearly distinct from that of the choir. The noise quickly fades and a droning G1 emerges. After a short pause, one of the basses sings an ascending D2-A2 perfect fifth above the tape's G1 fundamental provided by the tape voice (figure 8). They enter into a pulsing duet, the "ma-ma" of the bass singer and the inchoate "ah-ah" murmurings of the tape voice making the earlier connotations of nascence even more explicit.



Example 5.2: Rehearsal 2 from *Les Chants de l'Amour*

My experience in listening to this passage is that the voice's initial entrance is barely recognizable as a voice; it sounds like a low, droning synth pad. At rehearsal 2, when the voice starts to imitate the bass singer, I start to ascribe vocality to it, and the rhythmic repetition of the

pulsing gesture encourages this response. The use of phonemes for text registers as child-like, and the timbre of the bass voice is very clean and soft. When I adopt a second-person listening stance, it sounds as if the tape voice has crashed to Earth and begun to learn how to speak by imitating the human choir. By 2:20 I find myself tracking the pulsing "ao" sounds of the tape voice, tensing slightly in my chest to match the way I would perform the tape part with my own voice.

At 26:00, the soprani and contralti sing a Bb4-E5 tritone in even quarter notes while the tape part holds the same pitches two octaves higher. The tape part sounds like violin harmonics, much too high to resemble vocality in my hearing. A bass singer enters with a low Ab, gravelly and guttural and slow, and the tape begins a gradual glissando down above that droning bass and drops in and out. At 26:37 a remarkable shift occurs: the tape becomes much more strongly vocal, uttering "eee ahhh" vowel sounds in a pulsing rhythm reminiscent of the quarter notes of the soprani and contralti at the start of this section. The tape voice sounds strained and pinched, like it's running out of breath. I hear other voices too, or sometimes I hear the voice split into multiple voices. At 27:45 the same basic tape part repeats but trails off into the distance via the addition of reverb. I experience this as a strain, because I had been mimetically engaging with the tape voice's pulses, in a first-person subject position. As the tape voice recedes via reverb and is colored by a filter, I find myself quieting down while also changing pitch repeatedly, a contradictory easing (by growing quieter) and elevating (by singing higher pitches) of tension.

Chapter 6: Conclusion: For a Posthumanist Embodied Cognition

This dissertation has suggested that listeners evaluate sound by drawing from our lived, bodily experience. A cello played fortissimo, sul ponticello, and overbowed would sound discomfiting and angry to a listener has a sense of the exertion, effort, and tension—and the affects, such as agitated or angry, they signify to that listener—that they would feel if they were to make that sound. Because I do not think it is possible to completely transcend or escape the residue of our sensorimotor imagery, our lived and embodied experience always leaves its fingerprints on our evaluation of musical sound even if we acknowledge that we perceive sound in an aesthetic context different from in an everyday ecological one. A perceiver's deployment of embodied sensorimotor knowledge, encompassing the imagination of causal features of sounds, is hacked by electronic tools of sound creation and reproduction. In manipulating or outright creating instrumental timbre, performers and composers of electronic sound invite listeners to ascribe intentionality and agency to chimeric and impossible sounds. These impossible attributes are indexed in the timbre of sounds.

There arises a problem in this account of embodiment, which is made more pronounced in the course of considering the role played by the software and hardware in electronic and electroacoustic music. Without some nuancing, this descriptive/analytic approach risks reinscribing notions of the bounded individual that originate in Enlightenment humanism and radiate out across most of Western thought from the last 400 years. Braidotti (2013) critiques this received humanist tradition for its universalism, its reliance on binary oppositions like self and other, and its inextricable link with imperialism. "Subjectivity is equated with consciousness, universal rationality, and self-regulating ethical behavior," she writes. "In so far as difference spells inferiority, it acquires both essentialist and lethal connotations for people who get

branded as 'others'" (15). Does an account of embodiment simply reinscribe man—presumably white, able-bodied, centered and thus invisible to himself—as the literal measure of all things? Does embodied cognition merely move from a search for universals in music as an object—of quantifiable intervals between note X and Y generalized with formula J—to a search for universals in the perceiving subject?

My hope is that the patchwork of authors I've invoked in this dissertation suggest a way around this dilemma, toward an embrace of the contingency of perception and an embrace of the value of deploying ones' lived experience to convey an aesthetic experience intersubjectively. In shifting the focus from music as an object to music as a process—to musicking—we shift the emphasis to a musicking subject or subjects and to the social world in which they are embedded. I have centered my listening experience as a trained composer, performer, and music theorist, and at times extrapolated from my experience. But this is not in service of saying that one should or must hear in the way that I do; rather, it's to suggest that someone *could*, and that hearing in this manner might produce certain experiences which are not typical for that listener.

Braidotti crafts a theory that is alternately anti- and post-humanist, replacing the unitary, bounded, and universal human subject with "a more complex and relational subject framed by embodiment, sexuality, affectivity, empathy and desire as core qualities" (2013, 26). This posthumanism is one that sees non-human actors enfranchised with agency in our daily lives, in our thoughts and deeds. Artistic practice can make this relationship especially clear. Consider Boulez's comments on analog synthesis in chapter 4 or Grisey's use of the CHANT software in chapter 5: to say that the software enabled or constrained Grisey's compositional maneuvers is another way of saying that it exerted an agency. There are things that users are inclined to do

with their tools, which is related to but distinct from the things they enable users to do. The residue of these bidirectional interactions and negotiations with tools endures in the imaginative act of listening. When I hear a synthesizer play an upward glissando, I might conceptualize it in relation to the feeling of performing a cello glissando. I might also (or might then) compare the synth-glissando-as-cello-glissando to a glissando with my voice, but this does not mean that I've peeled back layers of mediation like an onion to arrive at the essence of my understanding of the sound. The objects I consider become co-constitutive of my sum total experience of the sound, a negotiation between vocal exertion, gestural exertion with an object, and whatever other experiences I might consciously or unconsciously bring to bear on the percept.

I return to Hayles' claim that "we have always been posthuman" (1999, 291), insofar as human thought has always been entangled in a relational stance with objects, social forces, and corporeality. How we discursively construct ourselves in relation to our tools has implications for music analysts looking to make a particular musical experience legible to another listener, or to explain and decode a composer's motivations for writing a particular passage. "As long as the human subject is envisioned as an autonomous self with unambiguous boundaries," Hayles writes, "the human-computer interface can only be parsed as a division between the solidity of real life on one side and the illusion of virtual reality on the other…By contrast, when the human is seen as part of a distributed system, the full expression of human capability can be seen precisely to *depend* on the splice rather than being imperiled by it" (290).

My claim that artists can use technology to construct or make possible a feeling that is outside of a listener's body's sense of itself—such as flying at the movies, or whispering but filling up a cavernous space—relies on the same distributed subjectivity and cognitive scaffolds

as all other manner of experience even if it feels qualitatively at a remove from it. It also relies on a capacity for imagination and for empathy (including empathizing with actors traditionally thought to be inanimate or inhuman). In pushing these experiences to their extremes, composers like Grisey, Murail, Saariaho, and Risset reveal for some listeners the co-constitutive relationship of body, tool, and world through the very act of straining it.

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