

NOISY FIELDS: INTERFERENCE AND
EQUIVOCALITY IN THE SONIC
LEGACIES OF INFORMATION THEORY

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by

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NOISY FIELDS: INTERFERENCE AND EQUIVOCALITY IN THE SONIC LEGACIES OF INFORMATION THEORY

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Noisy Fields: Interference and Equivocality in the Sonic Legacies of Information Theory discusses the ways in which noise causes interferences within disciplinary fields. Noise tends to bring diverse disciplinary approaches together, interfering in their constitution and their dynamics. I understand noise to be more than either positive revolutionary potential or negative disruption; instead, noise functions equivocally, possessing aspects of each pole in varying degrees. As such, it is vital to follow the machinations of noise. Considering noise as a material-discursive phenomenon, I trace its intersections with sonic practices and information theory. Noise was a key point of contention in the early debates surrounding the development of information theory, and I examine some situations that provide alternatives to the standard formulations. I then trace the interrelationships between information theory, noise, and early electronic music in the 1950s, outlining how artistic experiences necessitated the development of new information theories. Considering the confluence of sound and information in finance, I show how noise is both understood as a potential source of monetization while ultimately confounding attempts at complete capture. I turn to the nexus of speech, the voice, and noise, to consider situations of *parrhesia*, or “fearless speech,” that consists of noisy interferences within social systems via the activity of robotic performing objects. Finally, I listen to the electronic vocal manipulations of Maja Ratkje and Holly Herndon

to consider a micropolitics of the noisy voice. In sum, I show how the analysis of noise requires a transdisciplinary approach in order to elucidate the complicated dynamics of its interferences.

Biosketch

Nicholas Adrian Knouf was born in Fort Dodge, Iowa. He received his Bachelor's degree in Engineering and Applied Science from the California Institute of Technology in 2002. He worked as a research assistant and lab manager in a cognitive neuroscience laboratory from 2002–2005, conducting research on face and object perception using functional MRI. He received his Master's degree in Media Arts and Sciences from the Massachusetts Institute of Technology in 2007. He completed his PhD in Information Science at Cornell University in August 2013. Beginning in the fall of 2013 he will be an Assistant Professor of Cinema and Media Studies at Wellesley College.

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Preface

I began my PhD in the fall of 2007. At the very end of that academic year we found out that my dad had stage IV transitional cell carcinoma of the bladder.

This dissertation was completed shortly after his death on May 18th, 2013. I graduated a week later.

Writing a dissertation is always a time of highlights and setbacks. This process had the added complication of surgeries, chemo, and radiation. There was always the hope, however, that he would make it through to my graduation. My dad had an unbelievable will to live, a will that enabled him to endure much longer than the statistics suggested. In the end, he lived long enough to hear about my future job and to know that I would be attending my PhD ceremony just a few days later.

My dad had an insatiable curiosity; he delighted in discovering new details about science, history, music, computers, and most importantly, nature. His analytic mind was coupled with an artistic love for the natural sublime that he expressed through his large-format landscape photography. While his was a world where precision was preferred to noise, my interest in noise can be traced directly to the curiosity he instilled in me from a young age. Computers, technology, music, and the arts: the general fields of my work follow directly from his influence.

I know that this curiosity will continue to guide all that I do.

Introduction

In this dissertation, entitled *Noisy Fields: Interference and Equivocality in the Sonic Legacies of Information Theory*, I investigate the interferences noise makes within a set of disparate disciplinary fields. I approach noise as both a sonic and informatic phenomenon. Noise is often studied from one perspective alone, splitting what are actually conjoined and related perspectives. Noise has been an important touchstone in the history of the sonic arts since the Italian Futurists; similarly, noise has been a key component of information theory since the work of Claude Shannon. While often assumed to be distinct and separate, I show in this dissertation how these two different understandings of noise actually have influenced and affected each other.

Noise here is understood as a form of interference within different *fields*. I consider “field” to be an expansive term, one that encompasses a theoretical concept in sociology, pastoral and agricultural landscapes, an area that is enclosed, mathematical constructs, and explanations of scientific phenomena. However, I primarily focus on fields qua disciplinary fields, showing how noise has caused—and continues to cause—various disciplinary fields to question their underlying assumptions, thereby suggesting new potential formations and configurations. Noise produces ruptures within these fields that need to be taken into account, forcing a reconstitu-

tion and re-evaluation of how the world is constructed.

Interference is also a keyword throughout this dissertation. Like *field*, interference has a plethora of overlapping meanings. Yet I draw most directly from the interrelationship of “interference” and “field”; that is, how something causes a disturbance, a perturbation, within a varying system. Interferences, within scientific discourse, are often described as constructive or destructive: respectively reinforcing or diminishing the activity of a system. Think of two waves in perfect synchrony coming together to produce something larger (constructive interference) or cancelling each other out to eliminate the original waves altogether (destructive interference). While the binary of constructive and destructive is not helpful here, the connotations of those terms are. As such, noisy interferences within fields are *equivocal*; they are constructive, destructive, or some combination thereof. There is little that can be counted upon with noise other than its interference: it is my goal to describe these interferences and understand how things change as a result of this interference¹.

Noisy Practices

This dissertation is a tracing of the interferences noise makes within a set of diverse fields: information theory, electronic music of the 1950s, finance, the intersection of speech and robotics, and contemporary experimental vocal music. Such interferences show the equivocal nature of noise; that is, the fact that it cannot be un-

¹Annemarie Mol has additionally focused on the importance of “interference” to the enactment of multiple realities; see, for example, Annemarie Mol, *The Body Multiple: Ontology in Medical Practice* (Durham: Duke University Press, 2003), 142–149.

derstood as an inherently positive source of potential, nor as a negative, extraneous component to be removed.

While writing about noise in its equivocality gives you a good idea of the complexities involved, experiencing it within the context of material practices gives you another perspective—not better, simply different. During the writing of this dissertation I have been engaged in a series of artistic projects that, in retrospect, could be understood as each engaging with varying aspects of noise that will appear in the chapters to follow. As such, it feels important to break with the academic convention of the introduction to briefly convey some aspects of these projects that helped shape—consciously or not—the approach of this dissertation.

Vocal noises have been a part of my life from an early age—not simply those from my own mouth as a child, but also those of my sister, Robin. She was afflicted with Rett Syndrome, a degenerative neurological disorder on the autism spectrum². Girls with Rett Syndrome are often unable to talk and instead squeak, squeal, scream, shout—in short, noises of phonemic sounds, not the ordered phonemes of a symbolic or discursive order. The sounds were primarily *affectual*—auditory suggestions that cannot be decoded, but rather had to be heard, felt, internalized, and sometimes acted upon. It is no wonder, then, that my master's thesis was an object—a robotic marionette named *syngvab*—designed to, as I described it, “encourage the expression of the unspeakable.”³ Constructed to only respond to sounds that did not match the templates of speech, *syngvab* was an early experiment into

²For my own recollections of an important object in my family's experiences with Robin, see Nicholas A. Knouf, “The Patterning Table,” in *The Inner History of Devices*, ed. Sherry Turkle (Cambridge, MA: MIT Press, 2008), 49–54.

³Nicholas A. Knouf, “Encouraging the Expression of the Unspeakable: Influence and Agency in a Robotic Creature” (master's thesis, Massachusetts Institute of Technology, 2007).

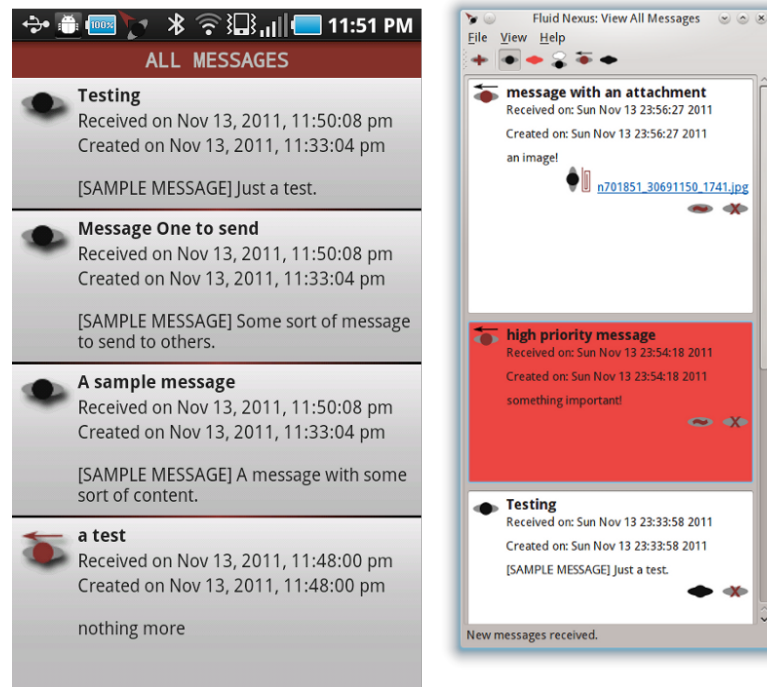


Figure 1: *Fluid Nexus* (2008–2011) Android and desktop screenshots

constructing a safe space for people to make sounds that they normally would not do.

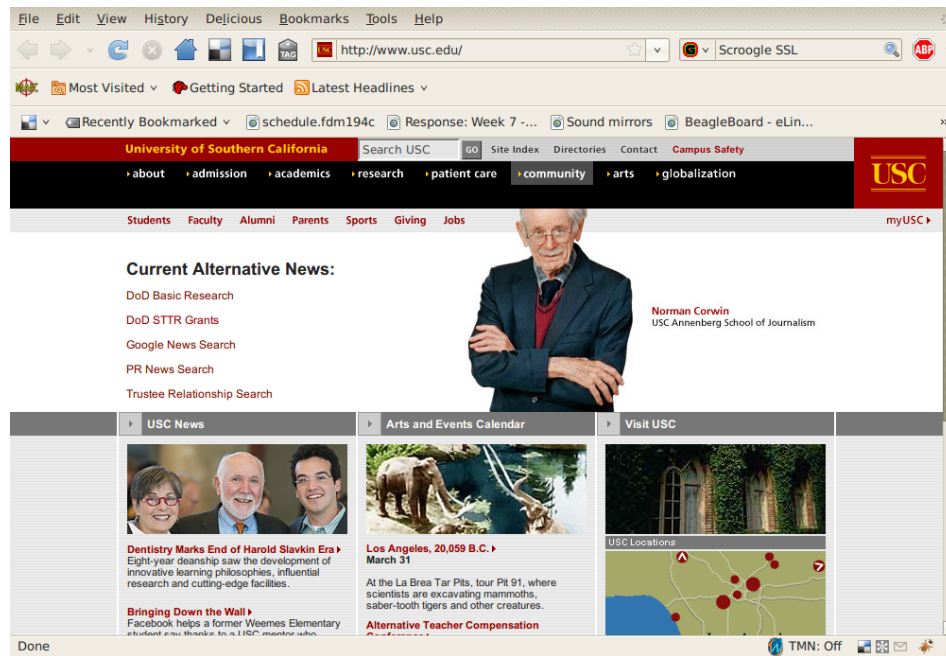
There was something about these experiences of sonic noise, the positive and negative interferences they can cause within particular systems, that caused me to think about these interferences in a more expansive sense, as something that could interrupt other domains of meaning. I began a project entitled *Fluid Nexus* (Figure 1; 2008–2011). Without realizing that this would ultimately also be a project about noise, I started thinking about different ways of moving information from one place to another. At the time there were already numerous examples of restrictions to access to information networks in response to natural disasters, protests, or wars. While the Internet was designed to route around areas where access is impinged, there is still a difficulty in getting information from a location where there

is no access to a place where there is. With *Fluid Nexus*, I began thinking about the basic components of networks—nodes and edges—in a more expansive fashion⁴. What if we think about the connections between nodes in a network as constantly in flux? If we take these connections as not fixed, we can perhaps think about other situations that fall out of our worldview when the goal is primarily one of stability. Thus in *Fluid Nexus* messages—text, images, video, or audio—pass from one person running the software on their mobile phone or laptop to another, bypassing any centralized networks. People thus become the carriers of information, rather than the more-centralized networks themselves. This message passing is opportunistic, using whatever means and/or carriers are possible. In retrospect, this was a project about thinking networks in a more noisy fashion; moving from the customary imagery and models of stable connections amongst the nodes of a network and to a construction that considers these links as fleeting and temporary, as connections that might only come into being once.

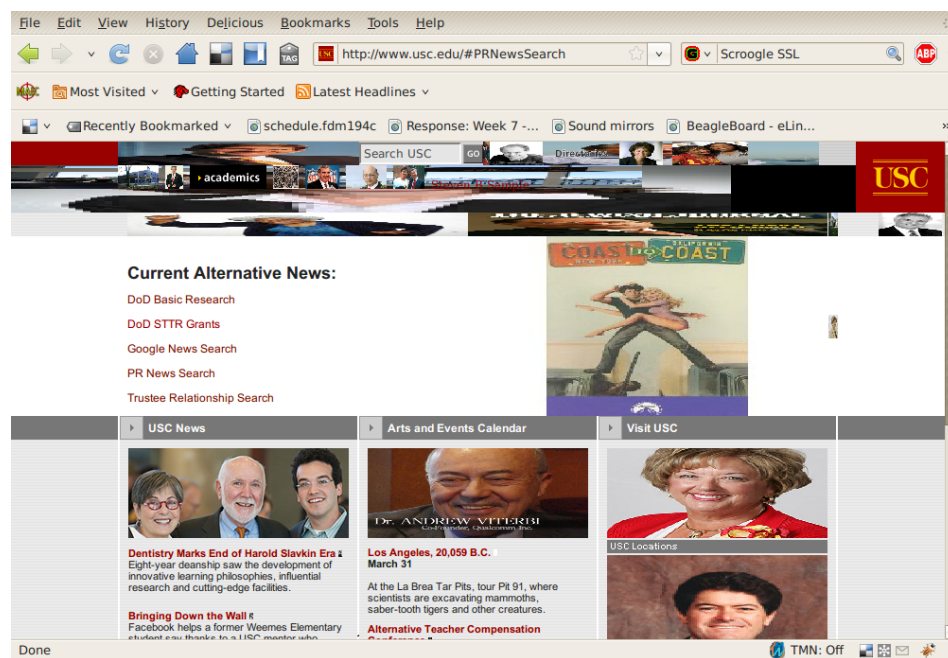
With this experience in a different form of noise other than the sonic, the next project furthered the idea of constructing a situation where noise can be injected into a system. *MAICgregator* (Figure 2; 2008), was a Firefox extension constructed to interfere within the space of academic websites⁵. Produced at the beginning of the so-called financial “crisis” and in the early days of its felt-impact on the campuses of colleges and universities, the project inserted alternative information into the staid spaces of academic website. If you had the extension installed, when visit-

⁴For more on the theoretical aspects of the project, specifically the connections with actor-network theory, see Nicholas A. Knouf, “Transnetworks and the Fluid Nexus Project,” in *Dis Connecting Media*, ed. Ulla Autenrieth et al. (Christoph Merian Verlag, 2011), 199–206.

⁵See the *MAICgregator* project website at <http://maicgregator.org>.



(a) Injected information on the page



(b) Images of trustees inserted on the page

Figure 2: Documentation of the use of *MAICgregator* (2009)

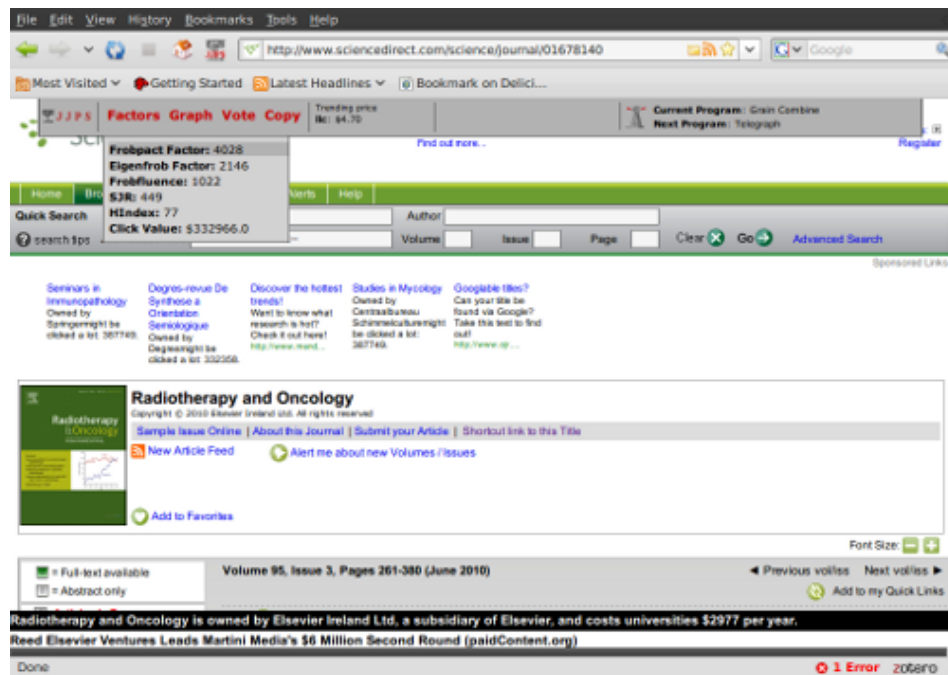
ing the homepage of a college or a university the default news information would be replaced with details about military funding (if any); relationships with the military, the school and small businesses; Google news searches of the school; mentions of the school in recent press releases; best-guess estimates of the trustees of the school; and clinical trials in which the school was involved⁶. A different mode of *MAICgregator* would randomly replace the links on the page with links the extension had found to the Google news mentions, press releases, and trustees. Additionally, the extension would optionally replace all images on the page with Google Image searches of the trustees in order to both provide a “face” on the crisis, while also visually highlighting the difficulty of automated datamining techniques. In short, *MAICgregator* was an experiment in the consideration of the web as a material; of understanding what means artists might have at their disposal to interfere with the presentation of others’ websites⁷.

Similar to *MAICgregator*, *JJPS* (Figure 3; 2010) included a Firefox extension that would inject various forms of information into the website of academic journals. The idea was to provide more data about how much journals cost academic libraries, how many journals a particular publisher owns, a variety of ways of calculating “impact” factors, and press releases of the journal publisher. Yet along with this extension I also created a fully automated internet radio station, *JJPS Radio*, that used academic journal articles as its source material⁸. With *JJPS Radio*, I was

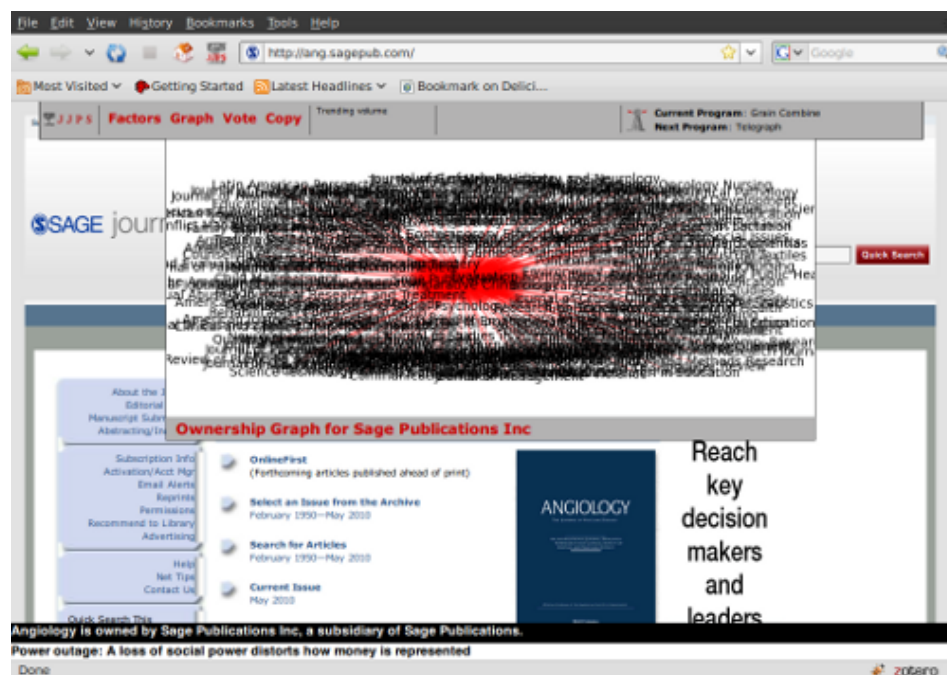
⁶For more information about these different data sources and the techniques involved in assembling them, see the Frequently Asked Questions page at <http://maicgregator.org/FAQ>.

⁷*MAICgregator* has been a topic of critical interest; see Anna Munster, “Data Undermining: The Work of Networked Art in an Age of Imperceptibility,” in *networked: a (networked_book) about (networked_art)* (turbulence.org, 2009); Carl DiSalvo, *Adversarial Design* (Cambridge, MA: MIT Press, 2012).

⁸You can listen live as well as through the archives at <http://turbulence.org/Works/JJPS/>



(a) Viewing various impact factors



(b) Viewing ownership graphs

Figure 3: Documentation of the use of JGPS (2010)



Figure 4: *afflator* (2011); still from video documentation

thinking about a potential future where it might be impossible to share PDFs with colleagues because of technical or legal restrictions. One of the shows on JJPS Radio simply reads out an article on the air via text-to-speech; this might not be the quickest way to get access to an article, but it works. I then realized that it might be able to transmit the PDFs directly by turning their binary code of zeros and ones into short and long sound pulses. Other shows provide “news” updates on academic publishing, as well as using various calculations on the text in the articles themselves to produce generative music. JJPS was specifically an attempt to consider noise in its sonic and information theoretic aspects together.

My most recently project, *afflator* (Figure 4; 2011), returned full-circle to the concerns of *syngvab*. I decided to try and construct a different situation in which one can explore the making of non-speech vocalizations. In *afflator*, the partici-
radio.

pant wears a mask with a tube that connects to a large fabric sheet that extends on the floor of the gallery. As you make vocalizations the sheet begins to undulate in response; you also hear *afflator*'s reworking of your own sounds. *afflator* will sometimes move or make sounds on its own as a way of encouraging the participant to explore different vocalizations. Coupled with this attention to the production of non-speech vocalizations, I was also interested in exploring different robotic morphologies, one that move beyond zoomorphic or anthropomorphic designs. I consider *afflator* a prototype, one that proved instructive and one that is only the beginning of further iterations.

Each of these projects was undertaken during different times of the preparation and writing of the dissertation. In short, each project focuses on how noise *interferes* with different types of systems. I often explored the (potential) productive or positive aspects of these interferences within the artistic projects; the dissertation will do this as well, while also turning to cases when the interferences are potentially negative.

On Noise

While “noise” has been a keyword within the sonic arts since the publication of Luigi Russolo's *The Art of Noises*, it has recently resurged as a frame to study “experimental” music⁹. A plethora of recent books attest to this, approaching noise from a

⁹Luigi Russolo, *The Art of Noises* (Pendragon Press, 2005). Michael Nyman made the distinction between “experimental” music (for example, John Cage, Christian Wolff, Morton Feldman, and Meredith Monk) and the avant-garde (for example, Karlheinz Stockhausen, Pierre Boulez, and Iannis Xenakis). Benjamin Piekut complicates this distinction by focusing on a series of performances in New York in 1964 by Cage, Henry Flynt, Charlotte Moorman, and The Jazz Composers Guild; see

disparate set of perspectives¹⁰. I focus on a few of these texts below.

In one of the most comprehensive recent books on the intersections of noise and music, Paul Hegarty defines noise as a “negativity” as it “can never be positively, definitively and timelessly located”. Noise, for Hegarty, is always relational, defined in part by how society resists it and understands what is not noise.¹¹ Through a series of chapters that contain ruminations on prog rock, free jazz, industrial music, Japanese noise music, and sound art, Hegarty analyzes how well noise functions in its purported capability to disrupt society. In Hegarty’s view, however, noise can never be properly political as such an event would immediately draw noise back into the space of “clearly assigned values”. As a result, noise is not “purist” and it therefore exists in a “paradoxical space” where it must continually fight against its own recuperation.¹²

This understanding of noise as the impure is picked up in Caleb Kelly’s *Cracked*

Benjamin Piekut, *Experimentalism Otherwise: The New York Avant-Garde and Its Limits* (Berkeley and Los Angeles: University of California Press, 2011).

¹⁰Besides the texts I discuss below see, for example, Aden Evens, *Sound Ideas: Music, Machines, and Experience*, Theory Out of Bounds (Minneapolis: University of Minnesota Press, 2005); Michael Goddard, Benjamin Halligan, and Paul Hegarty, eds., *Reverberations: The Philosophy, Aesthetics and Politics of Noise* (London and New York: Continuum, 2012); Greg Hainge, *Noise Matters: Towards an Ontology of Noise* (New York: Bloomsbury Academic, 2013); Douglas Kahn, *Noise, Water, Meat: A History of Sound in the Arts* (The MIT Press, 2001); Brandon Labelle, *Background Noise: Perspectives on Sound Art* (New York: Continuum International Publishing Group, April 1, 2006); Hillel Schwartz, *Making Noise: From Babel to the Big Bang & Beyond* (Brooklyn: Zone Books, 2011); Salomé Voegelin, *Listening to Noise and Silence: Towards a Philosophy of Sound Art* (New York and London: Continuum, 2010). In related areas to noise, but focusing more on ideas of error and glitch, are Peter Krapp, *Noise Channels: Glitch and Error in Digital Culture* (Minneapolis: University of Minnesota Press, 2011); Mark Nunes, ed., *Error: Glitch, Noise, and Jam in New Media Cultures* (London, UK: Continuum, 2011). Amongst all of these examples, *Reverberations: The Philosophy, Aesthetics and Politics of Noise* and *Noise Matters: Towards an Ontology of Noise* move beyond noise as a primarily sonic phenomenon. Earlier texts considered noise from various literary perspectives; see, for example, William R. Paulson, *The Noise of Culture: Literary Texts in a World of Information* (Ithaca, NY: Cornell University Press, 1988).

¹¹Paul Hegarty, *Noise/Music: A History* (New York and London: Continuum International Publishing Group, August 15, 2007), ix.

¹²*Ibid.*, 125–126.

Media: The Sound of Malfunction, where he takes the breakdown—intended or not—of specific forms of audio media such as vinyl and the CD as emblematic of a new aesthetic form.¹³ Kelly defines the “crack” as a point of rupture or a place of chance occurrence, where unique events take place that are ripe for exploitation toward new creative possibilities.¹⁴ Confusingly, Kelly will subsume the “everyday” tactics of “cracked media” into a non-political reading of Michel de Certeau, writing that the “tactic can also take the form of a nonpolitical action; this is important when the theory is applied to the contemporary sound and experimental music scene, which is not known for its overt political intentions. The tactic is a way of living and offers an approach to existence that relies on making life easier, or better, by making do.”¹⁵ For Kelly, then, working with cracked media becomes one act of simplification amongst others, a discursive move that erases other forms of working with cracked media, such as some forms of circuit bending, that are sometimes framed as overtly political practices.

Continuing this problematic thread, the American artist Joseph Nechvatal, in his *Immersion Into Noise*, constructs a transcendental account of “noise art” through a whirlwind tour of the history of Western art. For Nechvatal, “noise art” is an inherently oppositional practice to the so-called “blandness” of present-day mass-media communication.¹⁶ “Noise art”, especially when coupled with simulation technologies, thus provide a circumscribed, separate space to become connected to the “*magnificent more*.”¹⁷ Troublingly, Nechvatal’s “*magnificent more*” is undeniably

¹³Caleb Kelly, *Cracked Media: The Sound of Malfunction* (Cambridge, MA: MIT Press, 2009).

¹⁴*Ibid.*, 4.

¹⁵*Ibid.*, 287.

¹⁶Joseph Nechvatal, *Immersion Into Noise* (Ann Arbor: Open Humanities Press, 2011), 57.

¹⁷*Ibid.*, 59, emphasis in original.

and singularly feminine, as his text is literally overflowing with references to pregnancy, the “seminal”, and the “beauty” of feminine orgasm—all without reference to the complex discussion of these issues within the feminist literature of recent decades.

Attempts to attend to noise from a less-transcendental position can be heard in Joanna Demers’ *Listening through the Noise*, where she listens to the electronic music since the 1980s—post-Schaefferian *musique concrète*, electronica, microsound, maximal music such as noise, and situated sound such as field recordings—to suggest that it has “dismantled the musical frame” in order to produce an “aesthetic frame”. In this neo-Kantian form of “aesthetic listening” one listens primarily for the sound itself, rather than for its “meaning or communicative properties”. Yet Demers suggests that this should not be understood as a decisive split, as it’s possible to “hear both meaning and syntax simultaneously.” And this is both electronic music’s strength and weakness, as it lends it a “quivering sort of energy” that means “we will never be able to pin down its meanings decisively”.¹⁸

In one of the few texts to focus on women and noise, Tara Rodgers, musician, DJ, and founder of pinknoises.com, edited a collection of twenty-four interviews with women in electronic music. For Rodgers the collection “endeavors a feminist intervention in historiography—suggesting what feminisms can do for electronic music cultures—and it proposes what sound, as a category of critical and aesthetic analysis, can offer to feminist concerns”.¹⁹ Noting the dearth of women in conven-

¹⁸Joanna Demers, *Listening through the Noise: The Aesthetics of Experimental Electronic Music* (Oxford and New York: Oxford University Press, 2010), 161.

¹⁹Tara Rodgers, *Pink Noises: Women on Electronic Music and Sound* (Durham: Duke University Press, 2010), 2.

tional histories of electronic music, as well as the patrilineal standpoint of the historiography of sound (re)production, Rodgers notes that

To think against the grain of cultural ideologies that have aligned women with normative modes of heterosexual and capitalist reproduction, and to construct electronic music histories differently, we can consider how sounds themselves are reproductive. Reproductive sounds are variously *produced* by bodies, technologies, environments, and their accompanying histories; *reproduced* in multiple reflections off reverberant surfaces or in recording media; *reproducible* within spaces of memory and storage that hold sounds for future playbacks; and *productive*, by generating multiple meanings in various contexts. To account for reproductive sounds in all their temporal depth is to challenge the patrilineal lines of descent and the universalizing male claims to creation that have thus far characterized dominant discourses in electronic music.²⁰

For Rodgers the term *pink noises* encapsulates both the critique of how women are (not) represented in electronic music, as well as the potential of a new form of historiography and sonic production. Drawing on the overlapping definitions of pink, noise, and pink noise, Rodgers writes that the interviews are “sonic interventions from multiple sources, which destabilize dominant gendered discourses and work toward equal power distributions in the cultural arenas where sounds rever-

²⁰Rodgers, *Pink Noises*, 15.

berate”²¹.

Seth-Kim-Cohen, in *In the Blink of an Ear: Toward a Non-Cochlear Sonic Art*, takes umbrage at Pierre Schaeffer’s concept of the *object sonore*, the “sound-in-itself”, suggesting that sounds must be understood within a complex set of contextual situations. Following modernist visual art history and Rosalind Krauss’ notion of the “expanded field”, Kim-Cohen suggests that an “expanded sonic practice would include the spectator, who always carries, as constituent parts of her or his subjectivity, a perspective shaped by social, political, gender, class, and racial experience.”²² Paradoxically, and in contrast to the previous books that were engaged with sound’s materiality, Kim-Cohen argues for a linguistic turn towards the development of a “non-cochlear” sound art, mirroring his interpretation of Marcel Duchamp’s notion of a “non-retinal” art. Kim-Cohen writes that a “non-cochlear sonic art seeks to replace the solidity of the *object sonore*, of sound-in-itself, with the discursiveness of a conceptual sonic practice. Such a replacement adjusts the focus of producing and receiving sound from the window itself to its expanded situation.”²³

In parallel to this promotion of noise is a reactionary trend that extends back into the late-nineteenth and early-twentieth century with the practices of noise abatement campaigns in the West,²⁴ campaigns that were at times thinly-veiled at-

²¹ibid., 19. “Pink noise” refers to a signal where the “power density” is inversely proportional to frequency, in contrast to “white noise”, where the power density is flat as a function of frequency.

²²Seth Kim-Cohen, *In the Blink of an Ear: Toward a Non-Cochlear Sonic Art* (New York and London: Continuum, 2009), 107.

²³Ibid., 217–218.

²⁴Emily Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933* (Cambridge, MA: MIT Press, 2004); Karin Bijsterveld, *Mechanical Sound: Technology, Culture, and Public Problems of Noise in the Twentieth Century* (Cambridge, MA: MIT Press, 2008).

tempts to legislate taste. In a similar vein, but avoiding the moralism of the prior public movements, are the “soundscape” studies of R. Murray Schafer, a quest for an “audio ecology” that would see the world as a cosmic musical composition in the sense of a “music of the spheres.”²⁵ In contradistinction to the prior accounts, Schafer is highly tuned to the imbrication of noise and industrial capitalism, often suggesting that their combination admits no emancipatory possibilities for noise.

Yet noise has also been heard in its equivocal aspects, possessing potentials for positive disruptions in systems as well as the ability to be recuperated into constrictive frameworks. Jacques Attali is perhaps the most well-known exemplar of this approach.²⁶ Appropriately enough, Attali was trained as an economist and served as an advisor to François Mitterand’s government in the 1980s. For Attali music is sonic prophecy; new forms of music herald future changes in social order. Noise is neither valorized without question nor banished to the outside of music. Nevertheless, Attali’s book takes on a teleological bent in his historical succession of four “epochs” that fails to appreciate the regular reappearance of reconfigurations of noise.²⁷

Perhaps most provocatively of the recent scholarly writing on noise, Steve Goodman, in *Sonic Warfare: Sound, Affect, and the Ecology of Fear*, pulls away from “noise” altogether to describe a “politics of frequency” in order to move beyond the binary of noise and silence. Through so doing, he develops a set of new concepts to approach novel forms of sonic affect, both negative (its use in warfare and brand-

²⁵R. Murray Schafer, “The Music of the Environment,” in *Audio Culture: Readings in Modern Music*, ed. Christoph Cox and Daniel Warner (New York: Continuum, 2005 [1973]), 29–39.

²⁶Jacques Attali, *Noise: The Political Economy of Music* (Minneapolis, MN: University of Minnesota Press, 1985).

²⁷*Ibid.*

ing) and positive (its activation in Afrofuturism and dub techno).²⁸ Nevertheless, for reasons that will become apparent below, I retain the use of the term “noise” throughout the dissertation, even as I am sympathetic to Goodman’s approach.

In line with my attention to the interferences caused by noise, Henri Lefebvre, in *Rhythmanalysis: Space, Time and Everyday Life*, sketches an outline of a new form of analysis that attends to the specific dynamics of rhythms: those of the city, of music, of ritual. In every case his focus is on the embodied experience of rhythm and how combinations of rhythms can be discerned through careful analysis. In a poetic rumination on street activities from his window Lefebvre writes:

Noise. Noises. Murmurs. When lives are lived and hence mixed together, they distinguish themselves badly from one another. Noise, chaotic, has no rhythm. However, the attentive ear begins to separate out, to distinguish the sources, to bring them back together by perceiving interactions. [...] However, to grasp a rhythm it is necessary to have been *grasped* by it; one must *let oneself go*, give oneself over, abandon oneself to its duration. Like in music and the learning of a language.²⁹

Note that Lefebvre hears how rhythms are “mixed together”; therefore work needs to be done to “distinguish the sources” in order to understand their “interactions” — or interferences. Indeed, the rhythmanalyst must place himself or herself within the

²⁸Steve Goodman, *Sonic Warfare: Sound, Affect, and the Ecology of Fear* (Cambridge, MA: MIT Press, 2009).

²⁹Henri Lefebvre, *Rhythmanalysis: Space, Time and Everyday Life*, trans. Stuart Elden and Gerald Moore (New York: Continuum, 2004 [1992]), 27, emphasis in original.

rhythms themselves to allow for “abandon”. Nevertheless, the rhythm analyst, even in the embodied experiences of singular rhythmic temporalities, is always attuned to the ways in which these rhythms resonate (or not) with existing ones. Rhythms are thus more than the rhythms of music, and rather are the temporal dynamics that cause constructive or destructive interferences.

Yet it is Michel Serres’ work that has influenced the framing of the dissertation the most. Serres understands noise as being ontologically prior to rare islands of order: “Background noise is the first object of metaphysics, the *noise* of the crowd is the first object of anthropology. The background noise made by the crowd is the first object of history. Before language, before even the word, the noise”³⁰. Order must then be explained in the context of the incessant noisy background. Importantly for Serres, noise is transversal, reaching across static categories and infecting modes of being, be they information theoretical, philosophical, or musical:

There is noise in the subject, there is noise in the object. There is noise in the observed, there is noise in the observer. In the transmitter and in the receiver, in the entire space of the channel. There is noise in being and in appearing. It crosses the most prominent divisions of philosophy and makes a mockery of its criteria. It is in being and in knowing. It is in the real, and in the sign, already.³¹

Noise is therefore not primarily the matter of social relationships, or, in the case of

³⁰Michel Serres, *Genesis*, trans. Genevieve James and James Nielson (Ann Arbor: University of Michigan Press, 1997 [1982]), 54, italics in original. Serres often uses the archaic French word *noise* rather than the more common *bruit* in order to denote notions of “strife” and “contention”; these sense is given in italics in the English translation. See *ibid.*, 141.

³¹*Ibid.*, 61.

sound, defined as the complement of music; rather, noise is the material through which these things come to be. Serres, along with others we will see in chapters to come, additionally pulls from the language of information theory (transmitter, receiver, channel) in order to inform his approach to noise. Working from this account of noise, in contrast to those used in recent sonic scholarship, allows one to follow how noise transforms, and is transformed, through a variety of contexts, the sonic being only one of them. Noise therefore flows, and in flowing creates areas of vortices and rest: “Noise is a turbulence, it is order and disorder at the same time, order dissolving on itself through repetition and redundancy, disorder through chance occurrences, through the drawing of lots at the crossroads, and through the global meandering, unpredictable and crazy”.³² Noise, through its turbulence, causes interferences. Pulling these interferences apart is the job of this dissertation; it is thus a reformulation of Lefebvre’s *rhythmanalyst* into a noise analyst, one who is attuned to the equivocal interferences of noise within the nexus of information and sound.

Chapter Breakdown

The dissertation is divided into two parts. In the first part, “Noisy Legacies of Information Theory”, I begin with an excursus entitled “On Other Information Theories” that investigates the histories and prehistories of information theory and its manifestation within sonic practices. Noting that Claude Shannon’s formulation is dependent on research into sound at Bell Laboratories and AT&T from the

³²Serres, *Genesis*, 59.

early twentieth-century, I touch on the debates over “noise”, including what types of noises to send over the telephone. The early years of information theory were themselves noisy, as competing definitions—hitherto ignored in most critical histories of the period—proliferated, yet were soon to be dominated by Shannon’s equations.

The second chapter, “The Sounds of Information Theory”, details how information theory and music were fundamentally intertwined in the 1950s, as all of the major strands of avant-garde music at the time (*musique concrète*, *elektronische musik*, tape music, and algorithmic composition) involved researchers attuned to the latest developments in information theory. I consider how composers such as Milton Babbitt, musicologists such as Leonard Meyer, and engineers like John Pierce and Abraham Moles used information theory to expand the possibilities of the human “receptor” beyond the limits of traditional Western composition. This chapter offers a counter to recent attention to the role of first-order cybernetics in the period, as importantly these electronic works leave out feedback connections between the transmitter and the receiver.

The third chapter, “The Noises of Finance”, follows three different forms of financial noise, paying attention to how materiality and the interference of humans and machines cause the meanings of noise to shift over space and time. First I examine the attempts to incorporate “noise traders” into accounts of market efficiency to explain so-called “irrational” behavior. Second, I turn to the bodily practice of open-outcry trading to listen to how sonic noise in the pits indicates future market directions. Third, I turn to recent developments in the intersection of computers and trading to trace how material practices of human-machine hybrids again enable noise to become a means for the capture of profit, while additionally being attuned

to recent sound art that highlight the resonant properties of computer trading. The chapter shows how noise as both action and affect ensures that markets can never move continuously in one direction or the other.

The second part, entitled “Speech, Voices, Noises”, begins with the fourth chapter, “Noise, *Parrhesia*, and the Enunciative Potentials of Performing Objects”, and considers the intersection of enunciations, the practices of *parrhesia* or “fearless speech”, and the potentialities of computational devices. I draw on Michel Foucault’s excavation of the various histories of *parrhesia* and consider how *parrhesia* can function within the contemporary world. Expanding the notion of “performing objects” to encompass various computational devices, I listen to the noises of *parrhesia* made by the intersection of people and machines. Here I consider the prostheses of Krzysztof Wodiczko, the autonomous robotic creatures Little Brother and Beggar Robot, and the vocal non-speech enunciations made by the artist Kelly Dobson in her vocal works. Dobson’s ecstatic performances with construction workers amongst the din of equipment critiques simplistic notions of acoustic ecology, while Wodiczko’s mouthpieces translate one’s own voice via electronic mediation to paradoxically enable communication with the Other. Both Beggar Robot and Little Brother enable political enunciations by working within the interstitial spaces of the law. Each project considered allows us to understand how new forms of political speech are made possible through the interference of noisy *parrhesia*, computational devices, and existing political and social systems.

The fifth chapter, “Some Micropolitics of Noisy Voices”, listens to the practices of the electronic musicians Maja Ratkje and Holly Herndon in order to hear the micropolitical potentials of non-speech enunciations. I consider this within the con-

text of recent scholarship surrounding the voice that highlights its singular and material aspects. Ratkje and Herndon explicitly foreground the political potential of their work, and thus I hear it as well within a history of the recuperation of the hysterical voice within certain strands of feminism. Following the exploration of *par-rhesia* I also listen to Ratkje and Herndon's work within Franco Berardi's call for new types of poetic enunciations that would challenge the financialization of language. I conclude by outlining the contributions of this dissertation and discussing the importance of a transdisciplinary approach to noise.

Part I

Noisy Legacies of Information Theory

For the sonic arts, noise has been an indisputable touchstone for nearly a century. For the information sciences, noise has been something to be accounted for since the 1940s. In what ways are these two strands of noise related? This part, “Noisy Legacies of Information Theory”, considers the connections between sonic and informatic approaches to noise. I trace how early debates about noise and information come out of the sonic milieux of telephone transmission. I move to the uptake and transformation of information theory in the experimental and electronic music of the 1950s. From there I move to the intersection of noise and finance, a transition that requires some exposition. While the connection between noise, sound, and finance is not immediately clear, I show how concepts of noise from information theory required modifications in the fundamental assumptions finance had about the behavior of human agents. Sonic noises from the trading floors were found to convey information about the future movements in the market. And informatic noise becomes sonic noise in contemporary artistic projects about high-frequency trading. Thus finance becomes a key site to trace the legacies of noise and information theory.

Chapter 1

Excursus: On Other Information Theories

This short excursus examines some of the historical context of Claude Shannon's information theory. Drawing from the technical literature I pick up on various alternatives to Shannon's approach, different potentialities that were actively pushed aside or were simply ignored. My interest in these other theories is twofold: one, knowing that there were competing information theories enhances the historiography of the period; and two, these other information theories often considered noise beyond the dialectic of Shannon and Norbert Wiener's competing positions.

How noise is understood in the wake of information theory is the underlying theme throughout this dissertation. Being attuned to the noisiness of the *history* of information theory itself is necessary to understanding the vicissitudes of information theory's later manifestations. To make matters challenging, critical histories of information theory (in contrast to cybernetics) remain to be written¹. Thus my

¹William Aspray was one of the first to attempt a non-Whiggish history of information theory, but his work does not examine many of the people I engage with below. See William F. Aspray, "The Scientific Conceptualization of Information: A Survey," *Annals of the History of Computing* 7, no. 2

contribution is posed as an *excursus*, a series of tantalizing episodes highlighting other information theories. I follow the antecedents of Shannon's work at Bell Labs, specifically the acoustic research of Harvey Fletcher and his interest in the importance of noise in the intelligibility of communication over the telephone wire. Dennis Gabor, working in the United Kingdom, developed a novel dialectical model of communication two years prior to Shannon's work. Shannon, working within the milieu of Fletcher, other Bell Labs engineers, and wartime necessities, published a definition of the informational content of a message that gave the most random message the highest value; Wiener, on the other hand, published in the same year a diametrically opposed formulation. Shortly thereafter a series of conferences were held that showcased other potential ways of calculating and understanding information, some that brought back the semantic issues that Shannon attempted to keep at bay. No attempt has been made to be comprehensive; rather, I have chosen specific examples that are either referenced by figures who appear later in the dissertation or are otherwise important for highlighting novel approaches to the problematic of noise. We will hear echoes—if not always direct citation—of these alternatives

(April 1985): 117–140. Recently Bernard Geoghegan and Ronald Kline have produced more expansive histories of information theory, with Geoghegan interested in its relationship to structuralism and Kline the controversies surrounding disciplinary boundaries. See Bernard Dionysius Geoghegan, "Historiographic Conceptualization of Information: A Critical Survey," *Annals of the History of Computing, IEEE* 30, no. 1 (January 2008): 66–81; Bernard Dionysius Geoghegan, "From Information Theory to French Theory: Jakobson, Lévi-Strauss, and the Cybernetic Apparatus," *Critical Inquiry* 38, no. 1 (2011): 96–126; Bernard Dionysius Geoghegan, "The Cybernetic Apparatus: Media, Liberalism, and the Reform of the Human Sciences" (PhD diss., Northwestern University, 2012); Ronald R. Kline, "What Is Information Theory a Theory of? Boundary Work among Information Theorists and Information Scientists in the United States and Britain during the Early Cold War," in *Second Conference on the History and Heritage of Scientific and Technical Information Systems, November 16-17, 2002* (Chemical Heritage Foundation, 2002). Mara Mills has investigated some of the pre-history of information theory in acoustics research at Bell Laboratories; her work is key to understanding the broader context. See Mara Mills, "Deaf Jam," *Social Text* 28, no. 1 (2010): 35–58; Mara Mills, "Deafening: Noise and the Engineering of Communication in the Telephone System," *Grey Room* 43 (2011): 118–143.

within the uptake of information theory in music, the topic of the next chapter.

Shannon's Pre-Histories

Information theory's history customarily begins with Claude Shannon's essay in the July and October 1948 issues of the *Bell System Technical Journal*. Nevertheless, to anoint Shannon as the primary progenitor of information theory is both to efface Shannon's own references in his paper, as well as to ignore a series of key results that took place in earlier decades. From the perspective of a historical teleology, the British engineer E. Colin Cherry, in the first international symposium on this newly-defined area of study held in London between the 26th and the 29th of September, 1950, provided a breathless history of "information," moving from stone tablets and the languages of "drum beats," to Morse code and burgeoning engineering definitions by Shannon, Dennis Gabor, Norbert Wiener, Donald MacKay, and others². Shannon himself cites historical resonances with the work of Harry Nyquist and Ralph Hartley on the first page of his 1948 paper³. Both Nyquist and Hartley, like Shannon, were engineers at Bell Laboratories, the research arm of American Telephone and Telegraph (AT&T)⁴. With the growing reach of AT&Ts

²E. Colin Cherry, "A History of the Theory of Information," *Transactions of the I.R.E. Professional Group on Information Theory* 1 (1953): 22–43. See also James Gleick, *The Information: A History, A Theory, A Flood* (New York: Pantheon Books, 2012).

³Claude E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27 (1948): 379. Reprinted in Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana, IL: The University of Illinois Press, 1949).

⁴Bell Telephone Laboratories Incorporated was incorporated in 1925 with equal ownership being held by AT&T and Western Electric, the engineering and manufacturing arm of AT&T. Bell Labs would engage in fundamental research for AT&T, while working with Western Electric to turn that research into products for distribution throughout the network. See David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics* (Baltimore: Johns Hopkins Univer-

network of telephone lines and undersea telegraph cables, the efficient transmission of “intelligence” (as “information” was originally termed by engineers) became an area of intense research. Especially with respect to first, undersea cables, and later, transcontinental distribution lines, distortions—fluctuations, transients, noise—would make a clearly tapped-out telegraph signal unrecognizable on the receiving end (Figure 5)⁵. Both telegraph and telephone signals were being sent simultaneously on the undersea cables, making problems of distortion and “cross-talk” more prominent. Independently, Nyquist and Hartley determined that there was a limit to the speed by which signals of any form could be sent down the line. Nyquist provided a measure that depended on the total number of potential “values” to be sent, foreshadowing Shannon’s probabilistic definition.⁶ Hartley, choosing to eschew “psychological” factors linked to interpretation and considering only the physical “traces” of a mechanism on photosensitive tape, related Nyquist’s result to the “capacity” of the line (termed “channel”) by stating that “*the total amount of information which may be transmitted over such a system is proportional to the product of the frequency-range which it transmits by the time during which it is available for the transmission*”.⁷ Given that the cables were a limited resource—few people could use it at the same time—and a major source of revenue for AT&T—AT&T charged more to send a telegraph under the ocean than to send it across town—Nyquist and

sity Press, 2002), 113–114.

⁵As Jonathan Sterne notes in *The Audible Past: Cultural Origins of Sound Reproduction*, beginning in the 1850s “listening to the telegraph became the favored method among operators”, rather than reading the impressions made by the apparatus on tape. See Jonathan Sterne, *The Audible Past: Cultural Origins of Sound Reproduction* (Durham: Duke University Press, 2003), 138–154.

⁶Harry Nyquist, “Certain Factors Affecting Telegraph Speed,” *Transactions of the American Institute of Electrical Engineers* XLIII (January 1924): 415.

⁷Ralph Vinton Lyon Hartley, “Transmission of Information,” *Bell Systems Technical Journal* 7 (1928): 555, emphasis in original.

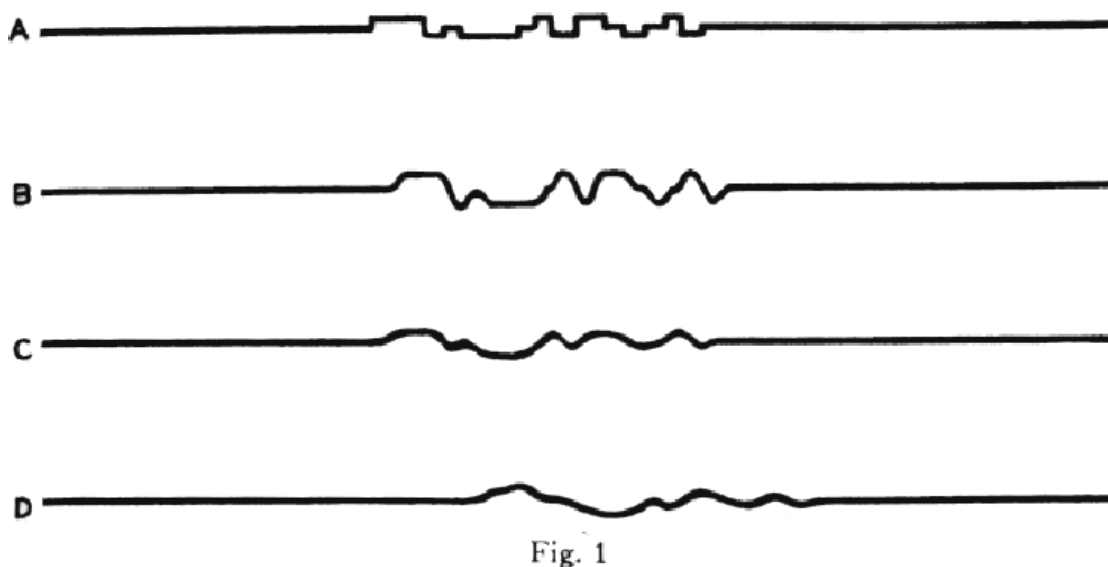


Figure 5: The distortion of a three-level telegraph signal (A) over varying lengths of cable (B–D). From Figure 1 in Hartley, “Transmission of Information,” 537.

Hartley’s results were important for more than just theoretical reasons.

Research into signal transmission was not limited to speech and the telegraph, however. Harvey Fletcher, first an engineer at Western Electric and later Acoustic Research Director at Bell Labs, noted in 1924 that while telephone transmission was tuned specifically for the intelligibility of speech, the spread of the radio had made it important to examine proper transmission of music, for “in the transmission of music or in broadcasting public speeches, the entertainment function makes it important that the naturalness of the speech and music be preserved.”⁸ In a lecture delivered to the joint meeting of the New York Electrical Society and the New York Telephone Society, Fletcher presented an overview of research into the spectral characteristic of different types of sounds, including speech, instrumental (such

⁸Harvey Fletcher, *Physical Properties of Speech, Music, and Noise: A Lecture Outlining the Physical Properties of Speech, Music, and Noise and Their Relation to Transmission Problems* (New York: Western Electric Company Engineering Department, 1924), 1.

as the pipe organ, clarinet, or violin), and “noise”. Fletcher importantly makes distinctions between three different types of noise. The first, known as “line noise”, is due to the “inductive effects of power lines on telephone lines which run parallel” and is still familiar today as the low hum of 60 cycles per second from power lines. The second, known as “room noise”, consists of noise “produced in the room at the listening end” due to “static and the squawks and howls from spark sets and regenerative sets.”⁹ While the engineer works to decrease the effects of these two types of noise in the intelligibility of speech or music, there is a third class that in certain circumstances should not be reduced:

The clapping of hands, the rattling of paper, the hammering of typewriters and the roar from the traffic in the street are typical types of noise. It is sometimes desirable to transmit these noises over the telephone or radio. Of the three classes of sounds discussed, namely speech, music and noise, the latter is by all odds the most difficult to transmit faithfully.¹⁰

Fletcher’s insistence on the importance of these noises evinces his understanding of the vital role of context on the interpretation of sound. Not content to make *a priori* distinctions between what type of sound is noise and what is not, Fletcher instead takes the engineering perspective, noting that “for a transmission system to be ideal, it must reproduce all the frequencies with the same efficiency”¹¹.

⁹Fletcher, *Physical Properties of Speech, Music, and Noise: A Lecture Outlining the Physical Properties of Speech, Music, and Noise and Their Relation to Transmission Problems*, 18, 19.

¹⁰*Ibid.*, 18.

¹¹*Ibid.*, 25. Fletcher was also involved in Bell Labs research regarding the “deaf” or “hard of hearing”. In this context he developed new devices to measure “average” hearing, but also investigated the effect

Even with Fletcher's expanded notion of noise, others at Bell Labs conducted research to simultaneously define the *minimum* elements necessary for intelligible speech, as well as to construct a secret speech transmission system. This necessitated an elimination of all three classes of noises and a reduction of speech far beyond its already bandlimited presence. To this end, Homer Dudley developed his famous Vocoder, publishing a paper on its workings in 1939¹². Short for "voice coder", the Vocoder analyzed the electric speech signal, divided it into ten frequency "bands" that were then sampled at 25 cycles per second each, and combined this with a separate channel for the transmission of pitch¹³. While the Vocoder drastically altered speech, Dudley noted that "the essential contribution to intelligibility comes from the spectrum while the emotional content is due chiefly to the pitch, particularly to the inflection of the pitch. Speech formed from either the hiss alone or the buzz is quite intelligible, the former sounding like a coarse whisper, the latter like a monotone chant".¹⁴ This ability to alter speech would be vital for the impending war, where Ralph Potter, another researcher at Bell Labs, would direct Project X, a highly-classified project to use the Vocoder in encrypted telephone transmissions amongst Allied leaders¹⁵. In order to mislead even the most-

of "noise" on the intelligibility of speech. For a detailed account of this research see Mills, "Deafening: Noise and the Engineering of Communication in the Telephone System."

¹²Homer Dudley, "Remaking Speech," *Journal of the Acoustical Society of America* 11, no. 2 (1939): 169–177. In this paper Dudley notes that the literature on speech analysis is "so large that no attempt has been made to provide references." Nevertheless, a "dial-controlled electrical synthesizer of simple speech sounds" was "demonstrated publicly by Fletcher in February, 1924". See *ibid.*, 169.

¹³Traditionally speech was transmitted over a frequency range of at least 3000 cycles per second, meaning that the Vocoder compressed the amount of information (or possibilities, in the language of Nyquist or Hartley) by a factor of ten.

¹⁴Dudley, "Remaking Speech," 177.

¹⁵"For reasons of secrecy the basic patents and all details were withheld until 1975". M. D. Fagen, ed., *A History of Engineering and Science in the Bell System: National Service in War and Peace (1925–1975)* (Murray Hill, NJ: Bell Telephone Laboratories, Incorporated, 1978), 297.

determined German eavesdroppers, Potter and the other members of Project X would overlay the Vocoder signals on top of recordings of thermal noise produced by the Muzak Corporation that were impressed on acetate, and then vinyl, records. Not only did the records need to be delivered to both the transmitting and receiving ends of the Vocoder terminals (in places such as London, Paris, North Africa, and a barge that tracked General Douglas MacArthur through battles in the Pacific), but both records had to be started in perfect synchrony, necessitating the development of some of the most accurate clocks of the time¹⁶. Potter was not only directing Project X; he too developed means for the visual analysis of speech. Like Fletcher, Potter was also interested in developing tools for the deaf. His “sound spectrograph” “opens the prospect of some day enabling totally deaf or severely deafened persons to use the telephone and the radio or to carry on direct conversation by visual hearing” (Figure 6).¹⁷ Simultaneously, this new mechanism of visualizing speech had been supported by the war effort: “Because of related war interests it was given official rating as a war project, and has progressed far enough during the war period to justify its being brought now to public attention”¹⁸.

¹⁶For more information on these aspects of the Vocoder, and its influence on different strands of music, including rap, hip-hop, and electronica, see Dave Tompkins, *How to Wreck a Nice Beach: The Vocoder From World War II to Hip-Hop: The Machine Speaks* (Brooklyn: Melville House Publishing, 2010). For a technical explication see Fagen, *A History of Engineering and Science in the Bell System: National Service in War and Peace (1925–1975)*, 291–317. In physics, “white noise” is defined to be equal power across all frequencies, meaning that it is equally likely to find one frequency as another. A measurement of “thermal noise”, such as from a vacuum tube, is impossible to reconstruct without the original noise “source” and is assumed to be impossible to predict. By overlaying the vocoder signals on top of the recordings of noise at the transmitting end, the receiving end could simply “subtract” the noise from the received signal, assuming they had the same record and it was synchronized to the transmitter. To an eavesdropper, it would indeed sound like static.

¹⁷Ralph K. Potter, “Visible Patterns of Sound,” *Science* 102, no. 2654 (1945): 463.

¹⁸*ibid.*, 463. Mara Mills, in a detailed study of Potter’s research on tools for the deaf, suggests that Potter’s team “built the sound spectrograph as the vocoder’s twin, a code-breaker”. See Mills, “Deaf Jam,” 39. In Bell Labs’ own history of the Vocoder project it is noted that Potter’s sound spectrograph

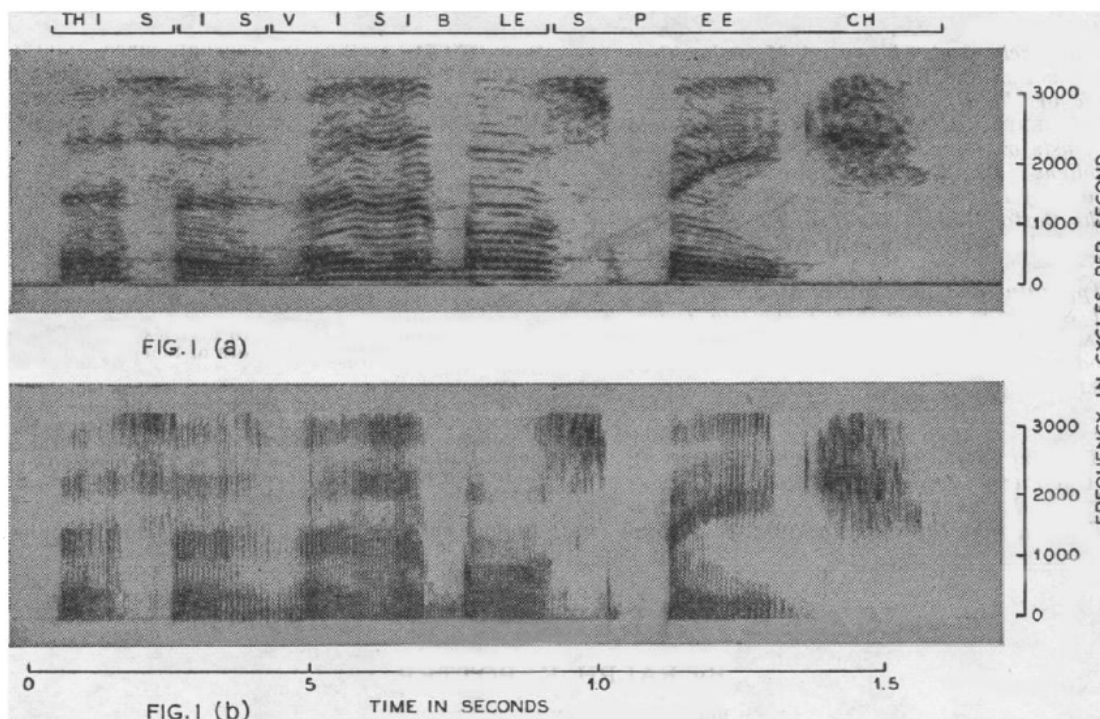


Figure 6: Visible speech spectrogram, with darker regions showing areas of resonance at different frequency levels while someone speaks, “This is visible speech”. From Potter, “Visible Patterns of Sound,” 464.

Potter’s sound spectrograph made material what had not yet been defined in a rigorous mathematical way. Yet this definition was to come in the guise of a “Theory of Communication”. Dennis Gabor, a Hungarian-British scientist and engineer, published a three-part paper with this title in 1946¹⁹. Gabor’s approach made clear existing deficiencies in the representation of signals whose frequency changes in time. Signals, as measured by the scientist or engineer, are usually given as some function of amplitude (height, voltage, pressure, etc.) over time. Since the nine-enabled trained observers to to not only determine the identity of the speaker, but also the means by which the speech was obfuscated. See Fagen, *A History of Engineering and Science in the Bell System: National Service in War and Peace* (1925–1975), 293.

¹⁹Gabor (1900–1979) won the Nobel Prize in Physics in 1971 for his development of holography. Gabor’s work has also found wide application in neuroscience, image processing and sonic production, the latter via “granular synthesis”; see Curtis Roads, *Microsound* (Cambridge, MA, USA: MIT, 2001).

teenth century it had been known that one could convert most signals as a function of time ($s(t)$) into signals as a function of frequency ($S(f)$) using the Fourier transform. The Fourier transform would “decompose” a given signal into an infinite sum of “elementary” functions, customarily chosen as the sinusoids (such as the $\sin t$ or $\cos t$ of trigonometry)²⁰. Yet the Fourier transform removes any temporal information; a signal that exists only as a function of frequency cannot provide information about how that frequency might change over time. Gabor notes that our physical intuition—especially our auditory experiences—does not exist at either extreme, at either the limits of instants of time ($s(t)$) nor infinitely extending signals of a given frequency ($S(f)$).²¹ This created a paradox: “If the term ‘frequency’ is used in the strict mathematical sense which applies only to infinite wave-trains, a ‘changing frequency’ becomes a contradiction in terms, as it is a statement involving both time and frequency”.²² Gabor suggests that the two extant methods for measuring the frequency characteristics of signals—the oscillograph and a bank of reeds—could be combined to give precise temporal *and* frequency data for a given signal, noting that aspects of this already existed in Potter’s sound spectrograph.

Yet there was a limit to the precision of simultaneous measurements of time and frequency. Gabor showed that there is not an infinite ability to resolve *both* time and

²⁰Briefly, for a signal $s(t)$ its Fourier transform is defined as $S(f) = \int_{-\infty}^{\infty} s(t)e^{-2\pi ift} dt$ and the inverse Fourier transform as $s(t) = \int_{-\infty}^{\infty} S(f)e^{2\pi ift} df$. This form of the transform depend on Euler’s identity, whereby $e^{2\pi i\theta} = \cos 2\pi\theta + i \sin 2\pi\theta$. Euler’s identity allows simpler mathematical manipulation while also enabling decomposition of a signal into sinusoids. For more information, see any standard engineering textbook on communication theory, such as Allan V. Oppenheim, Alan S. Willsky, and S. Hamid Nawab, *Signals and Systems*, 2nd ed. (New York: Prentice Hall, 1996).

²¹Dennis Gabor, “Theory of communication. Part 1: The analysis of information,” *Journal of the Institution of Electrical Engineers - Part III: Radio and Communication Engineering* 93, no. 26 (November 1946): 429.

²²*Ibid.*, 431.

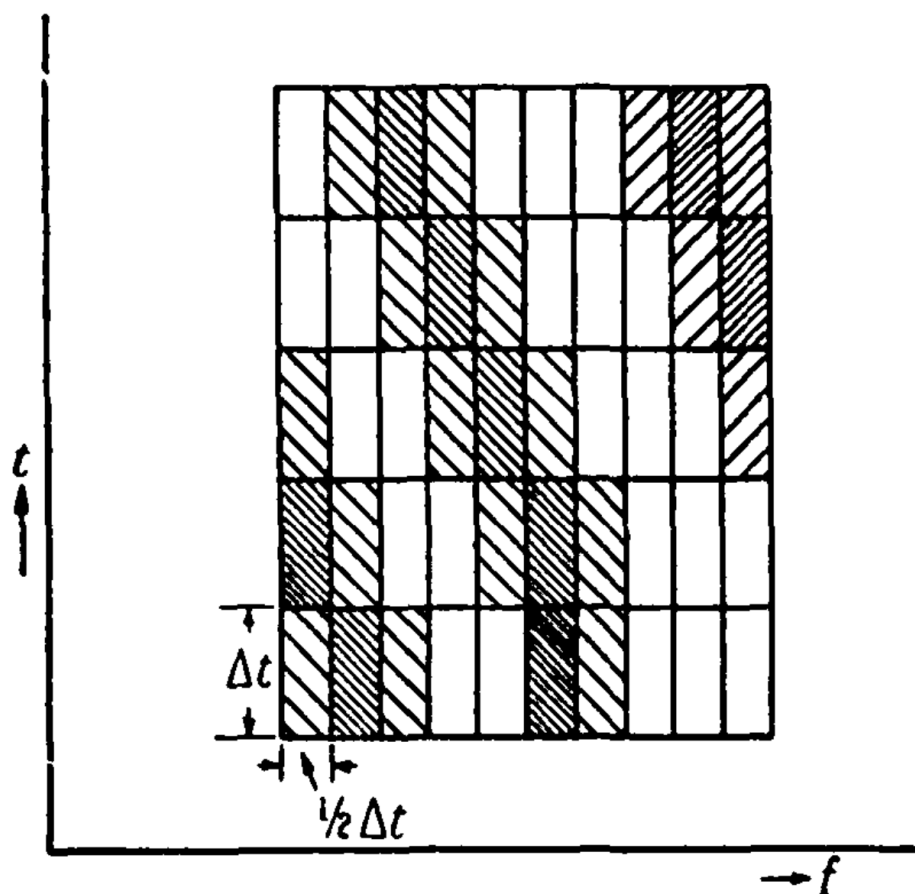


Fig. 1.7.—Representation of signal by logons.

Figure 7: Gabor's visual representation of the logon. From Gabor, "Theory of communication. Part 1: The analysis of information," 435.

frequency simultaneously. In other words, they are inextricably linked by way of an uncertainty relationship, in direct comparison to the one found in quantum mechanics for position and momentum by Werner Heisenberg²³. Gabor uses this re-

²³This inequality is $\Delta t \Delta f \geq \frac{1}{2}$, where Δt refers to change in time and Δf refers to change in frequency. Precise measurements of the frequency or temporary content of a signal was never in question, as it was only limited by the precision of a given measurement apparatus. Instead, Gabor's uncertainty relationship indicated that no matter how precise an instrument one has, there were always limits to its ability to resolve time and frequency at the same time. This comparison with the Heisenberg uncertainty principle is only analogical; Gabor does not suggest that his formulation has a basis in quantum mechanics.

lationship to motivate his new definition of information via a visual representation shown in Figure 7. The boxes of the grid were to be called “logons”: “Each of these areas, with its associated datum, represents, as it were, one elementary quantum of information, and it is proposed to call it a *logon*.”²⁴ The amount of shading in each box of the grid determined the magnitude of the logon. The x axis represented frequency, the y axis time, and thus the size of each side of the box must follow the uncertainty relationship. In the limit as one length of the box becomes infinitely small, we reproduce either the Fourier transform or its inverse. Logons thus rationalize Potter’s visible speech and define the ultimate limits of his apparatus, suggesting a potential unit of measure for the capabilities of hearing; they also provide theoretical support for the surprising intelligibility of Dudley’s Vocoder.²⁵ The logon formulation would influence Homer Jacobson, a researcher at Brookhaven National Laboratories, in his attempts to measure how well different forms of sonic reproduction match the resolving capacity of the human ear. Jacobson described the sound spectrograph as a machine that measured “logon intensities” and hypothesized that Gabor’s more precise formulation could itself be used as a recording medium.²⁶

Contemporaries of Shannon’s Theory

The context of Shannon’s paper should now be more clear. While initially Shannon’s information theory might appear to be a singular event, its situatedness within

²⁴Gabor, “Theory of communication. Part 1: The analysis of information,” 435, emphasis in original.

²⁵Dennis Gabor, “Theory of communication. Part 2: The analysis of hearing,” *Journal of the Institution of Electrical Engineers - Part III: Radio and Communication Engineering* 93, no. 26 (November 1946): 442–445.

²⁶Homer Jacobson, “Information and the Human Ear,” 23, no. 4 (1951): 463–471.

a milieu of research on communication—civilian and military—across a diverse set of media is without a doubt. Shannon importantly placed the dependence on *probability* on a more rigorous mathematical foundation. It was clear to the engineers by this point that the definition of information—for it was an engineering *definition*, not a mathematical representation meant to align with physical experiments—necessitated an attention to two things: the potential choices that could be made when sending a message and the relative frequency of occurrence of each choice. Nyquist already noted this when, in his derivation of a measurement of “intelligence,” he wrote that “it would be necessary to make an assumption as to the relative frequencies of the various characters.”²⁷ Hartley could write an equation of the form $H = n \log p$ to describe the “information” of a set of n elements with probability p , yet this moves little beyond Nyquist’s formulation as it still fails to take into account potentially different probabilities for each element.²⁸ Shannon, by a combination of the analysis of word frequency in English and “transition probabilities” between different words via a Markov process, incorporated this into his famous equation $H = -K \sum_{i=1}^n p_i \log p_i$; in short, the measure of “information” of any source was given by a sum over all possibilities (n) of the probability of a given element (p_i) in the source multiplied by the logarithm of the probability of that element²⁹. For example, in English the letter “u” follows the letter “q” more often than not; the

²⁷Nyquist, “Certain Factors Affecting Telegraph Speed,” 420.

²⁸Hartley, “Transmission of Information,” 540.

²⁹Shannon, “A Mathematical Theory of Communication,” 393. Markov processes are ones where the probability of any event depends on some number of events prior. So, for example, in a first-order Markov process the probability of an event depends on the event just prior to it, a second order depends on the event two times before it, and so on. Markov processes are characterized via tables or matrices of “transition probabilities” between any two events. We will come across Markov processes in the next chapter when listening to the early days of electronic music.

letter “e” is more common than the letter “z”; and so on. Such relationships were already noted by Samuel Morse in his telegraphic code; sending the letter “e” requires fewer keypresses than the letter “z”.

Shannon famously removed meaning from consideration, writing that these “semantic aspects of communication are irrelevant to the engineering problem.”³⁰ Warren Weaver, then-director of the Division of Natural Sciences at the Rockefeller Foundation, suggested that while Shannon’s removal of “meaning” was an important factor in the engineering problem, there were of course other levels of communication as well. Shannon’s approach was Level A, the “technical” problem, while Level B was the “semantic” problem (“How precisely do the transmitted symbols convey the desired meaning?”) and Level C was the “effectiveness” problem (“How effectively does the received meaning affect conduct in the desired way?”).³¹ Connecting the implications of Level C to questions of the “aesthetic” in fine arts and “propaganda” in the case of speech, Weaver suggests that levels B and C might ultimately overlap.³²

Noting that the form of his equation was similar to that given for “entropy” in statistical mechanics by Boltzmann, Shannon formed an equivalence between information and entropy. Being a measure of “disorder”, Shannon’s linkage of information and entropy meant that the more disordered, noisy, or unexpected a message, the greater its informational content. Norbert Wiener, however, took the opposite view. In his independent derivation of information the negative sign is not present; an increase of information means a decrease in entropy, or, in Wiener’s words, “the

³⁰Shannon, “A Mathematical Theory of Communication,” 379.

³¹Shannon and Weaver, *The Mathematical Theory of Communication*, 96.

³²*Ibid.*, 97.

processes which lose information are, as we should expect, closely analogous to the processes which gain entropy”.³³ In a sense, even though it is not explicitly stated by Wiener, this definition already takes into account the receiver of the information: information should cause uncertainty about the world to decrease, thereby decreasing entropy, rather than the inverse as with Shannon. This conundrum would also lead Léon Brillouin, a French physicist then working for IBM, to, like Wiener, work from negative entropy or “negentropy”. Brillouin would embed this within a much more complicated context than Shannon, considering the role of an increase of information on the energetics of a system in order to save the Second Law of Thermodynamics, which says that the entropy of a closed system remains constant or increases, but never decreases³⁴.

This field of research, messy as it was, came together in the United Kingdom from 26–29 September, 1950 for the first symposium on Information Theory, sponsored in part by the Royal Society, the UK Ministry of Supply, and the British Broadcasting Corporation³⁵. As mentioned earlier, presenters included Shannon,

³³Norbert Wiener, *Cybernetics: or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1961 [1948]), 64.

³⁴Léon Brillouin, “Thermodynamics and Information Theory,” *American Scientist* 38 (1950): 594–599. N. Katherine Hayles understands Brillouin and Shannon as looking in opposite directions regarding entropy, suggesting that since AT&T, Shannon’s employer, “made its living by satisfying people’s curiosity”, it had an incentive to increase uncertainty: the “more uncertain people were...the more telegrams they sent, phone calls they made, information they required”. See N. Katherine Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (Ithaca, NY: Cornell University Press, 1990), 31–60; for the quote, 59. However, I think Hayles’ explanation moves too quickly to an economic explanation for what she terms “Shannon’s Choice”. Rather, I understand Shannon facing the difficulty of shoehorning an engineering definition into the pre-existing semantics of the word “information”.

³⁵*Transactions of the I. R. E. Professional Group on Information Theory* 1 (1953). The Second London Symposium was held in 1952, while the third was held in 1955. See, respectively, Willis Jackson, ed., *Communication Theory*, Papers read at a Symposium on “Applications of Communication Theory” held at the Institution of Electrical Engineers, London, September 22nd–26th 1952 (New York, NY, USA: Academic Press, Inc., 1953) and Colin Cherry, ed., *Information Theory*, Papers read at a Sympos-

Gabor, Cherry, the physicist Donald MacKay, and the neurophysiologist and cybernetics researcher W. Grey Walter. Attending, but not presenting, were W. Ross Ashby and Alan Turing. Cherry opened the proceedings by giving a paper on the history of information, already referenced, that touched on issues of coding and cryptography, real and artificial brains, cybernetics and behaviorism.³⁶ MacKay's paper is important for how it both responds to Shannon's cleavage of meaning from information as well as brings in Gabor's logon theory. Recall that for Shannon, meaning had to be separated from the message in order to provide a rigorous mathematical definition. Yet for MacKay, this is unsatisfying: "information" is semantically a polyvalent term and therefore its mathematical form should take this into account. MacKay thus proposed three different forms of information. The first, termed "structural", refers to the number of "degrees of freedom" of a given measurement apparatus.³⁷ Consider an example given by MacKay of sheep jumping over a gate: we could simply count the number of sheep that jump over the gate; or, with the aid of a stopwatch, we could both count the sheep as well as record *when* they jumped over the gate. The second method would, in MacKay's terminology, give us more structural information as we have two independent means of making measurements: one sequence of numbers that records the number of sheep, and

sium on "Information Theory" held at the Royal Institution, London, September 12th to 16th 1955 (London, UK: Butterworths Scientific Publications, 1956). Many more papers were presented at these latter two events, including participation in both by Werner Meyer-Eppler, an important figure in the development of electronic music in the 1950s and discussed further in Chapter 2. Additional attendees included J.C.R. Licklider and Abraham Moles. The transcripts of these events importantly include the discussion following each paper, allowing one to both understand the controversies over definitions as well as to infer attendance absent a precise list of participants.

³⁶Cherry, "A History of the Theory of Information."

³⁷Donald MacKay, "Quantal aspects of scientific information," *Transactions of the I.R.E. Professional Group on Information Theory* 1, no. 1 (1953): 66.

a paired sequence that records the times of their jumps.³⁸ The unit of structural information is the “logon”, as in Gabor’s formulation. The second, termed “metrical”, refers to the precision of our measurements, whereby the “metron-content can be thought of as the number of elementary events which have been subsumed under one head or ‘condensed’ to form it”;³⁹ one then can speak of metrons per logon. MacKay suggests that these two types of information can be related within an abstract “information space” where the number of axes, or dimensions, of the space are given by each different logon, or unit of structural information; the square of the length of an “information vector” is then the “metron-content”.⁴⁰ This information space becomes important for MacKay’s final category of information, termed “selective information”. Like the other definitions of information defined earlier, selective information is related to the number of possibilities we have. In MacKay’s rigorous definitions the information space is quantized, and thus the amount of selective information is related to the total number of potential points within the information space.⁴¹ In MacKay’s view, each of these three potential forms of information are appropriate for different applications: “There is certainly no question of advocating the first two as against the third, or vice versa.”⁴² In other words, while it is true that one can increase the amount of selective information by simply increasing either the number of dimensions one is measuring (increasing the number of logons) or increasing the precision of any given measurement (increasing the metron-content),

³⁸Donald MacKay, “The nomenclature of information theory,” *Transactions of the I.R.E. Professional Group on Information Theory* 1, no. 1 (1953): 13.

³⁹*Ibid.*, 14.

⁴⁰MacKay, “Quantal aspects of scientific information,” 72–73.

⁴¹*Ibid.*, 74.

⁴²*Ibid.*, 75.

this might not always be desirable.

Indeed, MacKay's take on the question of "randomness" versus "unforeseeableness" is interesting for how it takes into account *meaning*. While any measurement in a large information space might be "unforeseeable", it might not matter if nothing had been expected in the first place. Similarly, a purely random result will always be unforeseeable, but it might not increase the amount of selective information because it does not inform the experimenter:

But the larger the random noise component in a result, the *smaller* will be the number of significantly distinct representations which the observer will have prepared. His aim is not to describe exactly what he observes, but what he can assert with reasonable probability *to be the case*—i.e. to be reproducible. He is no doubt perpetually being surprised by the noise-structure of his result. But he gains no selective information from it because he has prepared nothing in his ensemble which it can tell him to select. It is only when in a communication-system someone deliberately reproduces a recorded (and recognisable) noise-signal and transmits it as a code-signal, that its noise-like properties have any merit.⁴³

MacKay highlights an alternative to Shannon's notion of information, and his understanding of noise resonates with Fletcher's understanding of the role of context in the transmission of sound. Like N. Katherine Hayles and Mark Hansen, I consider MacKay as an important counterweight to and information theory divorced

⁴³MacKay, "Quantal aspects of scientific information," 76, emphasis in original.

from meaning⁴⁴. For MacKay, selective information is formulated and measured in much the same way as Shannon, yet it remains a pointless exercise if we have not created a frame in which to evaluate it⁴⁵. In the same way, a purely random signal, one that is highest in information in Shannon's formulation, is only so when *intended* by the transmitter. Intention and interpretation remain wedded to information, an attempt to reconcile the customary semantics of the word "information" while providing an operational, mathematical definition.

A different attempt to deal with the question of meaning can be found in the paper presented by D. K. C. MacDonald, a British physicist. MacDonald's work has not been remarked upon by scholars of this period, nor was his work taken up in any appreciable fashion by contemporary scholars of information theory. Yet MacDonald's formulations both give noise an important role in the production of knowledge, as well as raise an important issue in the temporal dynamics of the gathering of information. In "Fluctuations and Theory of Noise", MacDonald notes that there is a paradox between a given mathematical formalism, which would state the behavior of a system "throughout the realm of all time", and the fact that no physical system behaves exactly as predicted.⁴⁶ For MacDonald, it is precisely these fluctuations, or

⁴⁴See N. Katherine Hayles, *How We Became Posthuman : Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University Of Chicago Press, 1999), 54–56 and Mark. B. N. Hansen, "Cinema Beyond Cybernetics, or How to Frame the Digital Image," *Configurations* 10, no. 1 (2002): 69–78. Heims suggests that the context of MacKay's later philosophical thoughts on his approach must be understood in the "circumstance of his religious piety and the explicit effort to reconcile it with the Bible and his Calvinistic faith". See Steve Joshua Heims, *The Cybernetics Group* (Cambridge, MA, USA: MIT Press, 1991), 112.

⁴⁵"The bottom line for MacKay is that information remains meaningless in the absence of a (human) framer, and that framing cannot be reduced to a generic observational function, but encompasses everything that goes to make up the biological and cultural specificity of this or that *singular* receiver". Hansen, "Cinema Beyond Cybernetics, or How to Frame the Digital Image," 77, emphasis in original.

⁴⁶D. K. C. MacDonald, "Fluctuations and theory of noise," *Transactions of the I.R.E. Professional Group on Information Theory* 1, no. 1 (February 1953): 114.

random deviations in an otherwise perfectly defined system, that have the potential to “add significantly to our knowledge”.⁴⁷ MacDonald writes that,

In many situations to-day noise itself—as its name suggests—is regarded as an essentially undesirable intrusion whose influence on our measurements we wish to minimise. [...] On the other hand, it seems wise here to emphasise that a fluctuation itself may be a powerful source of information. The classic example is of course the original Brownian movement which finally settled the molecular theory controversy engendered by Ostwald’s school of “Energetics”. Again to-day the observation of electrical noise in crystal rectifiers, for example, can provide valuable aids to the theoretical investigations, In particular the “brain-waves” observed by the electro-encephalographer could well at first have been called noise, and we may interpret the regularities observed in the auto-correlation function of the records as appropriate to the transmission system of the brain whereby they are communicated to us.⁴⁸

MacDonald’s point is that the situations where noise can be considered “undesirable” are not easy to determine *a priori*; rather, certain aspects of “noise” can become generative for new forms of scientific knowledge. He continues these thoughts in a later paper, suggesting that, “It appears however that the measure H [Shannon’s definition of information] is *not* suited for the assessment and discussion of new

⁴⁷MacDonald, “Fluctuations and theory of noise,” 115.

⁴⁸Ibid., 118.

knowledge, and we shall try here to find a more appropriate measure for this latter ‘quantity.’ Apart from any academic or aesthetic considerations, this can only be of ultimate value if we find that such a measure can be used numerically to assess satisfactorily our gain or otherwise in some change of situation of primary knowledge.”⁴⁹ New knowledge could come from the fluctuations that were deemed as undesirable noise. MacDonald, using a technique similar to Shannon’s whereby the desired form of an equation shapes how it is derived, defines a new measure ΔI that encapsulates the change in “knowledge” after an experiment and that importantly is “*relative to the situation at hand*”⁵⁰. Returning to the question of noise, MacDonald writes:

We may perhaps sum up by saying that any communication system (in its most general sense) which has reached a state of “perfection” where all “redundancy” (or lack of efficiency as a conventional communication system) has been eliminated is impotent to produce new knowledge. While necessity may be the mother of invention it appears that efficiency is not always the father of knowledge.⁵¹

MacDonald’s brief but intriguing comments seem to have fallen on deaf ears; there are no citations I can find to either of these papers, save one. In a response to MacDonald’s definition of a change in information, A. Gamba in 1954 faults him for developing a measure that cannot be made harmonious with the definitions of en-

⁴⁹D. K. C. MacDonald, “Information Theory and Knowledge,” *Journal of Applied Physics* 25, no. 5 (May 1954): 619, emphasis in original.

⁵⁰*ibid.*, 621, emphasis in original. He continues: “it is meaningless in general to ask whether a sonata by Beethoven is ‘better’ (or ‘worse’) than a picture by Picasso.”

⁵¹*Ibid.*, 622.

trophy and the Second Law of Thermodynamics.⁵² What began for Shannon as a convenient resonance—the similarity between his definition of information and the definition of entropy in thermodynamics—had become in a few short years an unbreakable relationship for some information theorists, one whose postulates could not be violated.

As sketched in this excursus, information theory in both its immediate antecedents and its early history is messy with approaches contingent on disciplinary pedigree and philosophical orientation. My goal has not been to provide a comprehensive overview of these other information theories, but rather to select from a wealth of examples the ones most salient for my later arguments, namely those that impact on the uptake of information theory in electronic music, as well as the alternative approaches to the problematic of noise. This messiness of competing definitions and openness of what is known as “information theory” has been documented by Bernard Geoghegan, Ronald Kline, and to a lesser extent Hayles⁵³. Yet in all three cases the focus is on how information theory plays out in scientific, engineering, or psychological contexts. If we expand our purview to realms of artistic practice we will discover an alternate yet complimentary world, one where information theory became a generative model for new forms of aesthetic production.

⁵²A. Gamba, “Information Theory and Knowledge: Remarks on a Paper by D. K. C. MacDonald,” *Journal of Applied Physics* 25, no. 12 (December 1954): 1549.

⁵³See Kline, “What Is Information Theory a Theory of? Boundary Work among Information Theorists and Information Scientists in the United States and Britain during the Early Cold War” and Geoghegan, “Historiographic Conceptualization of Information: A Critical Survey.” Kline focuses on how boundary work demarcated the limits of the “field” of information theory, while Geoghegan categorizes the extant histories of information theory into different “genres” such as intellectual, official, institutional, national, and material.

Chapter 2

The Sounds of Information Theory

The unprecedented divergence between contemporary serious music and its listeners, on the one hand, and traditional music and its following, on the other, is not accidental and—most probably—not transitory. Rather, it is a result of a half-century of revolution in musical thought, a revolution whose nature and consequences can be compared only with, and in many respects are closely analogous to, those of the mid-nineteenth-century revolution in theoretical physics.¹

The February 1958 edition of the music magazine *High Fidelity* contained the American composer Milton Babbitt's now-infamous article, originally entitled "The Composer as Specialist". Changed by the editors of the magazine to "Who Cares if You Listen?", and sandwiched in its ending pages amongst advertisements for the "Glowmaster' AM-FM-SW Hi-Fi Tuner" and a "Fabulous 'Needle That Remembers'", Babbitt denied that contemporary music needed to cater to the popular tastes of the general public. For Babbitt, as indicated in the epigraph, developments in the

¹Milton Babbitt, "Who Cares if You Listen?," *High Fidelity Magazine* VIII, no. 2 (February 1958): 38.

first half of the twentieth century had transformed musical production into a specialized field, one that depended on a set of techniques that were as unintelligible to the untrained listener as a lecture on “Pointwise Periodic Homeomorphisms” would be to someone ignorant of the latest developments in mathematics². Babbitt suggested that contemporary composers enact a “withdrawal” into the “private life” of the university—a comment that would, along with the title of the essay, be repeated uncharitably by readers of his jeremiad ever since.³

Nevertheless, Babbitt’s comments contain an element of truth to them, as the compositional practices of serialism and then-current developments in the use of electronics and computers required a high degree of technical sophistication, both in terms of listening comprehension and practical production. For Babbitt this requires no lament, as it has ultimately increased the “efficiency” of music whereby the redundancies of diatonic harmony are respected no more:

First. This music employs a tonal vocabulary which is more “efficient” than that of the music of the past, or its derivatives. This is not necessarily a virtue in itself, but it does make possible a greatly increased number of pitch simultaneities, successions, and relationships. This increase in efficiency necessarily reduces the “redundancy” of the language, and as a result *the intelligible communication of the work demands increased accuracy from the transmitter (the performer) and*

²For the context of this fake presentation title, see Babbitt, “Who Cares if You Listen?,” 40. Babbitt was interested in mathematics his entire life, even serving on the mathematics faculty at Princeton during World War II. See Milton Babbitt, *A Life of Learning*, ACLS Occasional Paper, No. 17, Charles Homer Haskins Lecture, 1991.

³Babbitt, “Who Cares if You Listen?,” 126.

activity from the receiver (the listener). Incidentally, it is this circumstance, among many others, that has created the need for purely electronic media of “performance.” More importantly for us, it makes ever heavier demands upon the training of the listener’s perceptual capacities.⁴

Only a decade after the publication of Claude Elwood Shannon’s “A Mathematical Theory of Communication” in the *Bell System Technical Journal*, Babbitt mobilizes the language of information theory as his first argument against those who would desire “clear” communication in music. The entirety of musical production and reception becomes transformed in the highlighted phrase: the composer becomes a “transmitter” and the public, in its guise as a listener in the concert hall or in front of a “high fidelity” sound system there or at home, becomes the “receiver”. In terms of Shannon’s particular definition of information theory, a decrease in redundancy results in higher entropy and thus a larger amount of information; in other words, there is more chance for surprise at the resulting musical “message”. And since the message is now more efficient than before it requires specialized means of (re)production, those of “purely electronic media” such as synthesizers and hi-fi sound systems. In the language of mathematics, Babbitt creates an isomorphism between Shannon’s famous diagram (Figure 8) and the relationships between composers and the listening public. This is *created*, as work must be done to establish these connections. Composers (transmitters) needed to learn new techniques of sound manipulation, and receivers (listeners) required training in new forms of lis-

⁴Babbitt, “Who Cares if You Listen?,” 39, emphasis added.

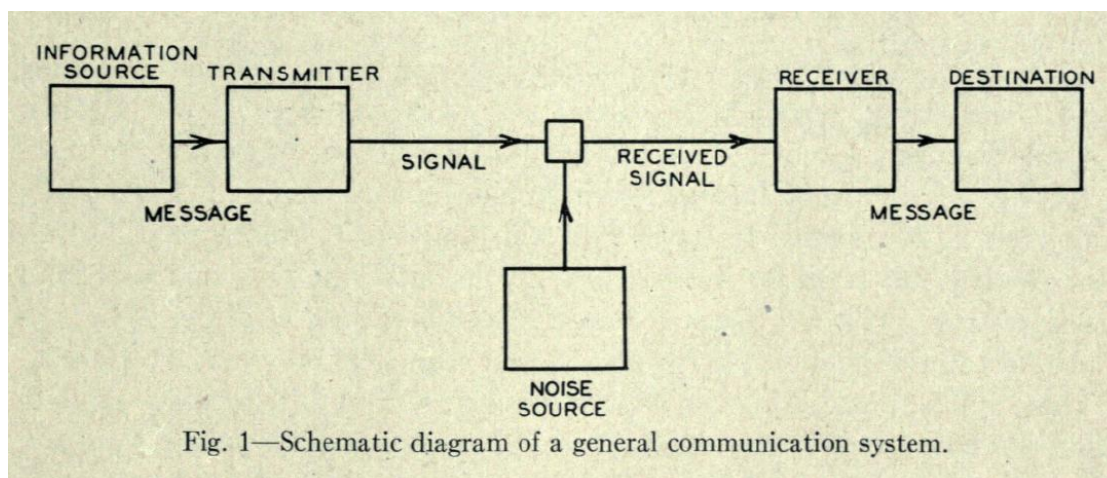


Figure 8: Diagram of the communication situation. From Shannon, "A Mathematical Theory of Communication," 381.

tening. Such training is of a piece with the paired fear and desire associated with post-war scientific and technological development.

Babbitt's translation of information theory into the domain of music is not an anomaly. Throughout the 1950s and into the 1960s, composers, technicians, musicologists, and engineers used the language of information theory to develop new techniques for the production and analysis of music. Rather than being an isolated occurrence, Babbitt's usage of terms such as "redundancy", "transmitter", and "receiver" are of a piece with then-current experiments and controversies in *elektronische musik*, *musique concrète*, tape music, computer music, and musicology. Nevertheless, there is a curious lack of scholarship, historical or otherwise, on the joint development of information theory and music during this time period⁵. An atten-

⁵Three exceptions should be noted. In a work of meticulous attention to musicological detail, Christoph Both surveys some of the important information theoretical work of the time and uses it to analyze compositions by Lejaren Hiller and Karlheinz Stockhausen. While my approach slightly diverges from Both and responds to different theoretical issues, his work is a vital analysis of this period. See Christoph Both, "The influence of concepts of information theory on the birth of electronic music composition: Lejaren A. Hiller and Karlheinz Stockhausen, 1953–1960" (PhD diss., University of Victoria, 1995). M. J. Grant, in her *Serial music, serial aesthetics: Compositional theory in post-war Europe*,

tion to the technical discussions of the time, in both specialized engineering and musical journals, highlights the importance of information theory. As such, I turn to these journals as an archive in their own right, pulling out the threads that link mathematical equations presented in engineering publications with ruminations on the connections between information theory and musical meaning found in journals of musicology. This does more than fill a hole in our historical account; rather, it both attunes us to the interferences between academic fields at the time as well as reworks our understanding of the relative importance of information theory to composers and musicians.

While Bernard Geoghegan has recently argued that information theory during this period was an area of “hypothetical inquiry for a small and specialized community of engineers,” I will show instead that it was an area of vibrant discussion and experimentation amongst a set of not only engineers but musicologists and composers as well, all involved in creating new forms of musical production.⁶ Leonard Meyer, a key figure of mid-century musicology who remains an important influence in contemporary music psychology, extended his own understanding of musical meaning through recourse to the probabilistic basis of information theory.⁷ Harry Olson and Herbert Belar of RCA Laboratories in Princeton, NJ created a new elec-

examines the context of serialism in post-war West Germany via a close reading of texts in the journal *die Reihe*. Grant pays attention both to the influence of physics and information theory on experiments in serialism, as well as the cultural conditions of life after *Stunde Null*. See M. J. Grant, *Serial music, serial aesthetics: Compositional theory in post-war Europe* (Cambridge, UK: Cambridge University Press, 2001). Finally, Robin Maconie questions why information theory has not been explored in detail with respect to Babbitt’s work; see Robin Maconie, “Care to Listen: Milton Babbitt and Information Science in the 1950s,” *Tempo* 65, no. 258 (2011): 20–36.

⁶Geoghegan, “From Information Theory to French Theory: Jakobson, Lévi-Strauss, and the Cybernetic Apparatus,” 97.

⁷Leonard B. Meyer, “Meaning in Music and Information Theory,” *The Journal of Aesthetics and Art Criticism* 15, no. 4 (1957): 412–424.

tronic synthesizer that would become the centerpiece of the Columbia-Princeton Electronic Music Center at the end of the 1950s.⁸ Werner Meyer-Eppler lectured on information theory to a group of composers in Germany, influencing Karlheinz Stockhausen and Pierre Schaeffer, among others.⁹ Abraham Moles, who worked with Schaeffer and Meyer-Eppler during the 1950s and visited the US on a grant from the Rockefeller Foundation, wrote extensively on the relationships between information theory and aesthetics, especially the perception of sound.¹⁰ This brief list, which I extend and examine below, begins to show the importance of information theory outside of a hermetic communications laboratory. Listening to how a form of engineering discourse impacted the development of the arts—in my case, music—forces us to rework the known histories of this time period. Thus looking at artistic research concomitant with the development of information theory in the 1950s expands our understanding of the ways in which artists and engineers worked together, presaging more well-known collaborations in the 1960s such as Experiments in Art and Technology (EAT), New Tendencies, and the Center for Advanced Visual Studies (CAVS).¹¹

Similarly, my focus on information theory contrasts with one that would highlight *cybernetics* instead. During this time period cybernetics understood systems—

⁸Harry F. Olson and Herbert Belar, "Electronic Music Synthesizer," *Journal of the Acoustical Society of America* 27, no. 3 (1955): 595–612.

⁹Otto Luening, "An Unfinished History of Electronic Music," *Music Educators Journal* 55, no. 3 (1968): 42–49, 135–142, 145; Ekbert Faas, "Interview with Karlheinz Stockhausen Held August 11, 1976," *Interface: Journal of New Music Research* 6 (1977): 187–204.

¹⁰Abraham Moles, "Some Basic Aspects of an Information Theory of Music," *Journal of the Audio Engineering Society* 6, no. 3 (1958): 184–186; Abraham Moles, *Information Theory and Esthetic Perception*, trans. Joel E. Cohen (Urbana, IL: University of Illinois Press, 1968 [1958]).

¹¹Margit Rosen, ed., *A Little-Known Story about a Movement, a Magazine, and the Computer's Arrival in Art: New Tendencies and Bit International, 1961–1973* (Cambridge, MA: MIT, 2011); Catherine Morris et al., *9 Evenings Reconsidered* (Cambridge, MA: MIT List Visual Arts Center, 2006).

human, animal, human-machine—as black boxes to be understood via input, output, and the correction of that output via feedback.¹² Few of the people I discuss below engage directly with cybernetics; in fact, the word is rarely found in their writings. While books by Paul Edwards, N. Katherine Hayles, Steve Heims, and Andrew Pickering have documented the important historical legacy of cybernetics, cybernetics as theory and practice fails to account for developments in electronic music during this time period.¹³ Christina Dunbar-Hester attempted to document cybernetic resonances in music from 1950 to 1980¹⁴; however, I will show instead that information theory, especially from the late 1940s until the early 1960s, was the generative model for musical experimentation. In contrast to the cybernetics of this time, information theory importantly lacks a feedback connection from receiver to transmitter, constructing situations that allow for musical works to enter fully-formed into the world without being modified by the actions of a listener. In a cybernetic world it certainly matters who is listening, but information theory enables “Who Cares if You Listen?” to be a valid question.

But the uptake of information theory within creative practice is of course not

¹²Wiener, *Cybernetics: or Control and Communication in the Animal and the Machine*.

¹³Heims, *The Cybernetics Group*; Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: The MIT Press, 1997); Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*; Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University Of Chicago Press, 2010).

¹⁴Christina Dunbar-Hester, “Listening to Cybernetics,” *Science, Technology & Human Values* 35, no. 1 (2010): 113–139. Dunbar-Hester’s work is problematic for the lack of historical specificity afforded to the works under discussion. For example, Cornelius Cardew’s *The Great Learning* (1968) is discussed in terms of cybernetics via recourse to comments by Brian Eno; however, none of Cardew’s own prolific writing is cited. In fact, Cardew’s militant Maoism is not mentioned at all, nor the fact that he repudiated *The Great Learning* and his earlier works in the 1970s. On this basis, it is highly unlikely that Cardew would see his work as related at all to what he would undoubtedly term a “bourgeois” science. On Dunbar-Hester’s account of *The Great Learning*, see *ibid.*, 127–128, 133–134; for Cardew’s repudiation, see Cornelius Cardew, *Stockhausen Serves Imperialism*, ubuclassics (London, UK: Latimer New Dimensions Limited, 2004 [1974]), 93–105.

dependent simply on developments within engineering. The post-World War II period was a time of extreme flux within the musical field, with tonal and stylistic retrenchment co-occurring with the re-activation of pre-war forms of avant-garde composition. With the “emancipation of the dissonance” via twelve-tone (or dodecaphonic) compositional practices by members of the so-called Second Viennese School such as Arnold Schoenberg, Alban Berg, and Anton Webern in the 1920s, modernist compositional practice had further moved away from notions that would enshrine Western tonality as something “natural”, a process that had, in an evolutionary understanding, developed directly from Richard Wagner’s expanded chromaticism or the whole-tone scales of Claude Debussy¹⁵. With the twelve-tone method, no pitch is considered more important than another; there is no “tonic” towards which a phrase tends. The twelve pitches of the chromatic scale are placed in a series, or row, whose ordering is strictly followed within a composition¹⁶. The rise of Nazism in Germany, and Schoenberg’s forced exile to America, muted twelve-tone compositional development throughout the 1930s and early 1940s. In some of the situations I discuss, the composers who came of age in the wake of the destruction in Germany and France (such as Pierre Boulez, Karlheinz Stockhausen, György Ligeti, Luigi Nono, among many others) often faced a particular breed of cultural conservatism that eschewed the “abstract” for the “realist”¹⁷. Dodecaphonic

¹⁵The question of *telos* in music history is a vexed one that I cannot begin to address satisfactorily here. Be that as it may, Schoenberg might have understood his own position within this history as a dialectic between a respect for continuity with the past and the need for a radical break with tradition. On this issue, see Michael Cherlin, *Schoenberg’s Musical Imagination* (Cambridge, UK: Cambridge University Press, 2007), 44–67.

¹⁶Various transformations of the tone row were often used, such as “retrogression”, where the row is repeated in reverse, and “inversion”, where the row is chromatically inverted.

¹⁷For a brief account of this in the arts in Germany, see Grant, *Serial music, serial aesthetics: Compositional theory in post-war Europe*, 11–22. In France there was a conflict over neo-tonal music that

composition further expanded into what has been termed “total” or “integral” serialism (composition partaking of orderings of dynamics, rhythmic values, and other parameters besides pitch); this can be understood as a political move in and of itself, one that argues for an autonomy of artistic production that is not linked to realist or party programs. The choice to use information theory—along with the linkage of composition to scientific and engineering discourse in general—was one component designed to lend rhetorical and public support to this approach. And information theory would prove its malleability, especially as it was drawn upon for the analysis and synthesis of diatonic material *in addition to* the serialist vanguard.

My approach in this chapter is to formulate a provisional mapping of an incredibly dense sonic field of interconnections and overlaps between engineers, scientists, composers, technologies, corporations, and geographic locations. A mathematical result in electrical engineering in the US becomes the prime component for experiments in *elektronische musik* in West Germany; acousticians lecture to composers; corporations lend synthesizers to universities. As Félix Guattari noted in *Chaosmosis*, to explain only the “pentatonic musical refrain” of Debussy would require an analysis that conjoins the Universal Exposition of 1889, Gregorian chant, the literary world of late-nineteenth century France, then-contemporary reappraisals of the composers Rameau and Couperin, and the influence of Wagner.¹⁸ Similar interrelationships must be explored here. I pick up from the Excur-

allowed it to be simultaneously promoted by Soviet Union-supporting socialist realists and American-influenced intellectuals keen on countering communist “expansion”. The place of serialist music and French avant-garde composers such as Pierre Boulez within this field is further complicated by the programming of these works on concerts supported the CIA-funded Congress for Cultural Freedom. For much more on this see Mark Carroll, *Music and Ideology in Cold War Europe* (Cambridge, UK: Cambridge University Press, 2003).

¹⁸Félix Guattari, *Chaosmosis*, trans. Paul Bains and Julian Perfanis (Bloomington: Indiana Univer-

sus to examine in-depth the diffusion of information theory into various forms of musical analysis and composition in the 1950s. Key to this story is the tension between information theory as a tool to reify existing understandings of music or a generative process to expand the range of material available for a listener. For the latter potential, a probabilistic understanding of “noises” becomes one of the main ways to stretch the listener’s capabilities. Such developments foreshadow the further coming together of computational technologies and art in the 1960s while simultaneously complicating understandings of the period that rely on feedback-oriented cybernetics alone.

Information Theory’s Music

The October 1949 edition of *Astounding Science Fiction* contained an essay entitled “Chance Remarks” by J.J. Coupling. Noting that it was ahead of “the papers” regarding the recent interest in “Cybernetics and the theory of communications,” Coupling references an earlier story in the magazine regarding the ability to produce “meaningful words from random letters”.¹⁹ Wryly he states that “something very like that has appeared in the most respectable sort of print”: Shannon’s article in the *Bell System Technical Journal*. Shannon motivated information theory through an examination of the probabilistic structure of English, creating a series of increasingly plausible sentences. Quoting a sentence from Shannon’s essay, “THE HEAD AND IN FRONTAL ATTACK ON AN ENGLISH

sity Press, 1995), 49–50.

¹⁹J. J. Coupling, “Chance Remarks,” *Astounding Science Fiction* (October 1949): 104.

WRITER THAT THE CHARACTER OF THIS POINT IS THEREFORE ANOTHER METHOD FOR THE LETTERS THAT THE TIME OF WHO EVER TOLD THE PROBLEM FOR AN UNEXPECTED”, Coupling comments that, “Certain passages in *Ulysses* and *Finnegans Wake* are scarcely more intelligible”²⁰. Suggesting that to follow Shannon’s procedure might “seem unduly difficult”, Coupling instead creates a game much like a literary version of the Surrealist exquisite corpse whereby participants must finish phrases based on a three-word prompt, thereby producing a sentence such as, “When cooked asparagus has a delicious flavor suggesting apples.”²¹ In a later article entitled “Science for Art’s Sake” published in November 1950, Coupling extends these chance procedures to the domain of music²². Much like with the production of English sentences by Shannon, Coupling produces a set of potential chords that were then selected by the roll of specially made dice. His three compositions are, in his opinion, “less dull than poor hymns but are considerably inferior to Bach.”²³ He extends this procedure for “the lover of modern music” by creating “a dissonant canon in the whole-tone scale”²⁴.

J.J. Coupling is actually the pseudonym of John Robinson Pierce, an American electrical engineer, high-level employee at Bell Labs, and a colleague of Claude Shan-

²⁰Coupling, “Chance Remarks,” 109. One of the few other scholars to note the importance of John Pierce to the story of information theory and cybernetics is Lydia Liu, where she focuses on Pierce’s interest in the works of Joyce. See Lydia H. Liu, *The Freudian Robot: Digital Media and the Future of the Unconscious* (Chicago: University of Chicago Press, 2011), 127–129.

²¹Coupling, “Chance Remarks,” 109, 111.

²²Suggesting that further exploration needs to take place in different fields of art, Coupling remarks that, “We may remember, too, that many years ago Marcel Duchamps [sic] allowed a number of threads to fall on pieces of cloth and then framed and preserved them.” Coupling is most likely here referring to Duchamp’s *3 Standard Stoppages* (1913). See J. J. Coupling, “Science for Art’s Sake,” *Astounding Science Fiction* (November 1950): 90.

²³*Ibid.*, 90.

²⁴*Ibid.*, 91. Such compositions based on chance have a long history prior to Coupling and Cage; consider the “dice game” attributed to Mozart or Duchamp’s experiments around 1915.

non²⁵. Pierce, in his position as director of electrical and communications research at Bell Labs, was also instrumental in the development of the first active commercial telecommunications satellite *Telstar 1*²⁶. Pierce's interest in the relationship between information theory and music is due in part to the organizational structure of Bell Labs: speech and hearing work were part of Pierce's division, and through this he learned of the research of Harvey Fletcher (the Bell Labs acoustician discussed in Chapter 1).²⁷ Such judicious juxtapositions would seem to be rife at Bell Labs²⁸. Thus Ralph Potter, of Project X and the sound spectrograph (discussed in Chapter 1), could write of the need for "New Scientific Tools for the Arts" in 1951, noting that, "Practically no direct efforts are being made to find new tools for either old or new arts. Commercial incentive is lacking and it has not been shown that other incentives exist."²⁹ Information theory, however, would help in this study:

²⁵Pierce co-authored a paper with Shannon in the same year as the publication of Shannon's article that investigated new methods for the encoding of speech as a result of Shannon's theory. See B.M. Oliver, J.R. Pierce, and C.E. Shannon, "The Philosophy of PCM," *Proceedings of the IRE* 36, no. 11 (1948): 1324–1331.

²⁶An extensive profile of Pierce was published in the *New Yorker* in 1963, shortly after the launch of *Telstar 2*. See Calvin Tomkins, "Profiles: Woomera Has It!," *New Yorker* 39 (September 1963): 49–110. Incidentally in this profile Pierce makes his disdain for cybernetics clear: "A number of years ago,' Pierce told a scientific audience recently, 'a publisher suggested that I write a book about machines that out think man, and the cybernetic revolution around us. He outlined, almost chapter by chapter, the fantasy for which I was to supply words and circumstantial detail. When I recovered my breath after this intellectual blow, I ventured to say that I didn't believe that all those things were true. The publisher misunderstood my objection completely. "You don't have to be for it, you can be against it," he assured me. Since that day, various people have written the book the publisher was seeking.' " See *ibid.*, 77.

²⁷John R. Pierce, Interview by Harriett Lyle. Pasadena, California, April 16, 23, and 27, 1979. Oral History Project, California Institute of Technology Archives. 1979, 35,41.

²⁸Pierce was also involved in the early development of computer music with Max Matthews, and was a colleague of Billy Klüver, allowing Klüver to draw from engineers in Pierce's division for the development of *9 Evenings: Theatre and Engineering* in 1966. See Patte Wood and John Robinson Pierce, "Recollections with John Robinson Pierce," *Computer Music Journal* 15, no. 4 (1991): 17–28.

²⁹Ralph K. Potter, "New Scientific Tools for the Arts," *The Journal of Aesthetics and Art Criticism* 10, no. 2 (1951): 126.

Systems of either the art or non-art types may be studied without considering the contents of messages sent over them, for the same reasons that we may study broadcast, television, telephone, or telegraph systems of all sorts without prying into the messages they convey. Art communication systems may be investigated without invading any of the prerogatives of the artist. That is, we may study the communication systems of the arts without attempting to analyze, or interpret the art messages themselves.³⁰

Surveying the work of Oskar Fischinger, Mary Ellen Bute, and Norman McLaren, Potter notes that while there exist “color music” and “abstract film,” there does not correspondingly exist “visual music,” although Potter suggests that his own sound spectrograph could potentially be used for this purpose. Returning to the question of funding and organization, and in a surprising move for someone employed at Bell Labs, Potter notes that while the new tools for the arts requires collaboration between artists and scientists, this will have to exist outside of companies since “commercial support will be small until the results begin to show entertainment value.”³¹ He posits a “Research Institute for the Arts,” ideally situated within universities, whereby a group of artists and scientists in collaboration “could be expected to add new and revolutionary dimensions to the arts”³².

This lack of institutional support was not the experience of composers and re-

³⁰Potter, “New Scientific Tools for the Arts,” 128–129.

³¹*Ibid.*, 134.

³²*ibid.* Of course, Potter’s hope for institutional support would develop throughout the 1960s and 1970s via the expansion of universities as a result of both increased state and corporate funding and higher enrollments.

searchers in Europe immediately after World War II. Due to the support of state broadcasting monopolies, sonic research centers came into being in conjunction with major radio (and later television) facilities. The beginnings of these centers in France was in fact during the war, where Pierre Schaeffer, trained as a radio engineer, set up the Studio d'Essai de la Radiodiffusion Nationale in 1942, which became a center of the Resistance³³. Following the war in 1946 this became the Club d'Essai de la Radiodiffusion-Télévision Française, and shortly thereafter Schaeffer began his research into the manipulation of “noises.”³⁴ It was here that Schaeffer would produce the works that were premiered in October 1948 on a concert broadcast on RTF entitled *Concert à bruits*, including his famous reworking of recordings of locomotives, *Étude aux chemins de fer* (1948)³⁵. For Schaeffer this emphasis on the manipulation of recorded material was his own response to the “crisis” of post-war Western music, specifically “the invasion of Austrian music, 12-tone music. We had liberated ourselves politically, but music was still under an occupying foreign power, the music of the Vienna school.”³⁶ Schaeffer’s project, with the composer Pierre Henry and the sound engineer Jacques Poullin, was termed *musique concrète*, or concrete music; in contrast with “abstract” music, where a composer conceives of sounds which are then notated and performed, the “concrete” composer begins

³³Schaeffer would in fact be involved in the first broadcasts from liberated Paris in 1944.

³⁴Carlos Palombini, “Machine Songs V: Pierre Schaeffer: From Research into Noises to Experimental Music,” *Computer Music Journal* 17, no. 3 (1993): 14.

³⁵Peter Manning, *Electronic and Computer Music* (New York: Oxford University Press, 2004), 20–21. Schaeffer credits Luigi Russolo’s concept of an “art of noises” as the precursor of his noise montage. See Otto Luening, “Some Random Remarks about Electronic Music,” *Journal of Music Theory* 8, no. 1 (1964): 93.

³⁶Pierre Schaeffer, “An interview with Pierre Schaeffer—pioneer of Musique Concrète,” Interviewed by Tim Hodgkinson, 2 May 1986 for ReR Quarterly magazine, volume 2, number 1, 1987, 2, accessed July 3, 2013, <http://www.timhodgkinson.co.uk/schaeffer.pdf>.

with existing sounds recorded separately, experiments with new manipulations and orderings of these sounds, and finally commits it to a medium such as a record or magnetic tape.³⁷ At various times during its existence the German composer Karlheinz Stockhausen and the French electrical engineer and physicist Abraham Moles would study and work with Schaeffer at the Club d'Essai.

In West Germany after the war a different practice developed, one that would, in theory and practice, be indebted to information theory. For in 1948, Werner Meyer-Eppler, then-director of the Department of Phonetics at Bonn University, was visited by Homer Dudley and given a demonstration of the Vocoder. In 1949 Meyer-Eppler would use the capabilities of the Vocoder to illustrate a lecture on new possibilities in sound. Coincidentally, Robert Beyer was in attendance; Beyer had written an article in 1928 on the possibilities of electronic sounds in music. Both presented lectures in 1950 on the potential of electronic music at the International Summer School for New Music at Darmstadt, with the composers Edgar Varèse and Herbert Eimert in attendance. The next year both Meyer-Eppler and Eimert would lecture at Darmstadt; Schaeffer attended these lectures and his work faced considerable hostility by the audience. Later that year, on 18 October, Eimert, Beyer, and Meyer-Eppler presented a forum with compositions entitled "The Sound World of Electronic Music" on the Cologne radio station; the same day, a committee at the station agreed to create a studio dedicated to the production of *elektronische musik*³⁸. The technologies of radio—honed via wartime development

³⁷Palombini, "Machine Songs V: Pierre Schaeffer: From Research into Noises to Experimental Music," 16.

³⁸For accounts of these events, see Manning, *Electronic and Computer Music*, 39–40 and Luening, "An Unfinished History of Electronic Music," 46–47. Lowell Cross provides a more detailed account of this time, including primary documents of the establishment of the studio; see Lowell Cross, "Elec-

in Germany, France, and elsewhere—would become reappropriated tools for new experiments in the arts.

While this conflict between *musique concrète* and *elektronische musik* has been understood primarily in terms of work practices (namely *musique concrète* worked with existing material and *elektronische musik* worked with synthetic sounds), M. J. Grant notes that the split cannot be understood in such simplistic ways, as Schaeffer attempted sonic transformations that would remove the identity of the original source, and Eimert stated the *elektronische musik* would include *both* synthetic and recorded material³⁹. Meyer-Eppler even compliments *musique concrète* on its “manifold expressive possibilities.”⁴⁰ Nevertheless, Meyer-Eppler’s interest in electronic music was due in part to his desire for an “authentic music” whereby, in the words of Grant, “the composer could compose and recompose directly on to tape, and the results would be transmitted directly to the public, not unlike the relationship which exists between the painter and the public.”⁴¹ According to Meyer-Eppler “authentic” compositions are those whose “musical life begins only at the moment of reproduction” and that are “put down by the composer in final form ready for reproduction.”⁴² Listeners then become part of the production of the composition, and perhaps paradoxically, the importance of the composer is reduced producing direct

tronic Music, 1948-1953,” *Perspectives of New Music* 7, no. 1 (1968): 45–54. M. J. Grant details the debates amongst Beyer, Eimert, and Meyer-Eppler, and the eventual disputes that would cause Beyer to withdraw from the studio; see Grant, *Serial music, serial aesthetics: Compositional theory in post-war Europe*, 58–59, 76–77.

³⁹ibid., 56. On Schaeffer’s frustrations, Grant references Manning, *Electronic and Computer Music*, 23.

⁴⁰Werner Meyer-Eppler, *The Terminology of Electronic Music*, Technical Translation TT-602, Translated From Tech. Hausmitt. NWDR, 6: 5–7, 1954 (National Research Council of Canada, 1956 [1954]), 7.

⁴¹Grant, *Serial music, serial aesthetics: Compositional theory in post-war Europe*, 57.

⁴²Meyer-Eppler, *The Terminology of Electronic Music*, 8.

interaction, mediated primarily by technologies of reproduction. To succeed in this, however, the composer must be cognizant of how individual sound events interact horizontally (in succession) and vertically (simultaneously). In the first issue of *die Reihe* (the Series), a periodical originally published in German but later translated for an English-reading audience, Meyer-Eppler introduced certain concepts from psycho-acoustics that were important for this understanding, such as the impact of loudness on the perception of pitch⁴³. More importantly for my interests here, he indicated the importance of statistical techniques in composition, using one of the early references to the word “aleatoric” in composition, wherein a “process is said to be aleatoric (from La. *alea* = dice) if its course is determined in general but depends on chance in detail.”⁴⁴ Aleatoric processes could be used to create new forms of sound generators, namely those producing noise: “The composer who disposes of the possibilities of aleatoric modulation will be surprised to discover that this kind of modulation leads him directly into a world of phenomena, previously described as ‘noises’.”⁴⁵ Instead of considering a “white noise” generator as merely a tool to test radio equipment, Meyer-Eppler here is pointing to its potential use as a generative technology, forshadowing what would become known later as subtractive synthesis. Thinking in terms of the statistics of musical material, Meyer-Eppler also discussed provisional applications of information theory to the analysis of compositions, suggesting “second-order” Markov chains to take into account relationships

⁴³Given that at this time serialist composers were building up their compositions from fundamental units of material, these sorts of interactions could derail a carefully-laid plan. On this issue, see Grant, *Serial music, serial aesthetics: Compositional theory in post-war Europe*, 62.

⁴⁴Werner Meyer-Eppler, “Statistic and Psychological Problems of Sound,” *die Reihe* 1 (1958 [1955]): 55.

⁴⁵*Ibid.*, 56.

between a given item and the one two items before it.⁴⁶ Meyer-Eppler was not only involved in sonic information theory research during this time period; he continued his explorations in the application of information theory to the extraction of visual signals from visual noise, presenting at the Second and Third London Symposiums on Information Theory mentioned earlier⁴⁷. Meyer-Eppler's interest in the visual as well as the sonic also led him to report on Potter's visible speech in the first issue of the *Gravesaner Blätter*, a new journal put out by the studio run by Hermann Scherchen in Gravesano, Switzerland and devoted to "interdisciplinary problems in music, electro-acoustics, and auditory science" ("musikalische, elektroakustische und schallwissenschaftliche Grenzprobleme")⁴⁸.

In the United States electronic music developed in a different manner due in part to differences in institutional structures and funding. . Works for tape began to be created in earnest in the early 1950s due to the influence of the recording engineers Louis and Bebe Barron, who possessed a home studio in New York City. Under the heading of a project called "Music For Magnetic Tape", the Barrons,

⁴⁶Meyer-Eppler, "Statistic and Psychological Problems of Sound," 57–58.

⁴⁷Werner Meyer-Eppler, "Exhaustion Methods of Selecting Signals from Noisy Backgrounds," in Jackson, *Communication Theory*, 183–194 and Werner Meyer-Eppler and G. Darius, "Two-Dimensional Photographic Auto-Correlation of Pictures and Alphabet Letters," in Cherry, *Information Theory*, 34–36. In a question that would resonate with his stated interest in Gestalt psychology, following the latter presentation Abraham Moles asked Meyer-Eppler about whether he had investigated the relationship of his work and the psychological problem of "defining the 'center of interest' of a picture". See *ibid.*, 36.

⁴⁸Werner Meyer-Eppler, "Sichtbargemachte Musik," *Gravesaner Blätter* 1 (1955): 27–31. Scherchen was a German conductor and a champion of avant-garde composers such as Schoenberg, Anton Webern, Alban Berg, and Edgar Varèse. Nevertheless, after a performance in Prague in 1950, Schoenberg, from America, accused Scherchen of having communist sympathies. Shortly thereafter, Scherchen moved to Gravesano, Switzerland, where he established his own electronic music studio and began publishing the *Gravesaner Blätter*. For more on Scherchen, the studio, and the journal, see Dennis C. Hutchison, "Performance, Technology, and Politics: Hermann Scherchen's Aesthetics of Modern Music" (PhD diss., Florida State University, 2003), 99–112.

along with John Cage, Earle Brown, Morton Feldman, David Tudor, and Christian Wolff created musical experiments from around 1951 until 1953; most were never released publicly, however Cage's *Williams Mix* (1952) was created during this period⁴⁹. Simultaneously, at Columbia University, Vladimir Ussachevsky and Otto Luening began tape experiments in 1951–1952 after Ussachevsky was able to use a tape recorder that was given to the music department for the recording of student concerts.⁵⁰ By 1953 the Rockefeller Foundation (RF) was already funding Ussachevsky for \$3,240 “for the purchase of basic equipment to be used for creative research in the field of electronic music.”⁵¹ Two years later after a series of public performances, including one at the Museum of Modern Art and one on NBC's *Today* show, Luening and Ussachevsky would be awarded \$9,995 from the RF to travel to various studios in Europe and the US to undertake a “study of recent developments in electronic music as they affect musical composition.”⁵² In Europe, Ussachevsky and Luening visited Schaeffer's studio in Paris, Meyer-Eppler in Bonn, Eimert's studio in Cologne, Scherchen's studio in Gravesano, and Luciano Berio's studio in Milan; in the US, they found less taking place, excepting the work of Lejaren Hiller at the University of Illinois, who was experimenting in algorithmic composition, and some work at Bell Laboratories. Luening suggested that this was because “most research in acoustics was being conducted under the defense program. Industry was hesitant about basic research unless it could be applied practically within six

⁴⁹See Cross, “Electronic Music, 1948-1953,” 54–56 and Manning, *Electronic and Computer Music*, 74–75.

⁵⁰Luening, “An Unfinished History of Electronic Music,” 48.

⁵¹Rockefeller Foundation, *Rockefeller Foundation Annual Report*, 1953, 313.

⁵²Rockefeller Foundation, *Rockefeller Foundation Annual Report*, 1955, 181; Luening, “An Unfinished History of Electronic Music,” 48–49.

months.”⁵³

Nevertheless, at the same time a short drive away in Princeton, New Jersey, Harry F. Olson and Herbert Belar of RCA Laboratories were developing a new “Electronic Music Synthesizer”. The music critic for the New York Times, Howard Taubman, wrote in 1955 that this machine, kept under “lock and key”, could produce “music without the intercession of musicians”⁵⁴. Incredibly complex for the time, the RCA Mark I synthesizer involved a set of twelve tuning forks that provided fundamental frequencies that could be shifted across eight octaves; intensity, attack/decay, vibrato, and portamento control; timbre control via a set of filters; programmatic control via binary selection of parameters on a punched stream of paper; and recording of output via a vinyl recorder.⁵⁵ Olson suggests that Carl Seashore, a prominent psychologist of music, had indicated the potential of new instruments to both produce any sound possible, as well as move beyond the limitations of human players.⁵⁶ Indeed, Olson and Belar emphasize continually in their technical paper on the Mark I synthesizer that it is not subject to the “undesirable noises” of bow scratches, rushing air, and “clatters and rattles”; these types of noises are “ob-

⁵³Luening, “An Unfinished History of Electronic Music,” 138.

⁵⁴Howard Taubman, “Synthesized Piano Music Found To Have Tone Matching a Grand’s,” *New York Times* (1955): 35. Concern about the position of the human within the dynamics of post-war technological developments would soon be directed towards a new phrase coined in 1956: “artificial intelligence”. See Ronald Kline, “Cybernetics, Automata Studies, and the Dartmouth Conference on Artificial Intelligence,” *Annals of the History of Computing, IEEE* 33, no. 4 (2011): 5–16. Nevertheless, the cultural zeitgeist was not prepared at this point to understand the potential for digital technologies to help augment human creativity, in contrast to the composers and engineers under consideration. Such potentials would be cogently articulated by J. C. R. Licklider in 1960; see J. C. R. Licklider, “Man-Computer Symbiosis,” *IRE Transactions on Human Factors in Electronics* 1, no. 1 (March 1960): 4–11.

⁵⁵Olson and Belar, “Electronic Music Synthesizer.”

⁵⁶Harry F. Olson, Oral history conducted in 1975 by Mark Heyer, IEEE History Center, New Brunswick, NJ, USA. 1975.

jectionable” and “disagreeable”⁵⁷. Yet they realize the limits of this absolute position in the realm of ordering of events, where they engineered the potential for “irregular deviation” since, “One of the beautiful and artistic characteristics of some types of music is the lack of a mechanical quality of the rendition.”⁵⁸ This capability would be key, for in a moment of honesty that resonates with their institutional affiliation, Olson and Belar note that the synthesizer can “make music for sale in the form of phonograph records. [...] the synthesizer can produce any kind of sound that can be imagined. Then if a person can imagine a hit, the synthesizer will facilitate the production of the hit.”⁵⁹ Olson and Belar would produce a second version, the Mark II, that had expanded technical capabilities, including the ability to record up to four tones at a time and to divide an octave into 36 separate tones. They note the influence of information theory on the development of new forms of synthesis, writing that, “The new systems of communication involving the processes of analysis, encoding, coding, decoding, and synthesizing are beginning to play an important part in communicating information in all forms.”⁶⁰ Yet institutional pedigree comes to the fore again; commenting on a series of compositions produced on the Mark II, “The aim was to perform an experiment in creating music which would be commercial in today’s market, not too different yet still possessing novelty”⁶¹. It would be the

⁵⁷Olson and Belar, “Electronic Music Synthesizer,” 595, 608, 609. This aspect of Olson and Belar’s paper has also been noted by Nick Patterson; see Nick Patterson, “The Archives of the Columbia-Princeton Electronic Music Center,” *Notes* 67, no. 3 (2011): 495.

⁵⁸Olson and Belar, “Electronic Music Synthesizer,” 597.

⁵⁹*Ibid.*, 610.

⁶⁰H. F. Olson, H. Belar, and J. Timmens, “Electronic Music Synthesis,” *Journal of the Acoustical Society of America* 32, no. 3 (1960): 311.

⁶¹*ibid.*, 318. In a footnote, and in contrast to the interpretation of Taubman, they write: “Except from a purely scientific viewpoint there is no interest and no desire to create music which can be produced by conventional means. The added effort and the new employment of musicians capable to perform synthesis is warranted only if it can produce something new or better in the art of music”.

RCA synthesizer, first the Mark I and then the Mark II, that in 1959 became the centerpiece for the new Columbia-Princeton Electronic Music Center (CPEMC). Funded by a \$175,000 grant from the RF, the CPEMCs founding composers included Ussachevsky and Luening from Columbia, and Milton Babbitt and Roger Sessions from Princeton⁶².

Within this milieu of a rapidly changing practice of electronic music composition, information theory found itself being stretched to support both traditional melodies and the avant-garde serialism. Shannon, while not directly commenting on its expansion into music *per se*, had derided recent moves to utilize information in a variety of domains far removed from communications engineering, suggesting that information theory “has perhaps been ballooned to an importance beyond its actual accomplishments.”⁶³ Yet this did not stop enthusiastic adherents to the new formulation from applying it to all forms of musical practice, from the analysis of melodies to the synthesis of new ones primarily through computation, aided in both cases by access to computation based on digital principles. Such practices enacted both a shift in the relationship between humans and machines as well as the transition from analog to digital computing, manifested in music by the development by John Pierce and Max Matthews of one of the first computer music systems in the

Note here “musicians” refers to those who created the punched tape fed into the synthesizer. See Olson, Belar, and Timmens, “Electronic Music Synthesis,” 318, note 2.

⁶²The dollar value of the grant is repeated in all accounts of the CPEMCs founding. However, I am unable to find that exact amount in any of the RF Annual Reports. In 1963, there is a grant for \$6,356 given to Columbia University for “Electronic Music”, and in 1965 there is a value of -\$237 (“(237)”) which appears to be an accounting move to close the accounts at the end of the grant term. However, there are no values in any of the reports from 1959–1965 that would add up to the \$175,000 value. See Rockefeller Foundation, *Rockefeller Foundation Annual Report*, 1963, 292; Rockefeller Foundation, *Rockefeller Foundation Annual Report*, 1965, 234.

⁶³Claude Shannon, “The bandwagon,” *Information Theory*, IRE Transactions on 2, no. 1 (March 1956): 3.

late 1950s.

The Malleability of Information Theory

In a detailed retrospective of research into information theory and music published up to 1962, the applied mathematician Joel Cohen suggested that the then-existent approaches could be grouped into three different categories: analytic (information theoretic analyses of music to determine levels of redundancy), synthetic (the construction of new musical examples based on *a priori* assumptions regarding redundancy), and analytic-synthetic (the composition of new musical examples via the analysis of existing works)⁶⁴. At the risk of further reduction of Cohen's typology, I want to suggest instead that we understand the use of information theory in music not so much on *how* it was used, but rather how it *approached* its material, and specifically whether or not it opened up new possibilities of composition otherwise unknown. On the one hand there were those using information theory to either analyze or replicate existing notions about music, most commonly those relating to simple tunes or composition prior to Wagner or Debussy. Information theory in this case becomes a closed tool that further supports assumptions regarding the "naturalness" of the Western tonal system. Modern music such as serialism was immediately removed from consideration in these approaches that took tonality as the only possibility. On the other hand, information theory became a tool to consider the expansive possibilities of new forms of composition. Information theory thus is used to characterize the perceptual capabilities of a human "receptor", not

⁶⁴Joel E. Cohen, "Information theory and music," *Behavioral Science* 7, no. 2 (1962): 137–163.

to align it with the so-called “rules” of composition, but rather to suggest new techniques that would activate those potentials. In this case information theory exceeds that which is being studied, partaking of an openness to new knowledge and experiences. In both cases the information theory being drawn upon is primarily Shannon’s instead of the alternative explanations of Gabor or MacKay; however, as with Wiener’s disagreement with Shannon over the relationship between information and entropy, the contrast between these two approaches to information theory and music often comes down to questions regarding the importance—or desirability—of unpredictability and noise.

Taming the unexpected

Harry Olson and Herbert Belar were not only developing new means for sound synthesis via the RCA synthesizers; they were also creating machines for the probabilistic composition of music. In the early 1950s, and partially as a consequence of the publication of Shannon and Weaver’s book, Olson and Belar built a system that generated “sequences of notes in a series which are not completely random nor completely ordered” in an attempt to replicate the music of Stephen Foster.⁶⁵ Commenting on their system, and making one of the few references by those working in the arena of music to the burgeoning field of “artificial intelligence,” they write:

The random probability machine described in this paper is charged
with information and upon command sends out a series of variations

⁶⁵Harry F. Olson and Herbert Belar, “Aid to Music Composition Employing a Random Probability System,” 33, no. 9 (1961): 1163.

of the information stored in the machine. When the stored information is music, the output consists of series of tones with a tremendous variety of sequences. The composer monitors the output and passes judgement as he would in the case of any musical rendition. Therefore, the random probability machine may be considered to be a halting step in the direction of systems for providing of “artificial intelligence.” For example, the system provides means for man to instruct the machine and the machine to apprise man⁶⁶.

Olson and Belar’s paper on this device was not published until 1961; however in the mid-1950s Richard Pinkerton, in an article entitled “Information Theory and Melody” in *Scientific American*, picked up where Coupling (Pierce) had left off in *Astounding Science Fiction*. Through an analysis of nursery rhymes, Pinkerton developed a set of transition probabilities that enabled him to synthesize new songs, something he called a “banal tune-maker”.⁶⁷ The next year, a team at IBM and Harvard published “An experiment in musical composition” that used eighth-order Markov chains to synthesize new hymns⁶⁸. Pinkerton notes that such algorithmic compositional methods are part of a longer history, especially considering the com-

⁶⁶Olson and Belar, “Aid to Music Composition Employing a Random Probability System,” 1170. As alluded to earlier in footnote 54, the term “artificial intelligence” was coined by John McCarthy in 1956 during a series of presentations on the topic held at Dartmouth University. Claude Shannon helped McCarthy edit a volume of the journal *Automata Studies*; see Kline, “Cybernetics, Automata Studies, and the Dartmouth Conference on Artificial Intelligence.” J. C. R. Licklider’s notion of “man-computer symbiosis”, which resonates with Olson and Belar’s definition here, was published in 1960; it’s unclear whether or not Olson and Belar knew of this work prior to writing their paper.

⁶⁷Richard C. Pinkerton, “Information Theory and Melody,” *Scientific American* 194 (1956): 84.

⁶⁸F. P. Brooks et al., “An experiment in musical composition,” *Electronic Computers, IRE Transactions on EC-6*, no. 3 (September 1957): 175–182. The authors also cite Pinkerton and a discussion that took place at the Third London Symposium on Information Theory regarding the work of Fred and Carolyn Altneave who developed a matrix of transition probabilities for “Western cowboy songs”. See Cherry, *Information Theory*, 168–169.

positional system of the American composer Joseph Schillinger. Schillinger, working from a set of principles which the musicologist and composer Christoph Both describes as “music as a time-space entity, capable of graphic projection into space”, not only helped George Gershwin with the orchestration of *Porgy and Bess* but also collaborated with Léon Theremin⁶⁹.

Outside of the realm of synthesis of new music in old styles, information theory was used to examine different notions of structure or “experience” of music, at times without any reference to concrete musical examples at all. In this vein, Edgar Coons and David Kraehenbuehl published two related articles that purported to show how musical structures need to play within a paradox of “high” and “low” information related to notions of the “nonconfirmation” of expectations in order to retain the attention of a listener.⁷⁰ Coons and Kraehenbuehl assume that music is representative of experiences outside of music itself and that the purposes of music is to communicate this representation⁷¹. Here information theory is used to buttress the importance of music’s denotative properties, ones that can be discovered through an analysis of the score alone. Similarly, Joseph Youngblood attempts an analysis of the “style” of Mendelssohn, Schubert, Schumann, and Gregorian chant via Shannon’s definition of redundancy.⁷² Yet his analysis is already biased against

⁶⁹Both, “The influence of concepts of information theory on the birth of electronic music composition: Lejaren A. Hiller and Karlheinz Stockhausen, 1953–1960,” 44–45. For more on Schillinger’s method, see *ibid.*, 43–46.

⁷⁰Edgar Coons and David Kraehenbuehl, “Information as a Measure of Structure in Music,” *Journal of Music Theory* 2, no. 2 (1958): 127–161; David Kraehenbuehl and Edgar Coons, “Information as a Measure of the Experience of Music,” *The Journal of Aesthetics and Art Criticism* 17, no. 4 (1959): 510–522.

⁷¹“The possibility of artistic communication by means of music relies also upon the structural relevance of the musical experience to the non-musical that the music is intended to convey.” See Coons and Kraehenbuehl, “Information as a Measure of Structure in Music,” 127.

⁷²Joseph E. Youngblood, “Style as Information,” *Journal of Music Theory* 2, no. 1 (1958): 24–35.

serialism, as he writes, “Because of aesthetic, traditional, or technical pressures, a composer rarely uses more than a small fraction of these possible [tonal] combinations; he [sic] reveals himself as predisposed to certain combinations and quite uninterested in others.”⁷³

Along with the burgeoning interest in information theory in 1950s, there was a parallel questioning of behaviorist psychology that consequently allowed questions to be asked about internal states. The behaviorist position eliminated any consideration of will, internal states, or motivations *tout court*, considering the human as a simple black box of input/output relations. Yet tentative steps away from this dogma can be found in the musicologist Leonard Meyer’s *Emotion and Meaning in Music* (1956). A landmark for its time, Meyer situates his psychology of emotions within learned patterns of musical form: “An understanding of the cultural and stylistic presupposition of a piece of music is absolutely essential to the analysis of its meaning.”⁷⁴ These relationships between different aspects of a piece can be upset or changed by the composer and/or performer, and it is these deviations that for Meyer arouse an emotional response: “Emotion or affect is aroused when a tendency to respond is arrested or inhibited.”⁷⁵ In Meyer’s view the affect produced must be interpreted within the general framework of the events being apprehended by the listener:

As soon as the unexpected, or for that matter the surprising, is experienced, the listener attempts to fit it into the general system of

⁷³Youngblood, “Style as Information,” 25.

⁷⁴Leonard B. Meyer, *Emotion and Meaning in Music* (Chicago: University of Chicago Press, 1956), ix.

⁷⁵*Ibid.*, 14.

beliefs relevant to the style of the work. This requires a very rapid re-evaluation of either the stimulus situation itself or its cause—the events antecedent to the stimulus. Or it might require a review of the whole system of beliefs that the listener supposed appropriate and relevant to the work. If this mental synthesis does not take place immediately, three things may happen: (1) The mind may suspend judgment, so to speak, trusting that what follows will clarify the meaning of the unexpected consequent. (2) If no clarification takes place, the mind may reject the whole stimulus and irritation will set in. (3) The unexpected consequent may be seen as a purposeful blunder. Whether the listener responds in the first or third manner will depend partly upon the character of the piece, its mood or designative content.⁷⁶

Meaning therefore can only be understood within a complicated system of relationships between musical events, with the precise affective response dependent upon how the composer or performer resolves—or does not resolve—the unexpected.

It would be little surprise, then, that Meyer would be interested in information theory: his language of musical meaning is based on probabilistic language (“tendency”) and the relationship between elements in a sequence (“events antecedent”). The year after the publication of *Emotion and Meaning in Music*, he expanded his theory of musical meaning in “Meaning in Music and Information Theory”: “...I subsequently found striking parallels—indeed equivalents—in information theory. Among these were the importance of uncertainty in musical communication, the

⁷⁶Meyer, *Emotion and Meaning in Music*, 29.

probabilistic nature of musical style, and the operation in musical experience of what I have since learned to be the Markoff process”.⁷⁷ Similar to his earlier formulation, here Meyer links *disturbance* with musical communication:

Latent expectation is a product of these probability relationships. And expectation becomes active only when these norms are disturbed. In other words, such latent expectations are necessary conditions for the communication of musical information, while the disturbances of these norms are the sufficient condition for musical communication.⁷⁸

Similarly, the lack of deviation results in neutral meaning. So, in a revised formulation of the statements from his earlier work, Meyer now defines meaning as such: “Musical meaning arises when an antecedent situation, requiring an estimate as to the probable modes of pattern continuation, produces uncertainty as to the temporal-tonal nature of the expected consequent”.⁷⁹ Probability, and not immutable musical laws, becomes the guide for the composer. This necessary uncertainty, however, cannot go too far. Unlike in Shannon’s formulation, where an entirely random signal is of maximum information, for Meyer some redundancy must remain; there must exist a sequence of events “where the listener can pause”.⁸⁰ Redundancy also works to “combat noise”, either the “acoustical noise” of a poorly-designed hall, or the “cultural noise” of “disparities which may exist between the

⁷⁷Meyer, “Meaning in Music and Information Theory,” 412.

⁷⁸Ibid., 414.

⁷⁹Ibid., 416.

⁸⁰Ibid., 420.

habit responses required by the musical style and those which a given individual actually possesses”.⁸¹ Due to “historical or anthropological” distance between cultures, cultural noise interferes with communication. In contemporary music, however, the noise is more due to a “time-lag between the habit responses which the audience actually possess and those which the more adventurous composer envisages for it”.⁸² In what must be interpreted as an underhanded rebuke to the serialists, Meyer suggests that, “in their zeal to ‘pack’ music full of meaning some contemporary composers have perhaps so over-loaded the channel capacity of the audience that one meaning obscures another in the ensuring overflow”⁸³.

Openness to the Unpredictable

Some of the most intricate use of information theory in the analysis and synthesis of music took place at the University of Illinois, Urbana-Champaign by Lejaren Hiller, Jr. and Leonard Isaacson. Hiller was originally trained as a chemist at Princeton, where he also studied with Babbitt and Sessions. He worked for a number of years at DuPont, but left in 1952 for the University of Illinois. There he joined a chemistry research laboratory that had access to the ILLIAC I computer. Working with Isaacson, who was a graduate student in the same lab, they utilized the stochastic “Monte Carlo” method—a technique they had learned through their chemistry

⁸¹Meyer, “Meaning in Music and Information Theory,” 420.

⁸²Ibid.

⁸³ibid. Meyer here is referring to Weaver’s understanding of human “channel capacity”. In a sense, he might also be referring the issues raised earlier, where serialist rows could interfere with each other and obscure the relationships between two or more simultaneous events.

research—to generate new compositions via computer programs.⁸⁴ Their four “experiments” resulted in a four movement work entitled *Illiac Suite for String Quartet* (1957)⁸⁵. In a book detailing the compositional and technical strategies involved in the production of the piece, Hiller and Isaacson note the importance of information theory to their work, referencing not only Shannon, Weaver, Brillouin and Pinkerton, but also the article Meyer-Eppler published in *die Reihe* as well as Abraham Moles’ *Information Theory and Esthetic Perception* (to be discussed in detail below). Hiller and Isaacson understand composition as the putting in order of a series of possible events drawn from an almost infinitely-large set. These processes, however, are not enshrined as eternal laws, but rather admit a range of potential approaches:

The first principle is that the formation of a piece of music is an ordering process in which specified musical elements are selected and arranged from an infinite variety of possibilities, i.e., from *chaos*. The second principle recognizes the contribution to a musical structure not only of *order*, but also the relative lack thereof, and even, in certain extreme cases, of the absence of order, namely, *chaos*; that is to say, the degree of imposed order is itself a significant variable⁸⁶.

⁸⁴Christian A. Wamser and Carl C. Wamser, “Lejaren A. Hiller, Jr.: A Memorial Tribute to a Chemist-Composer,” *Journal of Chemical Education* 73, no. 7 (1996): 601.

⁸⁵Christoph Both undertook a detailed musicological analysis of *Illiac Suite*; see Both, “The influence of concepts of information theory on the birth of electronic music composition: Lejaren A. Hiller and Karlheinz Stockhausen, 1953–1960,” 95–165.

⁸⁶Lejaren A. Hiller Jr. and Leonard M. Isaacson, *Experimental Music: Composition with an Electronic Computer* (New York: McGraw-Hill Book Company, Inc., 1959), 16, emphasis in original. The three other principles have to do with the importance of pitch and time, the necessity of musical memory, and the relationship between memory and tonality.

Thus already Hiller and Isaacson expand the potential of information theory beyond the work discussed in the previous section, allowing a wider variety of potential approaches and eventual results. This is seen specifically in their understanding of the mechanism of musical meaning as elucidated by information theory. They write that:

...music, being a nondiscursive form of communication, operates with a semantic peculiarly dependent upon technical structure as such. Therefore, the study of musical structure in terms of information theory should be a significant technique for breaking through the “semantic barrier” which seems to hamper current investigations in information theory and should perhaps also lead to an improved delineation of the aesthetic basis of musical composition. Specifically, in light of the apparent close dependence of meaning upon form in music, we suggest that Weaver’s overlap, if it exists, is particularly significant in music.⁸⁷

For Hiller and Isaacson, the analysis and synthesis of musical compositions through recourse to information theory suggest that Weaver’s attempt to delineate three levels of the “technical”, “semantic”, and “effective” is in fact illusory. In a sense this brings analysis back to the score, for it is through the construction of events as represented in the score that the “technical structure” is revealed. Yet, as occurred with the serialists, the underlying plan or structure of a particular musical piece may not be actually perceivable in the auditory presentation.

⁸⁷Hiller and Isaacson, *Experimental Music: Composition with an Electronic Computer*, 34.

Nevertheless, the deductive procedure involved a return to the score by codifying the particular techniques used in the production of specific musical forms. Thus *Illiac Suite*, described variously as a “research record” or “laboratory notebook,” proceeded through four movements, each progressively becoming more complex.⁸⁸ The first movement produced a series of two-part and four-part *cantus firmus* settings. However, this movement deviated from some of the “rules” of counterpoint, necessitating further refinement, which resulted in the second movement. The final two movements move into more interesting territory, as the third movement works from a serialist-style ordering of tones, intervals, rhythm, and dynamics, and the final movement progressively refines Markov transition probabilities producing what they term “Markov chain music”⁸⁹. So while *Illiac Suite* was in its first two movements based on musical forms deeply rooted in the Western musical tradition, the final two suggested new potentials for electronic computers in composition, with the last movement and its intricate Markov relationships whose construction would be nearly impossible without computational assistance. The success of these experiments enabled Hiller and Isaacson to suggest a plethora of potential extensions of their techniques, including the development of new textures, new forms (beyond their “Markov chain music”), the analysis and production of microtonal works, and linkage of their composition procedures with electronic synthesis and tape music⁹⁰.

⁸⁸Hiller and Isaacson, *Experimental Music: Composition with an Electronic Computer*, 5.

⁸⁹For details on the construction of these movements, see *ibid.*, Chapters 5-6. Christoph Both undertakes a detailed analysis of the *Illiac Suite* in the context of Hiller and Isaacson’s intentions; see Both, “The influence of concepts of information theory on the birth of electronic music composition: Lejaren A. Hiller and Karlheinz Stockhausen, 1953–1960,” 95–164.

⁹⁰Hiller and Isaacson, *Experimental Music: Composition with an Electronic Computer*, 165–177. In contrast to Olson and Belar they caution that their work might be used in the “efficient production of banal commercial music”. See *ibid.*, 176.

While Hiller and Isaacson used information theory to produce novel compositions based on the codification of certain rules, the French electrical engineer Abraham Moles took it as a conceptual and practical tool to suggest the unrealized potentials of aesthetic experience. Moles was present at many of the defining moments of electronic and experimental music in the 1950s: he worked with Schaeffer, interacted with Stockhausen, taught colloquia in information theory in Gravesano, attended at least one of the London symposia, and visited the United States on a Rockefeller foundation grant⁹¹. In Moles' *Information Theory and Esthetic Perception*, published in French in 1958, he suggested that the "concepts of *information, code, redundancy, complexity, the dialectic banal-original, foreseeability, and background noise* must take their places beside the quantum theory, the principles of relativity and uncertainty, and the opposition between the microscopic and macroscopic universe".⁹² Moles would derive the equations of information theory in a slightly different manner than Shannon, enabling him to suggest that his definition is more in line with Donald MacKay's: "Thus we shall be in agreement with the definition Mackay [sic] gives in his glossary of the terms of information theory: In the most general sense of the word, information is that which adds to a representation."⁹³ Recall that for MacKay a purely random event might not increase selective information if no structure (or frame, in Mark Hansen's terminology) had been con-

⁹¹Moles was awarded \$1,200 in 1956 "to observe recent developments in electronic music and related fields in the United States". See Rockefeller Foundation, *Rockefeller Foundation Annual Report*, 1956, 243. Moles additionally published an article with Ussachevsky on new forms of musical representation that would be more precise than the conventional musical score; see Abraham Moles and Vladimir Ussachevsky, "L'emploi du spectrographe acoustique et le problème de la partition en musique expérimentale," *Annals of Telecommunications* 12, no. 9 (1, 1957): 299–304.

⁹²Moles, *Information Theory and Esthetic Perception*, 2, emphasis in original.

⁹³*Ibid.*, 19.

structured around the event. Thus for Moles information is bound up with what he calls, using terminology from psychology, the “*form (Gestalt)*”, meaning “a group of elements perceived as a whole and *not* as the product of a random collection.”⁹⁴ Via information theory Moles determines the points where *Gestalt* perception breaks down into that which he terms “scanning”, whereby one must attend to individual components rather than a percept as a whole. Such scanning occurs within an entirely random message (from the point of view of the receiver), as in this case “the receptor is unaware of the intentions of the transmitter.”⁹⁵

The transition between the *Gestalt* and scanning is intimately related to noise where it becomes a question of intention, as Moles states emphatically: “A *noise is a signal that the sender does not want to transmit*.”⁹⁶ Referring to research that he had conducted on the perception of single sounds in the presence of white noise that showed that such sounds were detectable even in the presence of extreme levels of noise, Moles noted that there was the “emergence of form in noise” and the ability to “perceive an organized phenomenon *hidden inside* an amorphous phenomenon.”⁹⁷ As a result of this work Moles derived two uncertainty relationships that resemble those developed by Gabor. The first connects the ability to resolve the amplitude of a signal with the ability to determine its frequency, while the second links the ability to resolve amplitude with the ability to resolve temporal duration; the combination of these two principles would therefore mirror Gabor’s formulation. Therefore,

⁹⁴Moles, *Information Theory and Esthetic Perception*, 57.

⁹⁵*Ibid.*, 61.

⁹⁶*Ibid.*, 79, emphasis in original.

⁹⁷*Ibid.*, 82–83, emphasis in original.

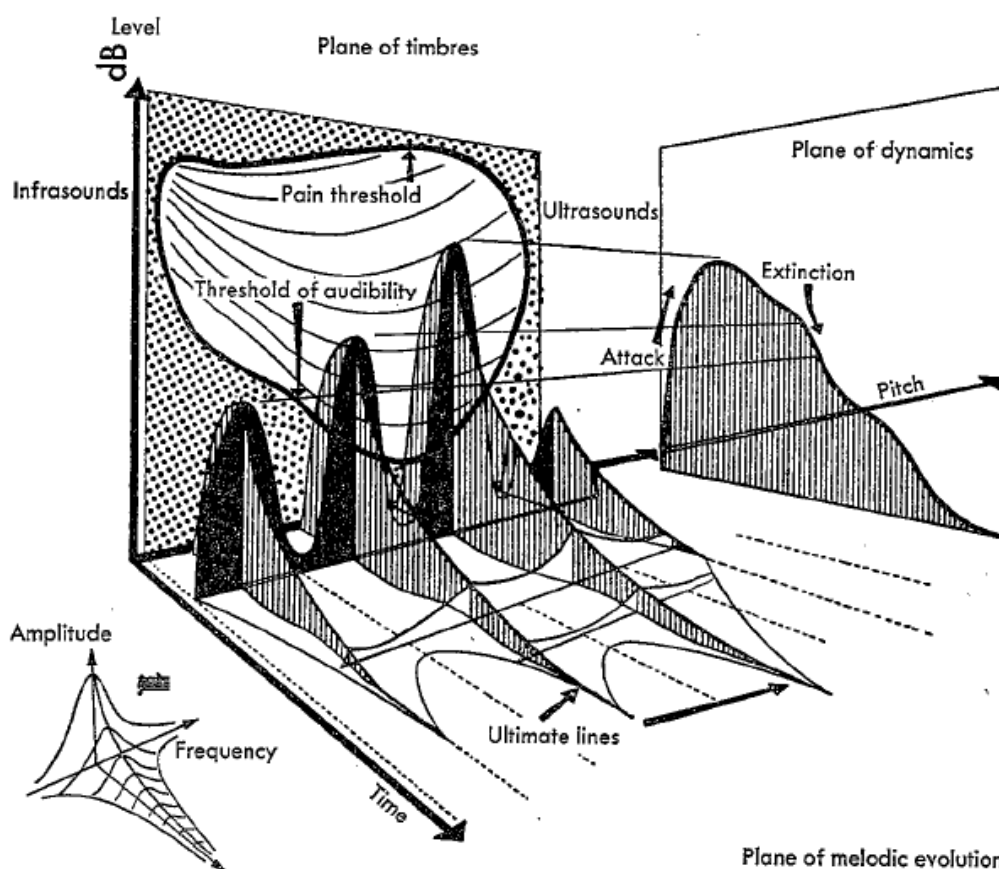


Fig. IV-3. Three-dimensional $L \times f \times t$ representation of the sonic object. In the plane $L \times f$, on the acoustic area, is projected the instantaneous spectrum of the sound. The evolution of the spectrum through time traces a volume representing the sonic object. Each slice with thickness the length of the present contains a recognizable "sonic symbol."

Figure 9: Three dimensional space of the "sonic object"; compare to Gabor's representation in Figure 7. See Moles, *Information Theory and Esthetic Perception*, 111.

"Noise thus appears as the *backdrop of the universe*"⁹⁸.

This focus on the materiality of perception revealed through experiment leads Moles to deeply question the tenets of Western music theory: "The dissolution of chords in dodecaphonic music, as well as their continual variation, and the sudden expansion of experimental music due to technological possibilities are experimen-

⁹⁸Moles, *Information Theory and Esthetic Perception*, 85, emphasis in original. For his derivations of these uncertainty relationships, see *ibid.*, 83–89.

tal proofs of the weakness of the foundations of ‘musical theory’.”⁹⁹ Information theory translates this into a decrease in the importance of the score, as “it is intended exclusively for the performers, but not at all for the listeners.”¹⁰⁰ Thus analysis should focus on the “sonic object” rather than its (potential, but not necessarily exclusive) representation in a score. Following Schaeffer, the sonic object should be understood as an isolated entity whose dynamics evolve in terms of loudness L , frequency f , and time t . And in line with Gabor, Moles would visualize this as a three-dimensional space whereby each plane cut through the space defines a different analytical approach (see Figure 9). The representation put forth by Moles recalls Potter’s visual spectrograph and provides a convenient visualization of the material of *musique concrète* and *elektronische musik* which are both enrolled in the process “to use any sonic object whatever in music which is only a dialectic of duration.”¹⁰¹

Yet all of this exposition of the relationship between information theory and music leads to a vexing paradox: how is it that an aesthetic work, such as a piece of music, is able to cause some sort of aesthetic response in the listener, even if he or she has heard the piece before? According to standard information theory, this should not occur: the listener has already heard the piece, therefore there is no new transfer of information. The title of the piece should be sufficient to arouse the same response, yet we know this is not the case. Thus Moles suggested that there was a division between “semantic” (“logical, structured, expressible, translatable viewpoint prepares actions”) and “esthetic” (“untranslatable viewpoint shapes states of mind”) information: “*Within the same material message, there is a superposition of several*

⁹⁹Moles, *Information Theory and Esthetic Perception*, 105.

¹⁰⁰Ibid., 117.

¹⁰¹Ibid., 119.

distinct sequences of symbols. These symbols are made of the same elements grouped in different ways".¹⁰² While semantic information has "a universal logic" and "serves in the behaviorist conception to prepare *actions*", aesthetic information, on the other hand, "refers to the repertoire of knowledge common to the particular transmitter and particular receptor. Theoretically this information cannot be translated into any other 'language' or system of logical symbols because this other language does not exist".¹⁰³ Aesthetic information arises because any given individual cannot have a complete recollection of a performance; each performance contains a "*field of freedom*" whereby variations in our apprehension of it changes our understanding of the message in a way that can never be entirely exhausted.¹⁰⁴ Nevertheless, the study of the precise means by which this happens "may constitute some ground rules for 'authentic composition' practiced in experimental music or *musique concrète*, where the essential problem is to assemble sonic objects in a sequence sufficiently ordered to be intelligible".¹⁰⁵

Meyer-Eppler would similarly divide information theory into two types, one referring to the "semantic" sphere ("signal attributes" or "symbols") and the other the "ectosemantic" sphere (including both "diagnostic" and "emotional" characteristics, namely the ability to identify personal traits or attributes of feeling, respectively)¹⁰⁶.

Drawing from linguistic terminology, Meyer-Eppler refined his notion of the "au-

¹⁰²Moles, *Information Theory and Esthetic Perception*, 128, 129, emphasis in original.

¹⁰³Ibid., 129, emphasis in original.

¹⁰⁴Ibid., 165–166, emphasis in original.

¹⁰⁵Ibid., 169.

¹⁰⁶Werner Meyer-Eppler, "Musical communication as a problem of information theory," *Gravesaner Blätter*, no. 26 (1965): 98–99. This article was also published in *die Reihe VIII*; see Werner Meyer-Eppler, "Musical communication as a problem of information theory," *die Reihe VIII* (1968 [1962]): 7–10. Meyer-Eppler died in 1960; it is unclear when this article was originally written.

thentic composition” by elucidating the potential overlap, if it exists, between the semantic symbols available to the composer (who is additionally the “interpreter” in authentic music) and the listener. This mismatch, remarked upon by as diverse commentators as Meyer and Moles, is understood as an aporia by Meyer-Eppler: “It follows that one and the same sound signal described as music may be classified in a completely different inventory by the composer and the listener, and a general, objective description of invariable inventory classifications on the part of an observer external to the communication chain is frequently impossible.”¹⁰⁷ Since in authentic composition there is no possibility of feedback from a listener to the composer there is no means to modify how these signals are classified; compositional intent becomes the primary guiding principle.

In a remarkable figure present in a 1958 presentation and later published in the *Gravesano Blätter*, Moles illustrates the differences between “conventional” and “experimental” musical composition (Figure 10). “Conventional” composition importantly has a feedback element from the audience, its reaction, to the performance of a work. In “experimental” composition, the composer creates the “authentic” work that is presented and appreciated by the audience—no feedback necessary. Experimental composers work to order “tonal systems” to produce a musical work which is the “*appearance of a certain degree of order out of the chaos of the world of sounds around us*.”¹⁰⁸ Information theory becomes useful to the composer by way of shedding “some light on the creative processes of musical thought”. And in a succinct statement of intention, Moles writes that, “The function of the musical message, as

¹⁰⁷Meyer-Eppler, “Musical communication as a problem of information theory,” 102.

¹⁰⁸Abraham Moles, “The Prospects of Electronic Instrumentation,” *Gravesaner Blätter* 4, nos. XV/XVI (1960): 36, emphasis in original.

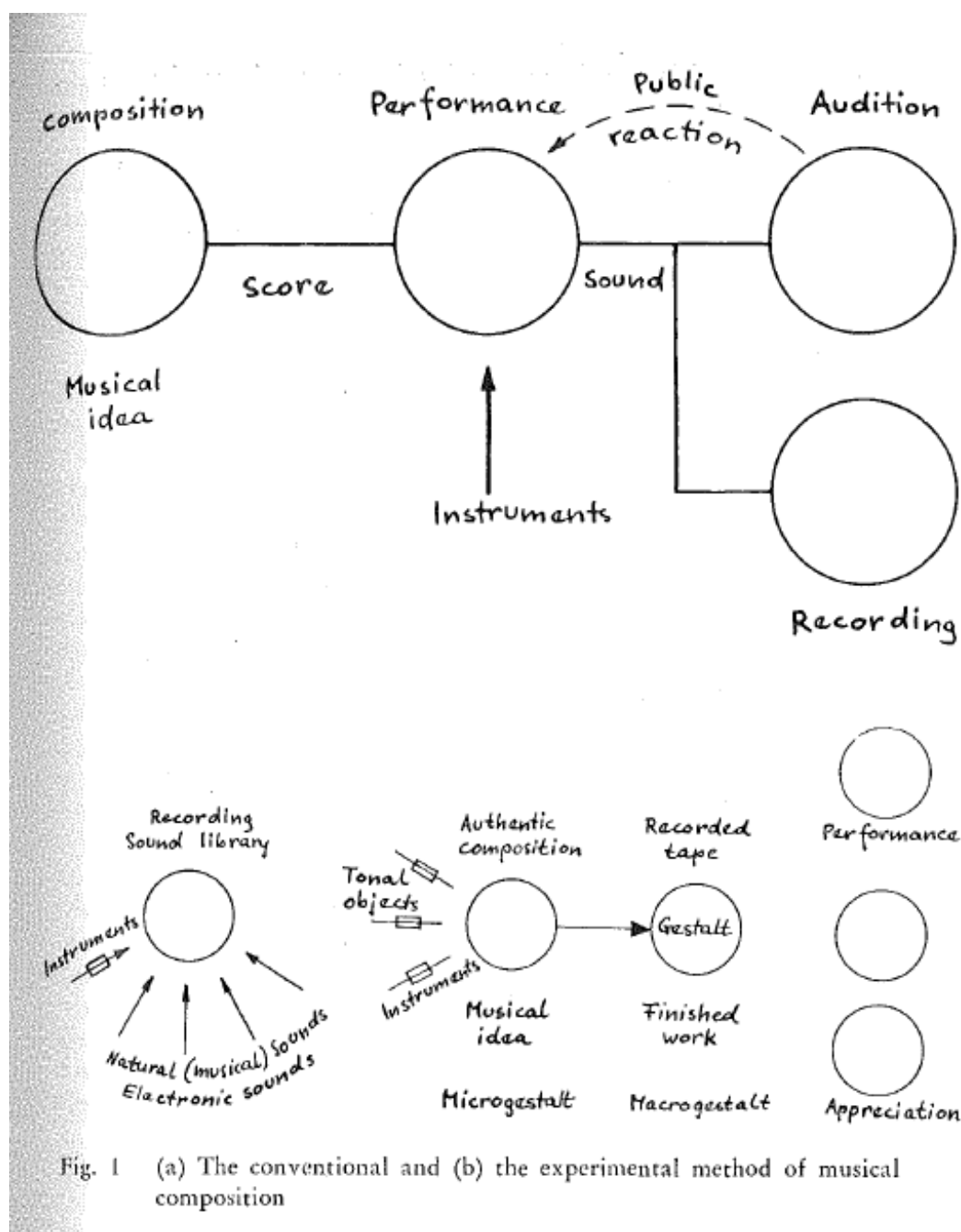


Fig. 1 (a) The conventional and (b) the experimental method of musical composition

Figure 10: Difference between “conventional” and “experimental” musical composition. From Abraham Moles, “The Prospects of Electronic Instrumentation,” *Gravesaner Blätter* 4, nos. XV/XVI (1960): 37.

a part of all messages in the surrounding world, is to augment the complexity of the receiver's universe at the transmitter's behest".¹⁰⁹

Information Theory's Complexities

It is clear that information theory generated an incredible amount of activity amongst those working in experimental music in the 1950s—composers, electrical engineers, musicologists, and a new category of researcher, the information theorist. Information theory helped to construct a new type of listener, a receiver that is both a vessel to be filled with compositional intent as well as an active agent in the re-production of an “authentic” composition. It is also clear that this combination of disparate disciplinary approaches produced a diversity of understandings that cannot easily be summarized. For on the one hand, researchers such as Coons, Coupling (Pierce), Kraehenbuehl, and Pinkerton began from the bottom, from the simplest musical “examples” possible (sometimes constructing abstractions that bear little resemblance to organized music proper). In certain situations, such as with Coons and Kraehenbuehl, the stated limits of their research immediately eliminated the potential inclusion of avant-garde musics such as serialism. Meyer as well would consider the potentials of information theory via recourse to tonal examples alone. Rudolf Arnheim, in an introduction to a set of papers in *The Journal of Aesthetics and Art Criticism* that included one of the articles written by Coons and Kraehenbuehl referenced earlier, noted the challenge of using information theory to explain or produce simple constructed examples:

¹⁰⁹Moles, “The Prospects of Electronic Instrumentation,” 44.

The problem at hand can be approached also from the other end. Instead of analyzing simple groups of elements, one can start with the peculiar patterns we call works of art and ask what kind of information they furnish. They are peculiar indeed because they take the word "in-formation" literally: they give shape rather than merely supply data. They do not intend to portray and present *things* but rather *properties* by means of things. They express the most universal through the most concrete; they use symbols that need not be codified; and they achieve high fidelity by deviating from what they reproduce. Can a theory fitted to the respectable objectives of engineering cope with such mavericks?¹¹⁰

Arnheim points to a new type of composer/musician and listener, one more aligned with Meyer-Eppler and Moles who considered information theory in a generative sense. While Pinkerton, Coupling (Pierce), and others used information theory to produce simple melodies, I mean something different here by the word "generative." For Meyer-Eppler and Moles, information theory became a method to understand the limits and potentials of sonic presentation to a human "receptor". Mapping these potentials and their limits creates a cartography that is not subsumed to historical compositional practices rooted in heuristics—recall Moles' disdain for music theory. This approach—one that pulls the description of humans into the language of communications engineering—is potentially more liberating than the

¹¹⁰Rudolf Arnheim, "Information Theory: An Introductory Note," *The Journal of Aesthetics and Art Criticism* 17, no. 4 (1959): 503, emphasis in original. Compare Arnheim's stance on the representational capabilities of music with that of Coons and Kraehenbuehl referenced earlier.

humanist one that underlies the techniques of Coons, Kraehenbuehl, Pinkerton, and others. By reducing humans to the status of a simple receptor of sonic stimuli, Meyer-Eppler and Moles expand the potential set of sonic objects beyond that of traditional Western diatonic harmony. As a consequence, music transitions into sound, divisions between humans and machines begin to wither away, and the composer becomes a transmitter of purposively arranged sonic information to a listener¹¹¹.

This potential of information theory needs to be carefully unpacked within its geopolitical field. Moles' language of human "receptors" might be disheartening when considered within the context of the 1950s and the destruction wrought by Allied and Axis powers during World War II. A reduction of human complexity to a simple sender–receiver paradigm provides a direct challenge to Enlightenment-style humanism and treads closely to the instrumentalization of behavior. Understood within the geopolitical climate of the 1950s in the US, France, and Germany, however, the application of information theory (and scientific and rationalistic approaches more generally) to music provides an alternative vector, one that cuts through attempts to recruit then-contemporary music for ideological battles between the post-war powers. For example, the musicologist Mark Carroll has demonstrated the importance of serialist works such as Pierre Boulez' *Structures 1a* to the cultural discussions of 1950s France through its programming on a con-

¹¹¹Meyer-Eppler found the terms "composer" and "listener" problematic and preferred instead the non-emotionally "prejudiced" terms "expedient" (composer) "transferent" (interpreter, performer) and "percipient" (listener). See Meyer-Eppler, "Musical communication as a problem of information theory," 98.

cert sponsored by the Congress for Cultural Freedom (CCF)¹¹². At a time when neo-tonal works by Stravinsky were being programmed alongside Boulez, Carroll writes that in France this “was seen as a cultural manifestation of reactionary forces which sought to reinstate values that had brought Europe to the verge of apocalypse, and threatened to do so again”.¹¹³ While the CCF programmed Stravinsky in order to appeal to the “masses”, Soviet propagandists turned to socialist realism. Within this milieu Boulez’ total serialism was a negation of the “need to communicate”, a deliberate rejection of both blocs in a situation where the “antagonists had demanded transparency in artistic expression in order to ensure fidelity to their political values”.¹¹⁴ Alongside the situation in post-war Germany mentioned earlier, Milton Babbitt, referenced at the beginning of Chapter 1, considered music to be limited only by the dictates of logic and psychoacoustic phenomena rather than history, a move the musicologist Martin Brody understands as responding to American intellectual debates amongst Clement Greenberg and the first Marxists, later anti-Stalinists Sidney Hook and James Burnham¹¹⁵.

Moles and Meyer-Eppler may not make this connection to prevailing cultural currents clear in their texts, but we can view and hear the resonance. The subsump-

¹¹²*Structures 1a* received a notorious analysis by Ligeti in the fourth issue of *die Reihe*; for more see Grant, *Serial music, serial aesthetics: Compositional theory in post-war Europe*, Chapter 5. The Congress for Cultural Freedom was an international organization started in 1950 to promote Western, anti-communist and anti-Stalinist values through support for cultural activities. Producing symposia and concerts while also sponsoring intellectual journals such as *Encounter*, the Congress was found to be sponsored by the CIA via a series of front organizations and foundations. For more on the Congress, see Christopher Lasch, “The Cultural Cold War: A Short History of the Congress for Cultural Freedom,” in *The Agony of the American Left* (Alfred A. Knopf, 1969), 61–114

¹¹³Carroll, *Music and Ideology in Cold War Europe*, 2.

¹¹⁴*Ibid.*, 3, 176.

¹¹⁵Martin Brody, “Music For the Masses’: Milton Babbitt’s Cold War Music Theory,” *Musical Quarterly* 77, no. 2 (1993): 161–192 Hook and Burnham additionally associated with the CCF.

tion of composition to the dictates of communication engineering provides a direct challenge to the notion of a heroic composer who draws from nature for (undeniably) his works. The composer is not erased, as Meyer-Eppler's "authentic composition" relies on a human for its production. Rather, the composer enters into a relationship with electronic or computational machines, be they the sine-wave generator of the Cologne studio or the mathematic procedures of Babbitt's formalism. While there are undeniably connections to the then-ascendant cybernetics, information theory cannot be entirely subsumed to it. Although Moles was certainly influenced by concepts from cybernetics, especially those of Ashby and Walter, he saw the direct of application of cybernetics to aesthetic questions as "premature."¹¹⁶ Rather than producing "models", which Moles understands as the purpose of cybernetics, information theory can characterize human perception in order to define the space of potential sonic objects.¹¹⁷ In Moles' understanding, then, information theory enables the generation of new sonic objects by way of its ordered, rational investigative procedure. Taken together, the ordering of sonic objects within a composition cannot necessarily be denotative of external realities but exists for itself, a musical communication that is dependent more on aesthetic information and less on semantic information. Such composition would fall outside of the purview of socialist realism, for sure, and would conflict with cultural approaches predicated on Enlightenment-style humanism. Additionally, composition influenced by the information theories of Moles of Meyer-Eppler would escape the negative feedback dictates of cybernetics at the time.

¹¹⁶Moles, *Information Theory and Esthetic Perception*, 93–94.

¹¹⁷*Ibid.*, 173–178, 119.

My attention to a certain moment within the conjunction of musical modernism and the history of technology is not meant as unquestioning acceptance of their joint tenets. For one, the composers, engineers, and theorists remain male, and alternative, less mechanistic and teleological approaches such as those of Daphne Oram remain marginalized. Composition continued to be the domain of a man, this time with access to expensive electronic equipment and the patronage of academic or state institutions. Moles would move in the 1960s to a particular type of bureaucratic cybernetic urbanism that was denounced by the students in Strasbourg associated with the Situationists through the throwing of tomatoes at Moles.¹¹⁸ Yet understood within the historical context, the engagement of Moles and Meyer-Eppler with both avant-garde composition and information theory provides a different understanding of the development of the arts within the 1950s. An expanded palette of both techniques and venues for development—communications engineering and academic, state, and corporate research labs—provided a basis for further developments in electronic arts in the 1960s such as the New Tendencies events in Zagreb and the *9 Evenings: theatre & engineering* events in New York¹¹⁹. And considered amongst strands of cultural conservatism, individualist humanism, socialist realism, questions of geopolitical alignment, and the rising stature of science and technology, the elucidation of the relationships between information theory and music by Meyer-Eppler and Moles foregrounds hybridity

¹¹⁸Situationist International, "Our Goals and Methods in the Strasbourg Scandal," in *The Situationist International Anthology*, ed. and trans. Ken Knabb, originally published in *Internationale Situationiste* #11 (1967) (Berkeley: Bureau Of Public Secrets, 2006), 263–273.

¹¹⁹Moles was additionally involved in discussions that took place in conjunction with New Tendencies; see Rosen, *A Little-Known Story about a Movement, a Magazine, and the Computer's Arrival in Art: New Tendencies and Bit International, 1961–1973*.

within a milieu of stark contrasts. This beguiling aspect of information theory—simultaneously supporting diatonic harmony as well as serialism, simultaneously having its roots in commercial development as well as suggesting new potentials of human-machine combinations—highlights the complexity of analysis required.

Moles' information theory in particular resonates with the alternative formulations I outlined in the first section. In the annals of history Shannon has been deemed the progenitor of information theory. Yet Moles draws not only from Shannon but also from Gabor, MacKay, and the cybernetically-influenced ideas of Walter and Ashby as well. Indeed, Moles' diagrammatic approach to the sonic object shares much with Gabor's logon formulation. Moles' understanding of *intention* with respect to "noises" recalls both MacDonald's questioning of how to incorporate new knowledge into information theory and Fletcher's insistence that communication systems be able to transmit the background noises of the room. The history of information theory needs to take into account the temporal dynamics of influence, tracing the waxing and waning of connections as they unfold over time. These connections can easily be missed when examined from the standpoint of the present, suggesting two important corollaries. First, if the historiography of this period focuses primarily on cybernetics to the exclusion of information theory these alternatives to Shannon's theory will not be heard. While MacKay has been at the periphery of recent retellings of this history, the diversity of approaches besides MacKay's deserves closer scrutiny. Second, the study of information theory in this period needs to acknowledge its interrelationship with the sonic arts. Cybernetics would be one of the key phrases in electronics arts in the 1960s, culminating in the important *Cybernetic Serendipity* exhibition in 1968; yet as I have hopefully shown

here, *information theory* was the generative engineering procedure for electronic and avant-garde musics of the 1950s and early 1960s. Engaging with artistic practice adds complexity to the history of this period, a complexity that indicates the interrelationship of the arts with the development of engineering concepts.

Chapter 3

The Noises of Finance

In the early twenty-first century information theory is no longer in question. While undergraduates in computer science and electrical engineering are taught the tenets of Shannon's approach, and academic and corporate research continues into ever more esoteric applications, "information theory" as a term that appears in public discourse has all but disappeared. Questions of the informational content of a particular representation have receded to the background, while research into coding and channel capacity is made manifest through new media compression technologies such as MP3¹. The openness, alternative formulations, and malleability of information theory as discussed in the previous two chapters would appear to be gone.

Yet if we listen to the echoes of information theory and its more popular cousin, cybernetics, in certain contemporary practices, we can trace the ways in which the problematic of noise interferes with the constitution of fields. The mechanisms of contemporary finance may not be the most obvious place from which to begin, yet as I will show in this chapter noise has haunted the discourse and practice of finance

¹For a recent text on the development of MP3 as a social-technical object, see Jonathan Sterne, *MP3: The Meaning of a Format* (Durham, NC: Duke University Press, 2012).

over a number of decades. Living in the low rumbling of the aftershock of the most recent financial crisis, we can follow how noise continues to both confound finance as well as provide the means for its acceleration.

The past decade has produced a growing body of work within what has been termed “economic sociology” or the “social studies of finance”². I cannot begin to summarize the plethora of studies here. Suffice it to say, however, that the particular aspect of finance I am interested in—namely, noise—surfaces only at the margins of published accounts. I nevertheless not only liberally draw on this work but also begin from similar conceptual positions, namely an interest in understanding the interplay, or interference, of humans and machines in their imbrication within financial processes. But I also wish to understand these situations through the reactivation of the now-subdued conceptual apparatuses of particular early 1970s philosophies, namely those of Deleuze, Guattari, and Lyotard (in, for example, *Anti-Oedipus* and *Libidinal Economy*), as well as more recent elaborations by writers of theory-fiction such as Nick Land and Sadie Plant. The potency of these writers’ thoughts has been greatly reduced in the intervening years, from Lyotard’s apparent disavowal of his “evil book” to the absence of Land and Plant from the canonical lists of recent cyberculture authors. This disparate juxtaposition of methodolo-

²For a set of recent books and edited collections on this topic, see Andrew Barry and Don Slater, eds., *The Technological Economy* (New York: Routledge, 2005); Michel Callon, ed., *The Laws of Markets* (Oxford and Malden, MA: Blackwell Publishers/The Sociological Review, 1998); Karin Knorr-Cetina and Alex Preda, eds., *The Sociology of Financial Markets* (London: Oxford University Press, 2005); Donald MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets* (Cambridge, MA: MIT Press, 2006); Donald MacKenzie, Fabian Muniesa, and Lucia Siu, eds., *Do Economists Make Markets? On the Performativity of Economics* (Princeton and Oxford: Princeton University Press, 2007); Donald MacKenzie, *Material Markets: How Economic Agents are Constructed* (Oxford: Oxford University Press, 2009); Fabian Muniesa, Yuval Millo, and Michel Callon, eds., *Market Devices* (Oxford: Blackwell Publishing, 2007); Trevor Pinch and Richard Swedberg, eds., *Living in a Material World: Economic Sociology Meets Science and Technology Studies* (Cambridge, MA: MIT Press, 2008).

gies, writers, and approaches is meant to reflect the elusiveness of noise, its stubborn tendency to escape any particular theoretical framing.

I follow three different forms of financial noise, paying attention to how materiality and the interference of humans and machines cause the meanings of noise to shift over space and time. First I consider how, starting in the 1980s, the “noisy” activity of traders began to be a valid topic of consideration in mainstream finance and economics as a result of the apparent failure of rational models of the market. Second, I turn to the bodily practice of open-outcry trading to listen to how sonic noise in the pits becomes recuperated into practices of financial valorization. Third, I turn to recent developments in the intersection of computers and trading to trace how material practices of human-machine hybrids again enable noise to become a means for the capture of profit. The last case especially raises the issue of *speed*, particularly when the race towards infinity turns into a race towards zero.

This chapter draws both from existing works within the sociology of economics and finance, as well as working papers and published articles within the fields of economics and finance. Because of the specialized terminology of finance and economic theory I have endeavored to define key terms and concepts in the Glossary. My aim is not simply to summarize these arguments, but rather to draw out the situations where noise causes a rupture in existing modes of thought³. The detail in which I present these aspects of economics and finance is meant to situate the arguments regarding noise within the discourses and practices of these fields. I attend especially to the elusiveness of noise as a concept, especially as it mutates between its

³In reference to recent events in the financial markets, the German media theorist Joseph Vogl has noted “in a crisis the noise of the system reveals its channels, its functional elements.” See Joseph Vogl, “Taming Time: Media of Financialization,” trans. Christopher Reid, *Grey Room* 46 (2012): 73.

existence as the dual of information and its embodiment within particular material practices, be they sonic, machinic, or something else altogether. Financial noise becomes a problematic intrusion that raises a question of acceleration while ultimately suggesting that contemporary critiques of the “crisis” require new formulations in order to provide meaningful alternatives.

Noisy Efficiency

Noise makes financial markets possible,
but also makes them imperfect.

Fischer Black, “Noise,” *The Journal of Finance*
41, no. 3 (1986): 530

Informational capitalism is impossible without the contribution of information theory and the “cyborg sciences” as termed by the economic historian Philip Mirowski⁴. The discourse of modern economics and finance is rife with references to questions of “information”: who has it, when do they have it, how is it transferred from one location to another, and how it can be acted upon in order to realize a profit. More than a decade prior to the publication of Shannon’s work, the Austrian economist Friedrich Hayek was already pushing for “information” to be considered as the term for economic messages⁵. Hayek’s interest in the problematics of economic information was crystallized in his well-known 1945 paper “The Use of Knowledge in Society.” Considering a rational economic system, “If we possess all the relevant infor-

⁴See Philip Mirowski, *Machine Dreams: Economics Becomes a Cyborg Science* (Cambridge, UK: Cambridge University Press, 2002).

⁵According to Mirowski, “in 1935 Hayek was precociously promoting the term ‘information’ as one of the central instrumentalities of market coordination”. See *ibid.*, 236.

mation, *if* we can start out from a given system of preferences and *if* we command complete knowledge of available means, the problem which remains is purely one of logic.”⁶ For Hayek such access is ultimately elusive and thus prices become the prime medium of market information: “We must look at the price system as such a mechanism for communicating information if we want to understand its real function—a function which, of course, it fulfills less perfectly as prices grow more rigid.”⁷ As the end of the previous quote indicates, Hayek argued in this paper against price controls, such as those that you might find within a planned economy. His policy suggestion would not come as a surprise to anyone versed in contemporary neoliberal rhetoric: because of the difficulty in collating all of the information in a society, centralized planning by a single actor can never work:

This is not a dispute about whether planning is to be done or not. It is a dispute as to whether planning is to be done centrally, by one authority for the whole economic system, or is to be divided among many individuals. Planning in the specific sense in which the term is used in contemporary controversy necessarily means central planning—direction of the whole economic system according to one unified plan. Competition, on the other hand, means decentralized planning by many separate persons.⁸

“[D]ecentralized planning by many separate persons”—or algorithms. For indeed Hayek’s watchers of the price signal are like little engineers—or governors—that

⁶F. A. Hayek, “The Use of Knowledge in Society,” *The American Economic Review* 35, no. 4 (1945): 519, emphasis in original.

⁷*Ibid.*, 526.

⁸*Ibid.*, 520–521.

keep an eye on the dials that reflect minute changes in information: “It is more than a metaphor to describe the price system as a kind of machinery for registering change, or a system of telecommunications which enables individual producers to watch merely the movement of a few pointers, as an engineer might watch the hands of a few dials, in order to adjust their activities to changes of which they may never know more than is reflected in the price movement.”⁹ Decentralized individuals acting independently on observed fluctuations in price: this is an approach that would resonate later with complexity theory, but is written at a time in which negative feedback has contributed to the winning of the war¹⁰.

In the intervening decades information technology expanded Hayek’s dream

⁹Hayek, “The Use of Knowledge in Society,” 527.

¹⁰Mirowski points to Hayek’s position *vis a vis* complexity by noting that it “did seem to be related obliquely to notions of Kolmogorov complexity theory”. Mirowski, *Machine Dreams: Economics Becomes a Cyborg Science*, 239. Hayek made this clear in the introduction to his three-volume opus *Law, Legislation and Liberty*:

The long period over which the present work has been growing also had the effect that I came to regard it as expedient to change my terminology on some points on which I should warn the reader. It was largely the growth of cybernetics and the related subjects of information and system theory which persuaded me that expression other than those which I habitually used may be more readily comprehensible to the contemporary reader. Though I still like and occasionally use the term “spontaneous order”, I agree that “self-generating order” or “self-organizing structures” are sometimes more precise and unambiguous and therefore frequently use them instead of the former term. Similarly, instead of “order”, in conformity with today’s predominant usage, I occasionally now use “system”. Also “information” is clearly often preferable to where I usually spoke of “knowledge”, since the former clearly refers to the knowledge of particular facts rather than theoretical knowledge to which plain “knowledge” might be thought to refer.

See F. A. Hayek, *Law, Legislation and Liberty* (London: Routledge, 1993 [1982]), xviii-xvix.

Yet according to Mirowski, Hayek’s direct influence on the cyborg transformations of economics paled in comparison to John von Neumann and others: “In a deeper sense, he [Hayek] was more akin to a romantic poet than a software engineer, in that he wanted to maintain that there was something inviolate and ineffable about rationality, something that could never be reduced to an algorithm or mechanical device” (Mirowski, *Machine Dreams: Economics Becomes a Cyborg Science*, 240). Even so, I isolate Hayek from von Neumann because of the former’s ideological importance to later neoliberal currents.

of decentralized “competition” to the realm of the computer. For finance, computation is vital for *derivatives* and the other exotic financial instruments that are key to understanding the contemporary financial “crisis”. Derivatives, as their name suggests, *derive* their value from another instrument such as a stock, bond, mortgage, or other commodity. Derivatives enable “hedging” of bets by the construction of positions that, for example, limit potential losses. For example, a farmer might enter into what is known as a “futures contract” that specifies now a particular price for a given amount of wheat at some future date. While the farmer is thus limiting potential profits by stating a price for the commodity today, he or she also limits potential losses in case of a decrease in prices in the market.. More recent types of derivatives include options, which provide the right (but not the obligation) to purchase (or sell) a given security at a given price at some future date, or swaps, which exchange future cash flows dependent on some underlying instrument such as interest or exchange rates. The complexity of derivatives trading has additionally required the contribution of mathematically-sophisticated financial analysts, termed “quants”, as well as high-powered computers in order to crunch through the computational models.

How to “price” one type of derivative, options, was a difficult question. For the past few decades it has been reliant on the Black-Scholes-Merton equation, developed by Fischer Black and Myron Scholes and independently by Robert C. Merton (son of the well-known American sociologist Robert K. Merton)¹¹. In both of their

¹¹Fischer Black and Myron Scholes, “The Pricing of Options and Corporate Liabilities,” *Journal of Political Economy* 81, no. 3 (1973): 637–654; Robert C. Merton, “Theory of Rational Option Pricing,” *The Bell Journal of Economics and Management Science* 4, no. 1 (1973): 141–183. Scholes and Merton were awarded the Nobel Memorial Prize in Economics in 1997; Black was ineligible as the award is not given posthumously. The widespread adoption of options was also hampered by US state laws

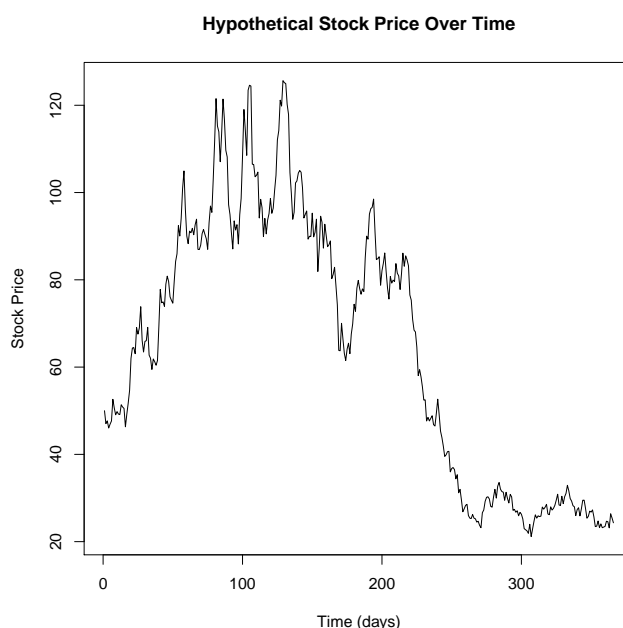


Figure 11: An example of a Geometric Brownian Motion process, often used to model stock prices.

models, Black-Scholes and Merton assume that stock prices follow what is known as a “continuous time random walk” or “geometric Brownian motion”. The details of such a process delve into complicated areas of mathematics and physics (some of which rely on Norbert Wiener’s pre-cybernetics research), but in short the idea is as follows. Consider a decision to take a step forward or a step backward, with your decision dependent on the flip of a “fair” coin: heads you move forward, tails you move backwards. Even though the coin is “fair”, and you might assume that over time your average location will be exactly where you started, in fact it is more likely that you “drift” from your position to some number of steps away from where you began.

What I just described is what is known as a “discrete” random walk; Black-Scholes

that would classify such contracts as “gambling” rather than protected financial transactions. In the end, Federal action was needed to preempt state laws on the matter. See MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*, 170–177.

and Merton considered a more complicated form that is both easier to work with mathematically and aims to capture more of the “dynamics” of actual stock prices. In their model the random walk is in “continuous” time (therefore without the discrete steps of my simple example), is “geometric” (meaning the random prices can never go below zero), and movements are based on sampling from the Gaussian or Normal distribution¹². A graph of one potential geometric Brownian motion run is shown in Figure 11. Not only does the Black-Scholes-Merton equation depend on stochastic assumptions that resonate with work in thermodynamics and statistical physics from the nineteenth century, the resulting equation can itself be massaged into what is known as the “heat” or “diffusion” equation that is also well-known to physicists¹³. In many ways we thus have a potentially constructive interference with Shannon’s approach to information theory discussed in Chapter 1; just as Shannon constructed information theory on the basis of the stochastic relationships between English words, Black, Scholes, and Merton used the assumption of a random walk to construction their options pricing formula. In both cases, assumed “regularities” of human-machinic systems are simplified and codified in order to produce a manageable representation of reality. In the financial case it would be of a piece with the

¹²The Gaussian “bell curve” is one of the most common probability distributions in use, in part due to its mathematical simplicity, a characteristic that leads to so-called “closed-form” solutions and prevents complications such as “infinite” variance. However, as the French mathematician and primary developer of “fractal” geometry Benoit Mandelbrot noted, stock prices tended to be distributed more in the “tails” (extremes) of a distribution than the Gaussian would allow. However, to model this type of distribution would require importing into economics a whole new type of mathematics, one that would dispense of the Gaussian’s simplicity and “elegance”. For more on these debates see MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*, 105–118.

¹³For more on the contribution of thermodynamics to new understandings of economics in the nineteenth century, see Philip Mirowski, *More heat than light: Economics as social physics: Physics as nature’s economics* (Cambridge, UK: Cambridge University Press, 1989).

simplifying assumptions underlying then-cutting-edge financial economics¹⁴.

These assumptions were vital to the two key frameworks then-underlying mathematical finance: the Capital Asset Pricing Model (CAPM) and the Efficient-Market Hypothesis (EMH). I will only explain briefly the CAPM as the EMH is more important to my argument. In short, the CAPM relates the expected return on a risky asset given the so-called risk-free rate (that is, the rate of return on an asset such as United States government bonds that are assumed to be riskless) and the expected return on the market as a whole. This is governed by the risky asset's "beta" (β), a factor that is meant to capture the relationship between the volatility of the market and the volatility of the risky asset. If the volatility of the risky asset is higher than the underlying volatility of the market, the β for the asset will be greater than one. Since there is underlying risk in assets with a β greater than one, investors in assets with higher β s will demand higher rates of return. The CAPM rests on a number of problematic assumptions, many of which also underly the EMH, namely that purchasing or selling of assets does not affect their prices, new information is available immediately to everyone in the market, there are no trade and transaction costs, and investors can lend or borrow at unlimited amounts

¹⁴As an aside, Black's PhD dissertation was a work of artificial intelligence, a "question answering" system written in LISP on MIT's early time-sharing system and overseen by Marvin Minsky. See Fischer Black, "A Deductive Question-Answering System," in *Semantic Information Processing*, ed. Marvin Minsky (Cambridge, MA: MIT Press, 1968), 354–402 and Marvin Minsky, "Introduction," in *Semantic Information Processing*, 1–32. Minsky notes that Black acknowledged another key early artificial intelligence researcher, John McCarthy; along with Shannon and others, McCarthy organized the Dartmouth Summer Research Project on Artificial Intelligence in 1956, one of the first meetings of this newly-termed field. For more on the debates surrounding the early days of artificial intelligence, see Kline, "Cybernetics, Automata Studies, and the Dartmouth Conference on Artificial Intelligence." Donald MacKenzie also remarks on this aspect of Black's work; see MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*, 127. It is an interesting thought experiment to consider what contributions Black would have made to artificial intelligence had he continued working with McCarthy.

at the risk free interest rate¹⁵

Cursory rumination on these assumptions will immediately invalidate them: not everyone has equal access to capital for investment, intermediaries charge transaction costs, information percolates at differential rates. Yet such problematics did not bother many economics of the time, partially as a result of a persuasive paper by a young scholar named Milton Friedman. In his essay “The Methodology of Positive Economics” Friedman distinguishes between “normative” economics, the description of what ought to be, and “positive” economics, the construction of possible testable hypotheses and named as such to reference positivism in the philosophy of science. Friedman further distinguishes, in the positive program, between the assumptions of a hypothesis and the attendant predictions the hypothesis makes: “To be important, therefore, a hypothesis must be descriptively false in its assumptions; it takes account of, and accounts for, none of the many other attendant circumstances, since its very success shows them to be irrelevant for the phenomena to be explained”.¹⁶ Noting that the assumptions surrounding the equations of motion for a freely falling object are most definitely unrealistic on Earth, Friedman suggests that critiquing an economic theory on the basis of its assumptions is a logical error:

...the entirely valid use of “assumptions” in *specifying* the circumstances for which a theory holds is frequently, and erroneously, interpreted to mean that the assumptions can be used to *determine* the circumstances for which a theory holds, and has, in this way, been

¹⁵For much more on the development of the CAPM see MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*, 37–67.

¹⁶Milton Friedman, “The Methodology of Positive Economics,” in *Essays in Positive Economics* (Chicago: University of Chicago Press, 1953), 14–15.

an important source of the belief that a theory can be tested by its assumptions.¹⁷

Friedman's riposte against those who would critique economic theory on the basis of its assumptions has become standard over the past fifty years¹⁸. By making analogies with the practice of the physical sciences, Friedman's arguments are of a piece with then-contemporary attempts to place the social sciences on seemingly more solid footing; indeed, Friedman notes that the inability of economics to construct controlled experiments is similar to the problem faced by astronomy.¹⁹ Nevertheless, it is clear that not only the assumptions, but the hypotheses themselves, are not value neutral; as the economists George Frankfurter and Elton McGoun note, "It is little wonder that having endowed markets with the same attributes as the physical universe (timeless, impartial, impersonal, and even beautiful and awe-inspiring), we should adopt a term applicable to physical processes (efficiency) to describe them"²⁰. In the introduction to a collection of papers on the EMH, the financial economist Andrew Lo used references from engineering (engine efficiency) and statistical mechanics (thermal equilibrium) to argue that "the EMH is an idealization that is economically unrealizable, but which serves as a useful benchmark for measuring relative efficiency", a statement that resonates with both Friedman's scientism and

¹⁷Friedman, "The Methodology of Positive Economics," 19.

¹⁸On why these unrealistic assumptions did not bother many supporters of these models see Donald MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets* (Cambridge, MA: MIT Press, 2006), 9–12.

¹⁹Friedman, "The Methodology of Positive Economics," 10.

²⁰George M. Frankfurter and Elton G. McGoun, "Ideology and the theory of financial economics," *Journal of Economic Behavior & Organization* 39, no. 2 (1999): 172. The economist Paul Samuelson suggested that Friedman's methodology is not value-free and instead defended the "perfectly competitive laissez faire model of economics." Samuelson quoted in MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*, 10.

his understanding of economic hypotheses never being absolutely true.²¹

Further expounding on this aspect of the philosophy of economics will unfortunately pull me too far afield, so I will instead return to a description of the EMH in order to show how its own *inefficiencies* (as defined by the developers of the hypothesis themselves) lead to a consideration of *noise*²². The EMH is dependent on the random walk properties presented earlier; if stock prices did not follow a random walk, the reasoning goes, then it would be trivial to exploit the underlying trend in order to make a profit. Eugene Fama, in one of the most well-known expositions

²¹Andrew W. Lo, "Introduction," in *Market Efficiency: Stock Market Behaviour in Theory and Practice*, ed. Andrew W. Lo, vol. I (Cheltenham, UK and Lyme, NH: Edward Elgar Publishing, 1997), xviii.

²²Importantly the question of how economic theories are taken up by the market participants themselves is key to the debates in the social studies of finance surrounding *performativity*. Following Michel Callon, who first formulated the thesis in *The Laws of Markets*, Donald MacKenzie, Fabian Muniesa, and Lucia Siu write in their introduction to a volume on performativity that Callon considers "economics not as a form of knowledge that depicts an already existing state of affairs but as a set of instruments and practices that contribute to the construction of economic settings, actors, and institutions" (Donald MacKenzie, Fabian Muniesa, and Lucia Siu, "Introduction," in *Do Economists Make Markets? On the Performativity of Economics*, 4). In a contribution to the same volume, Philip Mirowski and Edward Nik-Khah critique the performativity thesis via a wider critique of Actor-Network Theory (ANT). Noting that the ANT-based account tends to ignore asymmetrical power relationships, such as those that might be found in a major governmental auction involving large telecommunication companies, Mirowski and Nik-Khah write that:

The auctions as they finally materialized were a curious amalgam of technical achievement and crude politics, but this does not imply that a flat ontology of "actants" and networks would help us understand how they came about. Indeed, in our opinion, so far it has only served to obscure the actual causes of events—in the same manner that the economists themselves have misrepresented the causes (Philip Mirowski and Edward Nik-Khah, "Markets Made Flesh: Performativity, and a Problem in Science Studies, Augmented with Consideration of the FCC Auctions," in MacKenzie, Muniesa, and Siu, *Do Economists Make Markets? On the Performativity of Economics*, 200).

Susan Leigh-Star also noted this problem with ANT early in its development (Susan Leigh Star, "Power technologies, and the phenomenology of conventions: on being allergic to onions," in *A Sociology of Monsters: Essays on Power, Technology, and Domination*, ed. John Law [London, UK: Routledge, 1991], 26–56). I agree with the critiques of Mirowski, Nik-Khah, and Star, although further elucidating my position will again take me too far afield for this chapter.

of the EMH, entitled “Efficient Capital Markets: A Review of Theory and Empirical Work” (1970), argued that while knowing the distribution of past prices is important to understanding the distribution of future prices, “the *sequence* (or the order) of the past returns is of no consequence in assessing distributions of future returns”.²³ Fama’s exposition of the EMH considers three different potential informational efficiency situations. In the first *weak* form of the EMH the market is said to be efficient if it immediately incorporates information about past prices of a stock. The second form of EMH is known as *semi-strong*, and in this situation the market is efficient if it not only incorporates past price information but all public information about the firm (such as company earnings announcements). The third and most stringent form of EMH is known as *strong* and is when the market immediately incorporates all information known to insiders or groups who have special access. In sum, Fama suggested that the evidence up to that point suggested that capital markets, at least in the United States, supported at least the weak and semi-strong forms of the EMH and, in many cases, the strong form as well. In fact, Fama could at that point find only two situations where the strong form of the EMH did not hold. The first is corporate insiders in general, in which securities regulations already provided hefty consequences for trading on this information. The second situation was “specialists” on the floor of exchanges, those who have access to the limit order book. As a result of this informational asymmetry, specialists can advantageously order trades to eke out small profits based on minuscule price fluctuations. While Fama suggests that this type of activity is evidence for market inefficiency, he

²³Eugene F. Fama, “Efficient Capital Markets: A Review of Theory and Empirical Work,” *The Journal of Finance* 25, no. 2 (1970): 387, emphasis in original.

indicates that it could be eliminated through electronic market exchanges²⁴.

The EMH, and to a lesser extent the CAPM, had become dogma by the late 1970s, with one economist stating that “I believe there is no other proposition in economics which has more solid empirical evidence supporting it than the Efficient Market Hypothesis”²⁵. Nevertheless the EMH began to be attacked, not only in its ability to explain certain financial anomalies, but also as a result of new forms of economic and financial research that paid attention to what were termed “psychological biases”; this form of research came to be known as *behavioral finance* and is most linked to the early work of Daniel Kahneman and Amos Tversky in examining how people’s expectations of future events does not match the assumed underlying probabilistic models²⁶. As a result of this, a small number of financial economists began to ask how such inefficiencies—such as the inability to correctly estimate risk based on probabilistic models—might function within actual markets and whether or not they were a stabilizing or destabilizing force.

Perhaps surprisingly, one of the most cogent early discussions of these inef-

²⁴“With modern computers, it is hard to believe that a more competitive and economical system would not be feasible. It does not seem technologically impossible to replace the entire floor of the New York Stock Exchange (NYSE) with a computer, fed by many remote consoles, that kept all the book snow kept by the specialists, that could easily make the entire book on any stock available to anybody (so that interested individuals could then compete to ‘make a market’ in a stock) and that carried out transactions automatically.” (Fama, “Efficient Capital Markets: A Review of Theory and Empirical Work,” 399, footnote 22)

²⁵Michael C. Jensen, “Some anomalous evidence regarding market efficiency,” *Journal of Financial Economics* 6, no. 2–3 (1978): 95, quoted in MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*, 95.

²⁶For the financial anomalies that the EMH could not explain, see *ibid.*, 94–98; for Kahneman and Tversky’s early work, see Daniel Kahneman and Amos Tversky, “On the psychology of prediction,” *Psychological Review* 80, no. 4 (1973): 237–251; Daniel Kahneman and Amos Tversky, “Prospect Theory: An Analysis of Decision under Risk,” *Econometrica* 47, no. 2 (1979): 263–292. Kahneman went on to win the Nobel Memorial Prize in Economics in 2002; like Black, Tversky was ineligible for the award as he had died six years earlier.

ficiencies was by Fisher Black himself. In a 1986 presentation to the American Finance Association entitled simply “Noise,” Black constructed a binary between noise and information, suggesting that there were traders in the market who could not distinguish between the two:

In my basic model of financial markets, noise is contrasted with information. People sometimes trade on information in the usual way. They are correct in expecting to make profits from these trades. On the other hand, people sometimes trade on noise as if it were information. If they expect to make profits from noise trading, they are incorrect. However, *noise trading is essential to the existence of liquid markets*²⁷.

As Black admits, his theory is not based on mathematical formalism and might appear to be “untestable, or unsupported by existing evidence,”²⁸ an oblique reference to Friedman’s positive economics. But this does not matter: Black ultimately suggests that, in a prescient nod to later performative theories of finance, “someday, these conclusions will be widely accepted.”²⁹

For Black, the concept of “noise trading” is an attempt to rescue the EMH in the face of the “irrationality” of human actors. In a world that was governed exclusively by the EMH there would be no potential of making a profit on information:

²⁷Black, “Noise,” 529, emphasis added. While Black uses the language of Shannon-style information theory, his distinction between noise and information has, I would argue, more to do with Weaver’s popularization of Shannon than with Shannon’s more limited mathematical definition. For more on this distinction, see Chapter 1.

²⁸Ibid., 530.

²⁹Ibid.

market prices would instantaneously reflect existing information, making arbitrage impossible. However, the assumptions underlying EMH are not valid within existing markets, and thus those engaged in, for example, fundamental analysis can expect to make a profit trading on existing information. Yet these traders must trade with those who “think the noise they are trading on is information.”³⁰ This implies, then, that the “price of a stock reflects both the information that information traders trade on and the noise that noise traders trade on.”³¹ Black ultimately suggests, however, that even if prices incorporate noisy information, they are, for the most part, never more than a factor of two away from their value.³² Black’s distinction between “correct” and “incorrect” information implies, then, that over time the noise traders most likely will not earn a positive return on his or her erroneous beliefs.

Shortly after the publication of Black’s speech Andrei Shleifer (economist and early researcher in behavioral finance) and Lawrence Summers (economist, US Treasury Secretary under Bill Clinton, former President of Harvard University, and nephew of Nobel Memorial Prize in Economics winners Paul Samuelson and Kenneth Arrow) laid out the potential situations where noise traders might in fact do *better* than seemingly more informed investors.³³ For example, unlike in the assumptions of EMH and CAPM, buying and selling securities is not “frictionless” (i.e., there are transaction costs and limits to the amount one can leverage in short selling) meaning that more well-informed investors might not be able to take advan-

³⁰Black, “Noise,” 531.

³¹Ibid., 532.

³²Ibid., 533.

³³Andrei Shleifer and Lawrence H. Summers, “The Noise Trader Approach to Finance,” *The Journal of Economic Perspectives* 4, no. 2 (1990): 19–33.

tage of incorrectly priced securities. In these cases, what appear as arbitrage opportunities (as a result of noise traders pushing the price of a stock up or down) could be too costly to undertake for the more well-informed investor. In fact, over time noise traders and the informed arbitrageurs become indistinguishable:

When they bet against noise traders, arbitrageurs begin to look like noise traders themselves. They pick stocks instead of diversifying, because that is what betting against noise traders requires. They time the market to take advantage of noise trader mood swings. If these swings are temporary, arbitrageurs who cannot predict noise trader moves simply follow contrarian strategies. It becomes hard to tell the noise traders from the arbitrageurs.³⁴

Shleifer and Summers, along with their colleagues J. Bradford De Long and Robert J. Waldmann, incorporated these suppositions into a set of two econometric models. For example, one model showed that “noise traders can earn higher expected returns solely by bearing more of the risk that they themselves create. Noise traders can earn higher expected returns from their own destabilizing influence, not because they perform the useful social function of bearing fundamental risk.”³⁵ Another model suggested that, contra the suggestion of Milton Friedman that unsophisticated investors will quickly exhaust all of their available capital,

These results imply that a population composed entirely of rational investors is not “evolutionarily stable” (Maynard Smith 1982). If a

³⁴Shleifer and Summers, “The Noise Trader Approach to Finance,” 26.

³⁵J. Bradford De Long et al., “Noise Trader Risk in Financial Markets,” *Journal of Political Economy* 98, no. 4 (1990): 706.

small number of noise traders are introduced into the population, their relative wealth tends to grow. Noise traders can successfully “invade” the population. In a world in which investors occasionally “mutated” and changed from noise trader to rational investor or vice versa, it would be surprising to find a population composed almost entirely of rational investors³⁶.

This idea of the noise trader is now entrenched within the world of financial economics. Recent papers have, for example, performed empirical studies that purport to show that noise can become systematic in a market, correlated across distinct investors and subject to the same types of biases first shown by Kahneman and Tversky.³⁷ As Black surmised, the noise trader has become accepted by financial economists.

Indeed, the notion of the “noise trader” is additionally understood by at some traders themselves. In an attempt to come to grips with the economic and financial details of the most recent financial crisis, the writer Keith Gessen, in conjunction with the magazine *n + 1*, began a series of interviews with a person he calls “Anonymous Hedge Fund Manager” (HFM). HFM, embedded within the world of derivatives, arbitrage, and speculation, provided Gessen with an easy-to-understand primer on fundamental concepts that were obscured by a lack of in-depth discussion in the general press.³⁸ (HFM would eventually leave Wall Street

³⁶J. Bradford De Long et al., “The Survival of Noise Traders in Financial Markets,” *The Journal of Business* 64, no. 1 (1991): 17. The authors cite John Maynard Smith’s 1982 book on the application of game theory to evolutionary biology, *Evolution and the Theory of Games*.

³⁷Brad M. Barber, Terrance Odean, and Ning Zhu, “Systematic noise,” *Journal of Financial Markets* 12, no. 4 (2009): 547–569.

³⁸Anonymous Hedge Fund Manager and Keith Gessen, *Diary of a Very Bad Year: Confessions of*

altogether.) HFM, in a series of later interviews posted on the $n + 1$ website, noted how market inefficiencies, produced through Black's "noise traders", enabled the capturing of large profits during the internet bubble:

Yes, you want to be in an inefficient market, with "noise-traders"—people who believe that they have some skill but they really don't. A great time for stat-arb [statistical arbitrage] was during the inflation of the internet bubble, because so many people, so many average retail investors decided "I'm a stock market genius!" They were just crazy, they were just noise-traders that were creating a lot of distortion. They were sloppy in the way that they traded, and they were also doing things that were just foolish and that created a lot of anomalies that stat-arb guys were able to exploit. After the internet bubble collapsed, that next year was a much tougher year for stat-arb because those noise-traders were gone. It's sort of effectively functioning like the house in the casino, the gamblers are all like that, when there's more of them you do well.³⁹

Like Black, HFM understands the noise traders as being necessary for normal functioning. Noise becomes a vital component of the system, the unpredictable activity that paradoxically creates the conditions for the performance of the equations that underly modern finance. Additionally, HFM sees noise traders as part of a binary: those who have information, and those who do not, the latter being the noise traders

an Anonymous Hedge Fund Manager (New York: Harper Perennial, 2010).

³⁹Keith Gessen, "HFM Redux, Part Two," December 16, 2010, accessed July 3, 2013, <http://nplusonemag.com/hfm-redux-part-two>.

and thus able to be taken advantage of by those who trade on “real” information. Yet unlike Shleifer and Summers, HFM suggests that those better informed will ultimately be able to take advantage of the noise traders.

This distinction between “noise” and “information” is in the end, of course, untenable. All markets possess noise to some degree as transactions do not occur without some friction, either in time or space. Noise is an undeniable aspect of trading as a result of the material, embodied world—embodied in the sense of humans making the trades or writing computer algorithms, and material in the sense of the intersection of humans and machines within real systems, rather than idealized equations. Noise then is not easily assignable to those who are potentially “duped” into believing so-called “false” information; rather it is precisely a result of the factors just mentioned.

In a sense the more sophisticated accounts of noise presented in this section resonate with the alternative accounts of the distinction between noise and information discussed in Chapter 1. Recall that D. K. C. MacDonald understood noise as necessary to the production of new scientific knowledge, noting that Shannon’s approach could not deal with that which was previously unknown. To compute the entropy of a given message required knowing in advance all of the possible states of the message, an impossibility during the discovery of the novel. Yet even without taking this difficulty into account, Shannon’s formulation still assigned the highest informational content to an entirely random message. Therefore the ability to clearly demarcate information from noise—or signal from noise—remains only a pipe-dream. Noise and information remain intertwined, folded upon each other.

The interference between noise and information additionally arises because

what “information” and “noise” mean to these financial economists or hedge fund managers remains elusive. While the EMH makes clear predictions regarding *how* information is supposed to be absorbed within capital markets in order to become efficient, it has difficulty defining precisely *what* information is, leading to the tortured attempts to cleave “noise” from “information”. In a world where people do not act like rational agents every moment of the day, where behavior is not predictable to infinite accuracy and precision, some form of “noise” is inevitable. In the next section I discuss some situations where this noise becomes sonic, raising similar questions as to whether or not these seemingly extraneous sounds are, in fact, information.

Affectual Noise in the Pits

Specialists often cite factors peculiar to the floor, such as the ambient noise level, as important elements in their trading decisions.

Ananth Madhavan and
Venkatesh Panchapagesan, “Price Discovery
in Auction Markets: A Look Inside the
Black Box,” *The Review of Financial Studies*
13, no. 3 (2000): 638

While electronic trading—and its materiality of multiple screens and ubiquitous Bloomberg terminals—has transformed the practice of contemporary finance over the past two decades, the sights and sounds of physical, “open outcry” trading con-

tinue to dominate our cultural imaginary. The ringing of the opening bell at the NYSE, so cherished on the day of an initial public offering—the business reporter on the floor of the exchange, moving amongst the discarded paper littering the floor, weaving his or her way through the totems of screens and electronics, surrounded by the din of an unintelligible language—the shock of unexpected market movements captured in the faces of traders on the floor or in the pits, fear and anxiety that no psychochemical pill could relieve: these are the moments we recall in conjunction with the world of trading, affectual moments that suggest rather than signify. Yet the trader's tableaux is now primarily one of numbers, graphics, and text: the visual, rather than some combination of senses, a single modality rather than the intersection and interference of multiple ones. Such images—for they are primarily images—are to be found in the recent independent film *Margin Call* (2011), where the key moment of crisis is revealed through unseen graphs and values on a bank of computer screens. When drastic measures have to be taken in response to these numbers, endless rows of computer screens on the so-called trading “floors” are the primary visual accompaniment (along with the skyscrapers housing the firms) to the unseen voices on the phone that mark the decline of the firm (Figure 12).

This shift has taken place amongst a move towards algorithms that enable primarily electronic forms of trading (discussed in detail in the next section) as well as technological apparatuses such as the Bloomberg or Reuters terminals that provide ready access to real-time and historical financial information. Yet the transition has not been without conflict and controversy, as the anthropologist Caitlin Zaloom has so ably demonstrated in *Out of the Pits: Traders And Technology from Chicago to London*. Zaloom's ethnography details how the Chicago Board



Figure 12: Film still from *Margin Call* (2011).

of Trade (CBOT), one of the largest and most prominent derivatives exchanges in the world, dealt with pressures to move towards electronic exchanges and away from open-outcry trading.

Since my interest in sonic practices of finance is intertwined with open-outcry trading, it is important to explain this practice in some detail⁴⁰. An open-outcry pit, such as that found on the floor of the CBOT, pairs buyers and sellers through a bodily practice of trading involving the extremities of behavior. Orders to buy and sell a particular derivative, such as a grain future, stock market index, or bond contract, come into the floor and are routed through clerks to a series of brokers who line the top of the “pit” (see Figure 13). In the case of the CBOT, the pit is an octagonal

⁴⁰My account in the next few paragraphs draws heavily from Zaloom’s work as well as documentaries such as *Floored* (2009). See Caitlin Zaloom, *Out of the Pits: Traders And Technology from Chicago to London* (Chicago: University of Chicago Press, 2006) and for *Floored* see Trader Film LLC, “About - FLOORED,” 2009, accessed July 3, 2013, <http://flooredthemovie.com/community/> and JCL’s Forex, “Floored: Into The Pit - Epic Trader Movie!,” May 11, 2012, accessed July 3, 2013, <https://www.youtube.com/watch?v=tCcXr-fyF4Q>.



Figure 13: Chicago Board of Trade Corn Pit, 1993. Image taken by Jeremy Kemp and released into the public domain (originally from https://secure.wikimedia.org/wikipedia/en/wiki/File:Chicago_bot.jpg).

space with a series of raised steps. Hierarchy of power is reflected in position on the steps; movements of traders up and down do not come easily and are the result of particular actions by younger traders via attempts to raise their status in the pits, such as getting the attention of more experienced and well-regarded traders higher in the pits, as well as physical altercations with those occupying higher steps. Here, the metaphor of moving to higher rungs of a career ladder has an obvious spatial referent. Within the pits are traders of varying levels of ability and experience. Yet there are always those known as the “market makers” or “locals” in the parlance of the CBOT. These are traders who are not necessarily affiliated with large financial

firms but who trade with their own capital. Their purpose is to provide market “liquidity”; that is, they are obligated to buy and sell contracts no matter the state of the market, no matter how low it falls⁴¹. Locals hope to make a profit through the *speculation*, that is, correctly guessing short-term moves up or down in the market. The goal is to not make a large profit by holding a position for a long period of time, but rather make a number of small profits through short-term holdings, sometimes on the order of seconds. Besides the locals, other traders in the pit are affiliated with particular firms and receive a cut of the profits through a commission-based system.

Because of the number of potential buyers and sellers for the particular contracts, getting the *attention* of a particular party is of the utmost importance in order to ensure the best possible price. While garish jackets and ties, foam inserts in shoes to increase one’s height, and physical heft provide some of these signals, hand signals and the voice are the primary tools of the trade. Particular configurations of the hand in conjunction with the head and torso present certain data regarding a potential trade; such signals are specific to the various exchanges⁴². Coupled with the hand signals are shouts of pairs of numbers, the order of which differs depending on whether the traders wishes to buy or sell. This din, this *noise*, presents a cacophony to an untrained ear yet a carefully constructed system to the experienced trader. Zaloom comments on these paired aspects of pit trading:

⁴¹One of the many reports about the 1987 crash of the NYSE noted that NYSE “specialists” (with responsibilities similar to those of CBOT locals) had difficulty in supporting their stocks, while many involved in the over-the-counter market simply failed to answer their phones. See Mark Carlson, “A Brief History of the 1987 Stock Market Crash with a Discussion of the Federal Reserve Response” (Federal Reserve Board Finance and Economics Discussion Series 2007-13, 2007), 9–10, 5–6.

⁴²Attempts are underway to document these signals as open outcry trading fades in importance and is presumed to eventually disappear altogether. See Debrouillard Group, “Trading Pit History,” n.d. Accessed July 3, 2013, <http://tradingpithistory.com/>.

The presentation of market numbers in voice forces traders to cope with the immateriality of the bid or offer. A number is rarely shouted once. Because each bid or offer hangs in the air for only a second, the trader barks the number into the pit repeatedly to make sure he is identified with it. At the same time he holds out his hands, fingers extended into numerical signals, to bring a concrete visual presence to his bid or offer. The sounds of repeated numbers form the cadence of the market and can convey urgency or boredom. In receiving the numbers that others bring to the market, traders appeal to “feeling.” This word, encompassing all sensory information, is one traders use to characterize their knowledge of the market.

The body is a key interpretive instrument for the pit trader. Listening to rhythms of the numbers as they run in the pits leads traders to judge the market as “heavy” or “light,” likely to rise or fall according to their sensory estimations. Beyond creating the basis for individual traders’ economic judgments, the ambient noise of the pit affects the market as a whole. Economists studying the CBOT pits found that increased sound levels lead to higher trading volumes and foreshadow periods of high volatility in the pits.⁴³

Zaloom’s final sentence makes reference to one of the few academic studies regarding the role of sound in open outcry trading. In the wonderfully titled article “Is Sound Just Noise?,” Joshua Coval and Tyler Shumway ask whether or not the

⁴³Zaloom, *Out of the Pits: Traders And Technology from Chicago to London*, 150.

sounds of shouting in the pit (proxied in their study by the measurement of ambient sound level in decibels) might convey information that is not necessarily available on the computer screens that were then coming to dominate trading: "...we ask whether there exists information that is regularly communicated across an open outcry pit but cannot be easily transmitted over a computer network. Any signals that convey information regarding the emotion of market participants—fear, excitement, uncertainty, eagerness, and so forth—are likely to be difficult to transmit across an electronic network."⁴⁴ As Zaloom intimated, Coval and Shumway found that the ambient sound level of the pits *did* have predictive impact in a number of areas (such as the "depth" of the market, "information asymmetry", and the "cost of transacting"). Their conclusion reads not only as a paean to the specificity of the open outcry pit but also a cautionary tale of accelerated moves to electronic trading:

A key implication of this research is that in the trading arena, machine may not be a perfect substitute for man [sic]. Current electronic trading mechanisms are clearly not equipped to convey the kinds of signals for which a sound level is likely to proxy. Certainly computer terminals can be outfitted to offer some conveyance of nonmarket signals. But their ability to replicate the variety of signals that can be communicated in a face-to-face setting—for example, fear in a trader's voice—is likely to be limited. As a result, as trading volumes migrate to electronic exchanges, much of this information will be lost. The

⁴⁴Joshua D. Coval and Tyler Shumway, "Is Sound Just Noise?," *The Journal of Finance* 56, no. 5 (2001): 1890.

welfare implications of losing this information merit further study.⁴⁵

Coval and Shumway clearly suggest the importance of *affect* conveyed by the noise in the pits via their evocative set of nouns: “excitement”, “uncertainty”, “eagerness”, “fear”⁴⁶. For Coval and Shumway the intensities gestured towards by these words cannot be signified by changes in numbers on a screen. They note this via a particularly striking image: “For instance, a trader who tries to unwind a large short position by waving his arms and jumping up and down in an open outcry exchange might have difficulty communicating such eagerness across a computer screen.”⁴⁷ Through a focus on sound, Coval and Shumway attempt to understand whether the situations they discuss provide actionable information to other traders.

Their interests in evocative sounds is of a piece with recent discussion surrounding affect within the humanities and the social sciences. An introduction to a series of essays on affect describes it thusly: “affect is found in those intensities that pass body to body (human, nonhuman, part-body, and otherwise), in those resonances

⁴⁵Coval and Shumway, “Is Sound Just Noise?,” 1909–1910.

⁴⁶I consider “affect” as conceptually distinct from “emotion”. In the words of affect theorist Clare Hemmings, “Affect broadly refers to states of being, rather than to their manifestation or interpretation as emotions.” Clare Hemmings, “Invoking Affect: Cultural Theory and the Ontological Turn,” *Cultural Studies* 19, no. 5 (2005): 551. In my understanding “emotion” refers to the categorization of a limited number of states characteristic of contemporary cognitive science research. The uptake of emotion within human-computer interaction has mirrored the cognitive science model; as Kirsten Boehner, Rogério DePaula, Paul Dourish, and Phoebe Sengers note, “emotion has been treated as objective, internal, private, and mechanistic” (Kirsten Boehner et al., “How emotion is made and measured,” *International Journal of Human-Computer Studies* 65, no. 4 [2007]: 280). Nevertheless, I do believe there is a problem with approaching affect as primarily undifferentiated with no possibility of distinction. In this sense I am close to the position of Eve Sedgwick and Adam Frank who noted the problematics of antibiologist accounts of affect that, paradoxically, turn analog determinations into digital ones. See, for example, Eve K. Sedgwick, *Touching Feeling: Affect, Pedagogy, Performativity* (Durham: Duke University Press, 2003), 108–114. Sedgwick and Frank, however, hew too closely to the work of Silvan Tomkins and, as others such as Hemmings have recently argued, reproduce the very biologist accounts they are implicitly critiquing.

⁴⁷Coval and Shumway, “Is Sound Just Noise?,” 1890.

that circulate about, between, and sometimes stick to bodies and worlds, *and* in the very passages or variations between these intensities and resonances themselves.”⁴⁸ Such an expansive definition of affect is indebted to the work of Deleuze and Guattari, specifically their Spinozist concept of affect as a capacity or intensity between and within bodies⁴⁹. A key point of contention in these debates surrounding affect is the question of *intentionality*, or to put it more broadly, how much of affect is potentially pre-cognitive or pre-social. Here the interferences with scientific evidence itself becomes a problem. For example, Ruth Leys has recently taken affect theorists such as Brian Massumi and William Connolly to task for relying on both an anti-intentionalist paradigm and questionable (and dated) scientific results. Yet Massumi noted in his touchstone work that affect is not presocial (and thus not anti-intentionalist):

Intensity is asocial, but not presocial—it *includes* social clements but mixes them with elements belonging to other levels of functioning and combines them according to different logic. How could this be so? Only if the *trace* of past actions, *including a trace of their contexts*, were conserved in the brain and in the flesh, but out of mind and out of body understood as qualifiable interiorities, active and passive respectively, direct spirit and dumb matter. Only if past actions and contexts were conserved and repeated, autonomically reactivated but

⁴⁸Gregory J. Seigworth and Melissa Gregg, “An Inventory of Shimmers,” in *The Affect Theory Reader*, ed. Melissa Gregg and Gregory J. Seigworth (Durham: Duke University Press, 2010), 1, emphasis in original.

⁴⁹The aforementioned introduction nevertheless mentions eight potential theoretical orientations ranging from psychoanalysis to science studies. See *ibid.*, 6–8.

not accomplished; begun but not completed.⁵⁰

Perhaps more appropriate critiques come from Constantina Papoulas, Felicity Callard, and Clare Hemmings. Papoulas and Callard note that there is a disjunction between the rhetoric of affect theorists such as Massumi and the recourse to the language of definitive scientific evidence: “Even as affect theory shows how a biology of afoundational foundations can be imagined, the language through which the findings of neuroscience are invoked by cultural theorists is, paradoxically, often the language of evidence and verification, a language offering legitimation through the experimental method.”⁵¹ Hemmings, critiquing both Massumi and Sedgwick, argues that affect cannot be autonomous and therefore outside of social significance; in fact, it is precisely because it is *not* autonomous that it has political power.⁵²

Following Hemmings, then, the power of the affective events described by Coval and Shumway arises from their very embeddedness within the structures of contemporary finance. One would not understand the wildly gesticulating trader as suggesting an adverse event unless one has internalized the means by which the market functions. Flailing arms in the pits become affective only when they are linked to the loss of money. Hesitation in a trader’s voice is only accepted as fearful if one understands the context of the event. While such affective events may function in a fashion that bypasses certain cognitive processing, this can only occur if at some prior time the events were linked to an affective intensity. In this sense, both Leys

⁵⁰Brian Massumi, *Parables for the Virtual: Movement, Affect, Sensation* (Durham, NC: Duke University Press, 2002), 30.

⁵¹Constantina Papoulas and Felicity Callard, “Biology’s Gift: Interrogating the Turn to Affect,” *Body & Society* 16, no. 1 (2010): 37.

⁵²Hemmings, “Invoking Affect: Cultural Theory and the Ontological Turn.”

and Massumi are right: the intensities discussed by Coval and Shumway might be more direct than watching numbers on a screen, but this directness only happens as a result of ideological imbrication.

Like Coval and Shumway indicate, it might be possible to augment existing electronic trading terminals to help convey these “nonmarket” signals such as the ambient sound from the pits. Indeed, such services exist specifically for the day trader. Contributors to day trader forums such as “Elite Trader” have discussed a number of different potential sources provided by companies called “Traders Audio” and “Trade the News”.⁵³ These services are not cheap; “Traders Audio” charges \$125 a month for a feed with sounds and commentary from the S&P 500 pits at the Chicago Mercantile Exchange, and an additional \$125 a month for sounds and commentary from the grain pits at the CBOT; “Trade the News” costs upwards of \$175 a month.⁵⁴ Such feeds come direct over the Internet without the need for specialized hardware. These sounds additionally can come in much more complicated and specialized forms known as “squawk boxes”. Audio from the trading pits can be heard and controlled through equipment designed specifically for this purpose. They show up in fiction as well: in the novelist Robert Harris’ recent financial “thriller” entitled *The Fear Index*, the character Quarry, at a pivotal moment in the narrative when his firm’s automated trading system begins to go awry, “pressed a switch and picked up the live audio feed from the pit of the S&P500 in Chicago. It

⁵³Elite Trader Forums, “Forum - floor squawk box?,” August 23, 2006, accessed July 3, 2013, <http://www.elitetrader.com/vb/showthread.php?threadid=75425>.

⁵⁴Traders Audio, “[| Traders Audio |],” 2009, accessed July 3, 2013, <https://www.tradersaudio.com/amember4/signup.php>; TradeTheNews.com, “Live Stock Market Forex News Expert Market Analysis - TradeTheNews.com,” July 17, 2012, accessed July 3, 2013, <http://www.tradethenews.com/>.

was a service they subscribed to. It gave them an immediate feel for the market you couldn't always get just from the figures"⁵⁵.

Other types of "squawk boxes" have had more pernicious effects. Rather than a feed of sounds and commentary from the pits, squawk boxes within large firms are "internal intercom systems used by broker-dealers to broadcast institutional customer order information to traders and sales traders at the broker-dealer"⁵⁶. In other words, these squawk boxes are basically continually open intercoms that enable employees at the firm to assist with customer trading activity without having to continually re-telephone others who might be able to help. On reflection, access to the content of these conversations could be extremely useful for investors outside of the firm as it would provide information about potentially large upcoming movements in a particular financial instrument⁵⁷. In 2007 Merrill Lynch was sanctioned by the US Securities and Exchange Commission (SEC) for providing unaffiliated day traders with unauthorized access to these squawk box feeds:

the [Merrill Lynch] retail brokers called the day trading firm and

⁵⁵Robert Harris, *The Fear Index* (New York: Alfred A. Knopf, 2012), 198. Unfortunately, to my knowledge further academic studies regarding the use—or non-use—of these squawk boxes does not exist.

⁵⁶Tracy Alloway, "More bad news from Merrill, squawkbox edition," March 11, 2009, accessed July 3, 2012, <http://ftalphaville.ft.com/blog/2009/03/11/53471/more-bad-news-from-merrill-squawkbox-edition/>. Donald MacKenzie describes, in conjunction with this type of squawk box (which he calls a "voicebox"), the notion of "broker's ear": "the capacity aurally to monitor what is being said by all the other brokers at a cluster of desks, while oneself holding a voicebox conversation with a client" (MacKenzie, *Material Markets: How Economic Agents are Constructed*, 12). For MacKenzie this skill is necessary to the production of market liquidity. Thanks to Trevor Pinch for pointing me to this aspect of MacKenzie's work.

⁵⁷Fabian Muniesa considers three different situations where what he terms the "market device" of the telephone is productively used in ways that help to identify potential trading counterparts; see Fabian Muniesa, "Trading-Room Telephones and the Identification of Counterparts," in Pinch and Swedberg, *Living in a Material World: Economic Sociology Meets Science and Technology Studies*, 291–313. In Muniesa's study these telephone systems are used for legal communication with parties outside the firm.

placed their telephone receiver next to the equity squawk box for the entire trading day. As a result, the day traders received real-time access to the equity squawk box and the confidential order information transmitted over it. The day traders compensated the brokers for access to the confidential order information through kickbacks in the form of commissions and cash. The day traders used the information to trade ahead of the customer orders and many times profited when the price of the security moved in their favor because of the market impact of the institutional customer orders.⁵⁸

Merill Lynch was forced to pay a fine of \$7 million and implement appropriate controls over any future access to a squawk box or “squawk-related technology.”⁵⁹ This particular SEC action was prior to the most recent financial crises; however, access to these types of squawk boxes was also a key sticking point in attempts to strengthen regulations in the wake of revelations over inappropriate derivatives transactions. Since most of the volume (in number of trades and in size of the position) of exotic derivatives contracts still takes place over-the-counter (OTC), or through lightly-regulated transactions between individual entities and not on an open market, squawk boxes have been considered to be a necessary component of trading in order to discover the current prices for these instruments. Yet like the move from open-outcry trading to electronic exchanges, a similar move has been suggested for most OTC derivatives contracts—a move that would silence these

⁵⁸Securities and Exchange Commission, “Administrative Proceeding Release No. 34-59555” (March 11, 2007), 3.

⁵⁹*Ibid.*, 7.

types of squawk boxes as well—in the name of market transparency: “The more transparent a marketplace, the more liquid it is, the more competitive it is and the lower the costs for corporations that use derivatives to hedge their risks”⁶⁰. Paradoxically, however, these changes in the regulatory environment will perhaps silence the very signals—in digital form yet unquantifiable—that contribute to the transparency so desired.

Taken together these cases of affectual sonic noise function within varied situations of human responses to the dynamics of systems. The fields of individual traders and the market interfere during temporal conjunctions where orderly operation breaks down: interference becomes sonic, a signal that can precipitate further action. As the pace of trading increases, however, affectual sounds can only be directed towards past events, towards the noise of computational processes that produce their own conditions for the accumulation of profit or loss.

⁶⁰Gary Gensler, chairman of the US Commodity Futures Trading Commission (CFTC), quoted in Michael Mackenzie and Aline van Duyn, “Regulators may silence derivative squawk boxes,” July 21, 2010, accessed July 3, 2013, <http://www.ft.com/intl/cms/s/0/cce3f6e4-94f8-11df-af3b-00144feab49a.html>. As of writing this final shape of these regulations was unclear, as the SEC and CFTC worked together to refine their definitions of swap-based derivatives based on their respective spheres of influence. For the latest, see Rebecca Moore, “SEC Takes Another Step in Regulating OTC Derivatives,” July 9, 2012, accessed July 3, 2013, http://www.planadviser.com/SEC_Takes_Another_Step_in_Regulating_OTC_Derivatives.aspx.

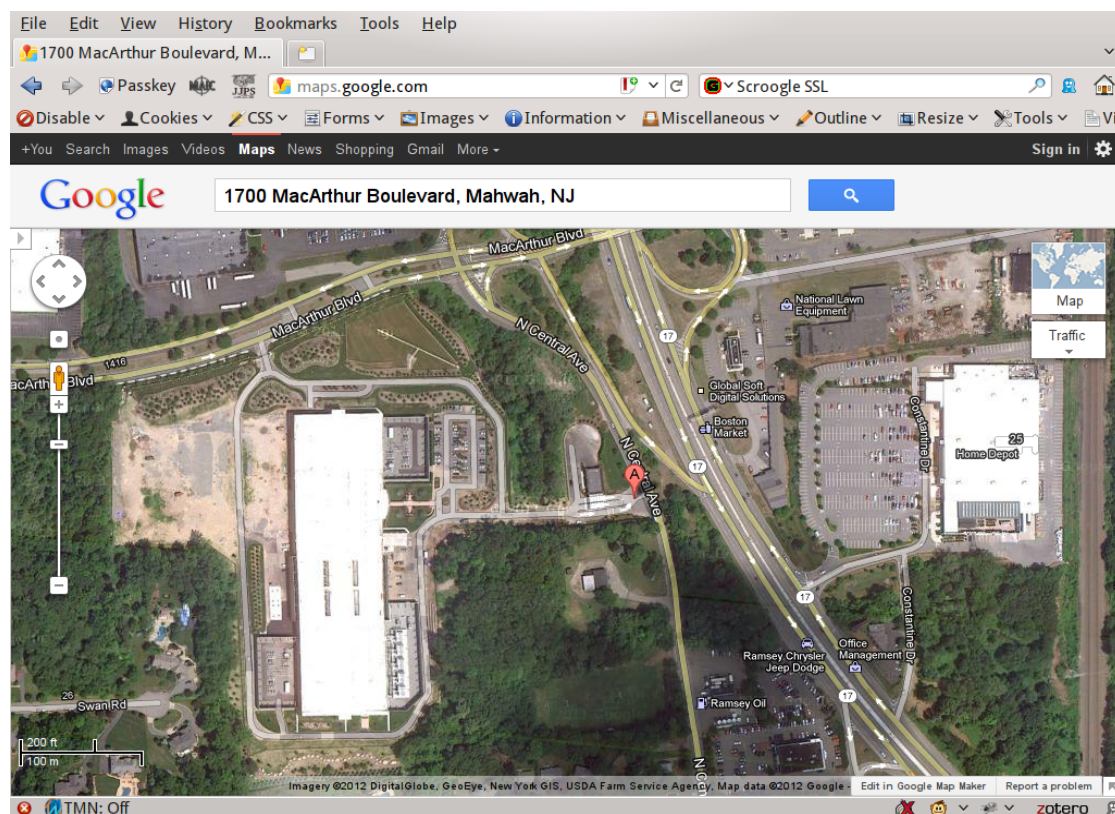


Figure 14: 1700 MacArthur Boulevard, Mahwah, NJ: the new location of contemporary finance

Algorithmic Noise Producing Noisy Profits

A price of a trade is not a noisy
observation: We introduce noise only as
a mathematical idealization.

Quoted in Frank J. Fabozzi,
Sergio M. Focardi, and Caroline Jonas,
“High-frequency trading: methodologies and
market impact,” *Review of Futures Markets*
19 (2011): 13

In Mahwah, NJ, next to a car dealership and across State Route 17 from a Home Depot, sits 1700 MacArthur Boulevard, what appears on Google Maps to be a rela-

tively nondescript large rectangular building, seemingly identical to scores of similar ones within this part of New Jersey (Figure 14). Zooming in closer we can see, however, a rather imposing guard house and what appear to be a number of hefty pop-up barriers to prevent speeding vehicles. A little bit of online searching reveals that this address is the location of the NYSE's newest data center, a 400,000 square foot facility⁶¹. The decrease in importance of open-outcry trading is imbricated with the increase in the importance of electronic market exchanges and electronic access to market information. New trading "floors" become the norm, this time populated by racks of servers in rooms of the most carefully controlled climate. Instead of the controlled chaos and noise of shouted trades of the human-populated trading floor we have the hum and white noise of air conditioning and whirring fans. Yet an additional type of noise can be found, one that resonates with the noise traders of the first section in this chapter.

While Zaloom's book detailed the conflicts over this transition from primarily human to primarily computational markets, it is safe to say that today the primary location of high finance is not at 11 Wall Street in New York City or 141 W. Jackson Boulevard in Chicago (the address of the CBOT) but rather 1700 MacArthur Boulevard in Mahwah, New Jersey. A variety of socio-technical shifts enabled this move to take place, including the move to decimalization in market prices,

⁶¹Anonymous, "1Q 2010 NJ Office, Industrial Markets Mixed," April 14, 2010, accessed July 3, 2012, <http://newyork.citybizlist.com/article/1q-2010-nj-office-industrial-markets-mixed-0>. As far as I am able to discover only the name of the city, but not this exact address, appears on the website of the NYSE. The size of the NYSE data center puts it on par with those recently built by Apple and Facebook, and is four times the size of the data center under construction in Utah for the National Security Agency (NSA); on the latter see James Bamford, "The NSA Is Building the Country's Biggest Spy Center (Watch What You Say)," March 15, 2012, accessed July 3, 2013, http://www.wired.com/threatlevel/2012/03/ff_nsadatacenter/all/1.

wider availability of powerful commodity computational technologies, and regulatory changes that opened exchange trading to more potential firms. Facilities like 1700 MacArthur Boulevard reflect important changes in the financial landscape, changes that are intimately related—yet perhaps more important—to the proliferation of the exotic accumulators of profit that were some of the primary causes of the most recent financial crisis.

Key to this whole field is electronic trading. In the US, electronic trading in some form has been around since at least 1971, the year of NASDAQ's founding. Throughout the intervening decades exchanges—and the ways in which traders interact with the exchanges—have become increasingly electronic and digital. While low-latency access to information through the medium of computer terminals such as those produced by Bloomberg and Reuters have in part changed the way traders interact with the market, arguably more fundamental shifts have occurred through the development of purely Electronic Communication Networks (ECNs), with names that fly below the public's radar such as BATS in the US and Chi-X Europe⁶². The development of these exchanges was in part enabled through regulations such as Regulation National Market System (regNMS) in the US and Markets in Financial Instruments Directive (MiFID) in Europe, both of a piece with larger processes of liberalization existing since the 1970s. As the anthropologist Marc Lenglet notes, MiFID restructured markets to both enhance the “competition between execution venues” and protect customers from the “‘natural’ dangers they may encounter in markets.”⁶³ Such ECNs are accessible not only through hu-

⁶²<http://www.batstrading.com/> and <http://www.batstrading.co.uk/chi-xeurope/> BATS now owns Chi-X Europe, which is separate from Chi-X Global.

⁶³Marc Lenglet, “Conflicting Codes and Codings,” *Theory, Culture & Society* 28, no. 6 (2011): 48.

man interaction but also Automated Trading Systems (ATSs), thereby enabling purely electronic trading and thus the development of Algorithmic Trading (AT)⁶⁴.

Efficiency is again the standard answer given for the production of AT. If an individual like myself wanted to sell, say, ten shares, I could do so with the expectation that the price will not decrease during the time that I made this transaction. But consider the institutional customer who wishes, for whatever reason, to sell 100,000 shares. Such a move would almost certainly cause the price of the security to decrease while the transaction was taking place. Perhaps there would not even *be* 100,000 corresponding buy orders. These situations of course invalidate some of the general assumptions of the EMH and CAPM, namely that buying or selling a security does not impact its price. AT developed in part to deal with this conundrum. Rather than selling all 100,000 shares at once, a specially-designed algorithm could split this order into smaller pieces—say 25,000 shares at a time—in order to cause a smaller impact on the market. This process of selling could then be programmed to take place over a given time frame, say an hour. Such an algorithm is called Time-Weighted Average Price (TWAP). But perhaps the security is rather illiquid; there might only be 15,000 shares being traded on average per hour. An order to sell 25,000 shares in an hour, then, would have an adverse impact. Trades could then be cut into smaller pieces based on the historical pattern of volume for the given security; the goal would be to not cause an appreciable impact on the volume by the trade. This type of algorithm is termed Volume-Weighted

⁶⁴For more on these shifts in the equity markets see Dave Cliff, Dan Brown, and Philip Treleven, “Technology trends in the financial markets: A 2020 vision” (The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 3, 2010), 5–14; for derivatives markets in the US, see Thomas J. McCool and Cecile O. Trop, “Commodity Exchange Act: Issues Related to the Regulation of Electronic Trading Systems” (General Accounting Office report GGD-00-99, 2000).

Average Price (VWAP). Current algorithms used in AT have become progressively more complicated, taking into more aspects of market dynamics, such as changes in the market during the execution of the algorithm, as well as attempting to position and time trades based on Natural Language Processing (NLP) of recently released news articles⁶⁵. The financial economists Peter Gomber, Björn Arndt, Marco Lutat, and Tim Uhle thus describe the characteristics of AT as follows: it is trading on behalf of clients, its goal is to minimize market impact, positions are held for relatively long periods, the goal is to match a particular pre-defined benchmark, and a given order is executed over a particular timeframe and across a number of markets.⁶⁶

It becomes relatively easy to foresee how algorithms such as those just described could become ever more complex, absent negative regulatory pressures or lack of engineering wherewithal. Given that the space of potential market algorithms is practically unlimited, it is unsurprising to find out that there has developed, in the words of an official from the Bank of England, a “race to zero” that has pushed both timeframes and complexity beyond normal human comprehension.⁶⁷ These new types of algorithms are termed in general High-Frequency Trading (HFT) and have come under intense scrutiny for reasons that will become clear in a moment.

Before explaining some of the more prominent HFT algorithms we have to step back a bit to examine the infrastructure that has in part enabled them to exist. Besides the establishment of new exchanges like BATS and Chi-X Europe there have

⁶⁵For more on these algorithms, see Peter Gomber et al., “High-Frequency Trading” (Working paper commissioned by the Deutsche Börse Group, 2011), 21–23.

⁶⁶Ibid., 14.

⁶⁷Andrew G Haldane, “The race to zero,” Speech given to the International Economic Association Sixteenth World Congress, Beijing, China, July 8, 2011, accessed July 3, 2013, <http://www.bankofengland.co.uk/publications/Pages/news/2011/068.aspx>.

been the expansion of electronic trading activities at more established exchanges such as NYSE and the CBOT resulting in the building of data centers such as the one at 1700 MacArthur Boulevard. Overall this has led to a pushing of computational limits as firms with immense levels of capital hire computer engineers and purchase specialized equipment in order to ensure their algorithms are microseconds faster. For example, *co-location* is one of the latest trends in electronic trading. While light travelling down fibre-optic cables is fast, it is not instantaneous. Therefore, one of the reasons for the size of the NYSE data center is to provide rack spaces for interested firms (who possess both the expertise to manage the systems and capital to pay the fees) to be closer to the actual machines executing the trades. Evidently much effort goes into ensuring that servers in racks nearest those running the trading system do not have an advantage over those located a bit further away, even going so far as to ensure that all cable lengths are the same⁶⁸. For those unable to co-locate their servers, straighter and faster fibre-optic lines have been laid between New Jersey and Chicago by a company called Spread Networks enabling them to both cut three milliseconds off the previous time (distance) *and* describe their distance from a New Jersey data center and NASDAQ as “8 microseconds away”⁶⁹. Injecting a bit of seeming science fiction into the mix are now attempts to

⁶⁸See, for example, Donald MacKenzie’s comments on the Mahwah facility in Donald MacKenzie, “How to Make Money in Microseconds,” *London Review of Books* 33, no. 10 (2011): 16–18. J. Doyne Farmer and Spyros Skouras make the unsubstantiated claim regarding cable length: “the length of wires from market servers to all customers’ co-located services is the same regardless of where the servers happen to be located in the market data centre” (J. Doyne Farmer and Spyros Skouras, “An ecological perspective on the future of computer trading” (The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 6, 2010), 23). Given the secrecy involved in these data centers it is not surprising for there to be no reference for this claim.

⁶⁹Spread Networks, “Spread Networks® Collocation Centers” (Specifications Sheet, 2011), 2. Because most existing fibre optics follow railway lines their paths are not always the straightest, thereby increasing the distance light has to travel. Spread Networks laid their fibre by purchasing new right-

take into account *relativistic* conditions in order to choose the optimum placement of new data centers with respect to existing ones so as to create potential arbitrage opportunities, raising troubling regulatory issues in the process.⁷⁰ And data centers, while relatively “self-sufficient” in the sense that they have extensive systems for electrical backup, are still reliant on extraordinarily precise timing provided by GPS signals. Such signals, while originating from geo-stationary satellites, can be spoofed by a more powerful signal closer to the receiver. Some have suggested that such jamming could cause havoc for financial organizations dependent on HFT, potentially causing timing confusion that could have a ripple effect throughout a market.⁷¹

This sort of infrastructural investment, couched in the language of financial return, must enable firms who engage in this work to capture some additional amount of profit that would not otherwise be possible. So why might these properties—of low latency, of close proximity to market computers—be so attractive? There must be a separate logic at work than with AT, as the algorithms previously discussed do not necessarily depend on *speed*. It is precisely due to minuscule fluctuations in price—a form of noise that I will return to shortly—that enable HFT to command so much attention in today’s financial climate. In contrast to the qualities of AT

of-way, sometimes boring through mountains in order to make the straightest link. See Christopher Steiner, “Wall Street’s Speed War,” September 9, 2010, accessed July 3, 2013, <http://www.forbes.com/forbes/2010/0927/outfront-netscape-jim-barksdale-daniel-spivey-wall-street-speed-war.html>.

⁷⁰A. D. Wissner-Gross and C. E. Freer, “Relativistic statistical arbitrage,” *Phys. Rev. E* 82 (5 2010): 056104; James J. Angel, “Impact of special relativity on securities regulation” (The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 15, 2011).

⁷¹Olivia Solon, “GPS ‘spoofers’ could be used for high-frequency financial trading fraud,” February 22, 2012, accessed July 3, 2013, <http://www.wired.co.uk/news/archive/2012-02/22/gps-spoofing>.

described earlier, Peter Gomber, Björn Arndt, Marco Lutat, and Tim Uhle suggest that HFT involves extremely high number of bids or asks, rapid cancellation of existing orders, proprietary trading, capture of spreads, no desire to hold a position for a long period of time (thus meaning that positions are held on the order of seconds or minutes, rather than days, months, or years), and very low margins.⁷² We can now understand a bit why the question of *location* is key to HFT. Given the material limits of communication networks, and assuming all else being equal, it is a truism that it will take longer for data to travel between a machine in New Jersey and one in Chicago, than it will to travel between two machines in the same data center in New Jersey. Therefore, if an algorithm can take advantage of this latency delay then it might be possible to enact some sort of arbitrage opportunity. For example, HFTs might work as a market maker (described earlier in the context of open-outcry trading) in order to capture the spread between the bid and ask, an activity that offers very low returns for each trade but can add up to large profits over time. In the HFT domain this capability is improved by being able to react to market data faster than other participants. Other forms of so-called technical analysis, such as statistical arbitrage, enables HFTs to use pre-defined statistical models of securities to detect situations where the price seems to be out of line with its expected value, enabling an arbitrage opportunity. Again, being able to quickly get in and out of a position, made possible in part by fast computers and low latency to the market system, can produce small profits that add up over time. Latency itself can become equivalent to profit in other strategies whereby an algorithm discovers a price discrepancy between the same security available on multiple ECNs,

⁷²Gomber et al., "High-Frequency Trading," 15.

that is, one traded on, say, both BATS and NASDAQ⁷³. More esoteric and, from the point of view of some participants, problematic strategies come under what has been termed “the darker arts”. For example, “stuffing” is when a HFT algorithm submits more orders to the market than the market can handle, potentially causing problems for so-called “slower” traders. “Smoking” involves submitting orders that are initially attractive to slower traders that are quickly changed to less generous terms, while “spoofing” is where a HFT algorithm posts orders to, for example, sell when the actual intent is to buy⁷⁴.

HFT for years was indeed was a “dark” practice, both in the sense of the shadow that hid open discussion of these techniques, as well as its obscurity to the general public. All that changed on May 6th 2010, the day of what became known as the “Flash Crash”, and the main reason for my exposition of AT and HFT. The full details of this day are beyond the scope of this chapter, so I will only outline it schematically, following the findings of the official US report produced by the CFTC and the SEC.⁷⁵ In short, between the hours of 2 and 3PM Eastern Time the NYSE had both its largest single day loss as well as its largest single day gain, a swing of over 600 points (see Figure 15). The actual dynamics of the event were difficult to reconstruct after the fact, but it would appear that a single large sell-off (to the order

⁷³For more on these strategies see Gomber et al., “High-Frequency Trading,” 24–31.

⁷⁴Bruno Biais and Paul Woolley, “High Frequency Trading” (Preliminary Paper, 2011), 8–9. The recent Dodd-Frank act to “overhaul” the financial system in the wake of the crisis would seem to outlaw the practice of spoofing; see Silla Brush and Asjlynn Loder, “CFTC Told Disruptive Trading Rules Threaten Market Liquidity,” December 2, 2010, accessed July 3, 2013, <http://www.bloomberg.com/news/2010-12-02/commodities-regulators-told-disruptive-trading-rules-threaten-liquidity.html>. However, in practice it is very difficult to actually detect this activity.

⁷⁵Commodity Futures Trading Commission and Securities and Exchange Commission, “Findings Regarding the Market Events of May 6th, 2010” (Report of the Staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues, September 30, 2010).

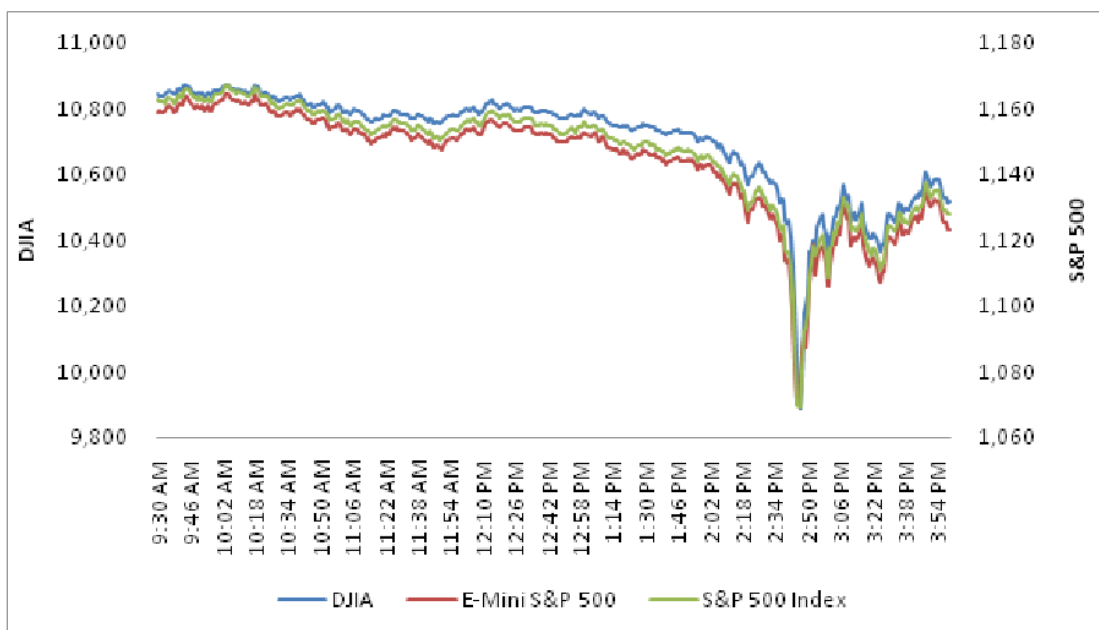


Figure 15: Market indices on the day of the Flash Crash; image from Commodity Futures Trading Commission and Securities and Exchange Commission, “Preliminary Findings Regarding the Market Events of May 6, 2010” (Report of the Staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues, May 18, 2010), 11.

of \$4.1 billion) of a particular index security, the E-Mini S&P, caused a cascade of trading activity by HFT algorithms using many of the techniques just described. This initial trade was, in retrospect, due to a relatively poor choice of a given AT that did not take into account its own potential impact on the market. Activity by various HFT algorithms responding to this trade resulted in the buying and selling of over 27,000 E-Mini S&P contracts with a net change of only 200. While built-in trading “pauses” occurred because of the activity on the E-Mini S&P, liquidity still evaporated as the time passed, causing share prices on some stocks to go to extremes, such as a penny or \$100,000, which were the computational limits on prices on these exchanges. Even so, the pauses in trading enabled the same algo-

rithms and participants to buy-up seemingly erroneously-priced securities, leading to the trading in over 2 billion shares over a twenty minute period and the recovery of the market⁷⁶.

Speculation around the cause(s) of the flash crash began immediately, with much of the blame directed at HFT. While the report of the CFTC and the SEC does not lay blame on HFT in particular, it did indicate how these algorithms contributed to the large price swings, the immense number of shares traded, and the drying up of liquidity. Trying to work out the exact dynamics of the flash crash has become popular, but determinations are made difficult by a number of factors. First, since trading on these exchanges is done relatively anonymously, there is no way to gather, after the fact, the distribution of trades due to all of the participating firms. Second, and as a result, reconstructions of the event must rely on a number of assumptions of what exactly constitutes HFT and which sets of trades might be due to individual participants. Nevertheless, most of the post-mortems—as well as studies published prior to the Flash Crash—affirm relatively positive contributions of HFT to the markets, specifically in their ability to provide liquidity—the very thing that evaporated during the Flash Crash⁷⁷. In short, the consensus amongst most financial economists is that the Flash Crash was a particularly extreme event

⁷⁶For another take on the sequence of these events, see MacKenzie, “How to Make Money in Microseconds.”

⁷⁷See, for example, Gomber et al., “High-Frequency Trading”; Joel Hasbrouck and Gideon Saar, “Low-Latency Trading” (Johnson School Research Paper Series No. 35-2010, 2011); Andrei Kirilenko et al., “The Flash Crash: The Impact of High Frequency Trading on an Electronic Market” (Working paper, 2011). David Easley, Marcos M. Lópezde Prado, and Maureen O’Hara suggests that minor structural changes would have enabled liquidity to remain in the market even during the Flash Crash; see David Easley, Marcos M. Lópezde Prado, and Maureen O’Hara, “The Microstructure of the ‘Flash Crash’: Flow Toxicity, Liquidity Crashes and the Probability of Informed Trading” (Working paper, 2010).

and HFT does not in general increase volatility in the market, thus HFT ultimately improve the “efficiency” of the market⁷⁸. Some, however, are beginning to have reservations. A recent article in the *New York Times* written after another algorithmic trading meltdown notes the following:

Terrence Hendershott, a professor at the University of California, Berkeley, said he had been an advocate for technological innovation in the past, but had begun to wonder if the continuing battle for technological superiority had become too much.

“You’ve got arguably too many people, in too small a space, and they just keep spending enormous amounts of money,” Professor Hendershott said. “Can I convince myself that we are really seeing a lot of benefits? No.”⁷⁹

What is clear is that HFT, along with other changes in the market as a result of different behaviors by humans and machines, as well as regulatory pressures for more competition, have made the markets more interconnected, leading to definite challenges for the authorities in assigned clear blame. Recent studies commissioned by

⁷⁸The papers suggesting that HFT does not increase market volatility are reviewed in Foresight Project, “The Future of Computer Trading in Financial Markets” (Working Paper, UK Government Office for Science, 2011), 9–12, with a contrarian perspective found in Frank Zhang, “High-Frequency Trading, Stock Volatility, and Price Discovery,” 2010, accessed July 18, 2012, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1691679; Zhang’s result is dismissed by the authors of the Foresight report on methodological grounds.

⁷⁹Nathaniel Popper, “On Wall Street, the Rising Cost of Faster Trades,” August 13, 2012, accessed July 3, 2013, <https://www.nytimes.com/2012/08/14/business/on-wall-street-the-rising-cost-of-high-speed-trading.html>. For Hendershott’s previous positions, see Terrence Hendershott, Charles M. Jones A., and Albert J. Menkveld, “Does Algorithmic Trading Improve Liquidity?,” *The Journal of Finance* 66, no. 1 (2011): 1–33; Terrence Hendershott and Ryan Riodan, “Algorithmic Trading and Information” (NET Institute Working Paper No. 09-08, 2011).

the UK government suggest that it therefore might be necessary to understand markets today within an “ultra large-scale system of systems”—similar to nuclear power plants or highly-complex technical artifacts such as the Space Shuttle—that require appropriate modeling, or an “ecology of practices” that would recognize multiple market equilibria with multiple paths towards efficiency⁸⁰.

If HFT were only important in situations such as the Flash Crash, then it might be considered simply a contributing factor to so-called “Black Swan” events, events whose probability is extremely low yet not non-zero. However, it is estimated that HFT is responsible for anywhere between 40% to 70% of all trading volume in the US, 35% to 40% of trading volume in Europe, and slightly less in Canada⁸¹. Given that HFT seems to contribute to volatility of the market, and that HFT strategies depend on taking advantage of minuscule, millisecond-level changes in price, it behooves us to ask how a concept of “noise” might contribute to our understanding of the phenomena. A recent paper by Frank J. Fabozzi, Sergio M. Focardi, and Caroline Jonas draws from a concept from econometrics known as “microstructure noise” to help explain activity of HFT and what they term High-Frequency Data (HFD), HFT’s necessary counterpart. A definition of “microstructure noise” is difficult to pin down, but one quant suggests two important distinctions: first, to an economist, microstructure noise is whatever makes it difficult to estimate the value

⁸⁰Dave Cliff and Linda Northrop, “The global financial markets: an ultra-large-scale systems perspective” (The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 4, 2010); Farmer and Skouras, “An ecological perspective on the future of computer trading.” Recall the reference to ecology in the work on noise traders mentioned earlier in footnote 36.

⁸¹Fabozzi, Focardi, and Jonas, “High-frequency trading: methodologies and market impact,” 8. Finding out how these figures are determined is difficult. I would argue that we should not vest them with too much truth-value; as I have mentioned earlier, it is extremely difficult to determine what exactly is or is not HFT absent tagging and tracking of all trades.

of some particular time series; second, to market participants, microstructure noise is whatever causes observed values to deviate from the “fundamentals”⁸². I am interested in this second aspect of microstructure noise, as it is precisely this assumed *deviation* that enables HFT to work, as well as what could connect HFT to the earlier discussion of noise traders.

The work of Fabozzi, Focardi, and Jonas is one of the few to pay attention to the role of noise within HFT. Their study is both a meta-review of other papers investigating HFT, as well as a series of interviews with market participants themselves. Importantly their interviews show the role that the *infrastructure* plays in the construction and propagation of this noise. Information received from the exchanges must go through a process of “cleansing” in order to remove “erroneous data”; similarly, the amount of noise within a sample will depend on the exchange it came from and the types of securities being traded there.⁸³ More fundamentally, noise would seem to be the corruption of what is assumed to be a ideally perfectly observable process. As indicated by the epigraph at the beginning of this section, noise is for some researches simply a “mathematical idealization” that enables one to provide a better measure of the “true” nature of the process.

Yet for others, microstructure noise does have an independent existence from the mathematics that that make it necessary. Consider, for example, the comments by Ravi Jagannathan, Co-Director of the Financial Institutions and Markets Re-

⁸²Palace Chan, “statistics - What exactly is meant by ‘microstructure noise?’,” November 11, 2011, accessed July 3, 2013, <http://quant.stackexchange.com/questions/2360/what-exactly-is-meant-by-microstructure-noise>. This question and its answers come from the “quant” section of the well-known computer technology question-and-answer site “StackExchange”, and reflects the importance of computer technology to contemporary finance.

⁸³Fabozzi, Focardi, and Jonas, “High-frequency trading: methodologies and market impact,” 11, 19.

search Center at Northwestern University:

If markets are frictionless, that is, if there are no microstructure effects, the higher the frequency, the better the measurement of values as volatility. However, in rare or severe events, HFD are of no help; microstructure—the way people trade, the strategies used, lack of knowledge of what the others are doing—becomes more important⁸⁴.

Microstructure noise becomes the necessary deviation as a result of human activity, of interconnected systems, of processes that do not follow mathematical formulae. While it would seem that in this quote Jagannathan understands microstructure noise occurring only at the level of the rare event—such as the Flash Crash—others are beginning to understand this noise as a continual component of the market. Frederi Viens, a Professor of Mathematics and Statistics at Purdue University, says that “My guess is that microstructure noise is real, so that we simply have to deal with it, that is to say, account for the added uncertainty in our prices.”⁸⁵ At a more stark level, Nikolaus Hautsch of Humboldt University observes:

HFD are affected by a lot of noise, lots of data with no information content. What matters is the ratio between the signal to noise. The signal-to-noise ratio must be greater than 1. If not, we have more noise than signal, and no gain. In the very beginning, the role of noise

⁸⁴Ravi Jagannathan, quoted in Fabozzi, Focardi, and Jonas, “High-frequency trading: methodologies and market impact,” 16.

⁸⁵*Ibid.*, 17.

was overlooked. Over the past four, five years, we have gained a better understanding of this⁸⁶.

Nevertheless, for Hautsch noise becomes reinscribed within standard information theory as the dual of signal, of something to be removed, of something lacking in “information content”. Microstructure noise, in the accounts of both Hautsch and Viens, is a continual component of the market, yet remains an impediment to ever-more-precise estimates of the “actual” price⁸⁷.

Other expressions of noise, beyond the narrowly informatic, have also come about as a result of the Flash Crash; these noises interfere with the attempt to cleave noise from signal. Recall from the previous section my discussion of “squawk boxes”, audio feeds from the open-outcry pits, and specifically the services provided by companies such as Traders Audio. On the day of the Flash Crash these feeds were of course live, resulting in recordings of the sounds from the pits during the event. Ben Lichenstein of Traders Audio has become somewhat of a minor celebrity on financial blogs because of his reporting that day; a recording of his reporting is available

⁸⁶Nikolaus Hautsch, quoted in Fabozzi, Focardi, and Jonas, “High-frequency trading: methodologies and market impact,” 18.

⁸⁷Philip Mirowski considers microstructure noise to be one of five areas in which financial economics has taken to heart aspects of the computational program outlined by John von Neumann. However, Mirowski considers microstructure noise to be inadequate in both explaining the complexities of recent “crises”, as well as in failing to heed the dramatic computability results of Alan Turing and Kurt Gödel. In contrast he offers a theory of “markomata”, or the market as a diverse set of evolutionary automata. For Mirowski, then, financial crises such as the Flash Crash are a result of the market automata failing to halt, or, in other words, facing an undecidable computation: “In markomata economics, the very notion of ‘market failure’ thus assumes an entirely different meaning. When a markomata fails, it appears unable to halt. Prices appear to have no floor (or ceiling, in the case of hyperinflation), and the communication/coordination functions of the market break down” (Philip Mirowski, “Markets come to bits: Evolution, computation and markomata in economic science,” *Journal of Economic Behavior & Organization* 63, no. 2 (2007): 229). See also Philip Mirowski, “Inherent Vice: Minsky, Markomata, and the tendency of markets to undermine themselves,” *Journal of Institutional Economics* 6, no. 04 (2010): 415–443.

for download from blogs such as Zero Hedge⁸⁸. Listening to this recording is a disorienting experience, not the least of which is the problem of the specialized terminology of the pits. More importantly is the affect, the *tone* of Lichenstein's voice as the recording goes on. He begins in what I would characterize as an incredulous voice, questioning the very trades that he can see and hear before him. But shortly this shifts into pure anxiety and fear, the gravel in his voice bouncing from lows to highs in pitch. While the microphone is clearly directed at him, the shouts and cries from the pits can be heard in the background. Heavy breathing fills what would normally be heard as pauses. The intensity of the volume—perhaps a mirror to the volume of the securities—is distorted by what sounds like a poor-quality microphone. In short, the archive of Lichenstein's reporting produces a bodily trace of the anxiety of that day, one that cannot be captured by the plethora of graphs, tables, and commentary produced in response to the event. It is a trace that again we can accept as affectual because of the ultimate effects of the financial crisis dynamics.

A different, yet just as entrancing, marker of that day comes from the French artist collective rybn. For a number of years their work has explored the concept of “antidatamining”, that is, the use of the “data mining” techniques of computational capitalism in order to shed light on the intersection of data and society:

Antidatamining is an research project, based on the recovery and the viewing/visualization of web-extracted data. It aims at creat-

⁸⁸Tyler Durden, “MUST HEAR: Panic And Loathing From The S&P 500 Pits,” May 7, 2010, accessed July 3, 2013, <http://www.zerohedge.com/article/panic-and-loathing-sp-500-pits>. Zero Hedge is a group blog with most posts signed anonymously by “Tyler Durden”, the character from the novel *Fight Club*. Zero Hedge writers have been regularly critical of what they see as manipulation of the markets by, among others, HFT, the Federal Reserve, the European Central Bank, and large financial firms.

ing various audiovisual and digital works—mainly installations and websites—written, fed and updated in real time. The goal of this project is to make emerge, by using the Data Mining processing, several social and economic imbalance “phenomenas”. ADM seeks to identify and visualize these phenomenas; and tries to establish a global imbalance cartography.⁸⁹

One of their recent exhibited works, ADM8, is an automated “trading bot performance” that uses AT to predict price movements in stocks in order to capture profit. Working with a fixed amount of capital, at the time of writing the bot was predicted to have 9086 days (nearly 25 years) until bankruptcy.⁹⁰ But it is an earlier work I want to listen to, namely their direct response to the Flash Crash called *FLASHCRASH SONIFICATION*.⁹¹ Sonification is a well-known practice within experimental music, as well as recently being taken up in the sciences. Briefly put, sonification is the translation into sound of data collected for non-sonic purposes⁹². For *FLASHCRASH SONIFICATION* rybn took trading data from

⁸⁹rybn, “ANTIDATAMINING,” n.d. Accessed July 3, 2013, <http://www.antidatamining.net/>.

⁹⁰rybn, “ANTIDATAMINING VIII,” April 19, 2012, accessed July 3, 2013, <http://rybn.org/ANTI/ADM8/>.

⁹¹rybn, “FLASHCRASH SONIFICATION,” n.d. Accessed July 3, 2013, <http://rybn.free.fr/ANTI/FLASHCRASH.html>.

⁹²For debates on the meaning of sonification, see Alexandra Supper, “The Search for the ‘Killer Application’: Drawing the Boundaries Around the Sonification of Scientific Data,” in *Oxford Handbook of Science Studies*, ed. Trevor Pinch and Karen Bijsterveld (Oxford: Oxford University Press, 2011), 249–270. For a recent collection of a variety of different approaches from the community of sonification researchers, see Thomas Hermann, Andy Hunt, and John G. Neuhoff, eds., *The Sonification Handbook* (Berlin: Logos Verlag, 2011). Sonification has also been used in the financial domain in the context of multi-modal task performance and the detection of correlations between securities; see Petr Janata and Edward Childs, “Marketbuzz: Sonification of Real-Time Financial Data,” in *Proceedings of ICAD 04—Tenth Meeting of the International Conference on Auditory Display* (2004); Keith V. Nesbitt and Stephen Barrass, “Evaluation of a Multimodal Sonification and Visualisation of Depth of Market Stock Data,”

nine different exchanges on the afternoon of the Flash Crash and created an austere, digitally-sharp yet undulating soundscape that recalls the work of Ryoji Ikeda or Carsten Nicolai without the rhythmic precision. The data rybn used come from the market data firm Nanex⁹³. It's important to listen to their online-available, two-channel mix on headphones in order to appreciate the details of the piece. Beginning with a loud uncorrelated noise the piece quickly becomes quiet, punctuated in a seemingly random fashion with high-frequency bursts. About six minutes in a ghostly wave of mid-frequency noise starts to wobble, joined by lower-frequency rumbling. Four minutes from the end the high-frequency pulses become louder and more rhythmic, sounding as if the spaces between them are slowing decreasing. A few seconds before the sonification ends the pulses rapidly start to smear together until they merge into a continuous sound, thereby ending the piece.

rybn constructed the piece specifically for the installation environment, a planetarium, at Le Lieu Multiple in Poitiers, France for an exhibition in Spring 2011 entitled *Raison d'Agir*. The two-channel version is a mixdown of the complete nine channels presented in this space in which the sounds from eight different exchanges surrounded the sonification of the NYSE in the middle. While the recording is somewhat quiet the live version was louder, not so much as to recall noise music acts

in *Proceedings of the 2002 International Conference on Auditory Display* (2002); David Worrall, "The Use of Sonic Articulation in Identifying Correlation in Capital Market Trading Data," in *Proceedings of the 15th International Conference on Auditory Display* (2009); David Worrall, "Sonification and Information: Concepts, Instruments and Techniques" (PhD diss., University of Canberra, 2009); David Worrall, "Using Sound to Identify Correlations in Market Data," in *Auditory Display*, ed. Sølvi Ystad et al., vol. 5954, Lecture Notes in Computer Science (Springer Berlin / Heidelberg, 2010), 202–218.

⁹³The data are available from http://www.nanex.net/20100506/FlashCrashAnalysis_Intro.html. Nanex has been critical of recent HFT techniques and have performed extremely close analyses of the millisecond microstructure of market anomalies. Free access to this kind of detailed data is rare and thus absent Nanex's posting of it online the sonification would have been expensive and perhaps impossible to produce.

such as Merzbow, but rather to emphasize the intensity of the bass levels. The building towards the end of the piece was meant to “emphasize the moment of the crash, [by] adding an effect of resonance, which propagates slowly, making it more tense, as the krach goes on.”⁹⁴ Thus instead of merely transparently translating the data into sound, rybn constructed the sonification in order to bring out this resonance: “resonance is pointed [to] as one of the major risk[s] of HFT by many economists and the feedback phenomenon was in the center of our discussions when we were preparing the piece.”⁹⁵ Isolating the Flash Crash was important for rybn as it was perhaps the “moment when people started to understand financ[ial] orientations more clearly” thereby highlighting the symptomatic nature of the “speculative short-term loop finance seems to be stuck in.”⁹⁶

Noise thus works here via multiple interfering fields. There is on the surface the resonance with various strands of noise music and contemporary sonic practice that takes any form of data and transforms it into sound. But there is informatic noise in the digital signal as well, a trace that we encountered earlier as microstructure noise. In rybn’s view this is due to the fact that “HFT brings in more confusion and chaos (in mathematical terms)”. This is not something “natural”, however: “the whole signal remains fabricated, and is based on very complex phenomen[a] of feedback interactions.... Financial noise is created by the sum of all its internal feedbacks, anticipation process[es], and mimetic forces. The noise we can produce in the framework of antitamining, is based on the matter we explore. HFT provides a wide range of frequencies, infinite structural composition sets, and a strong

⁹⁴rybn, *E-mail interview with the author*, April 27, 2012.

⁹⁵Ibid.

⁹⁶Ibid.

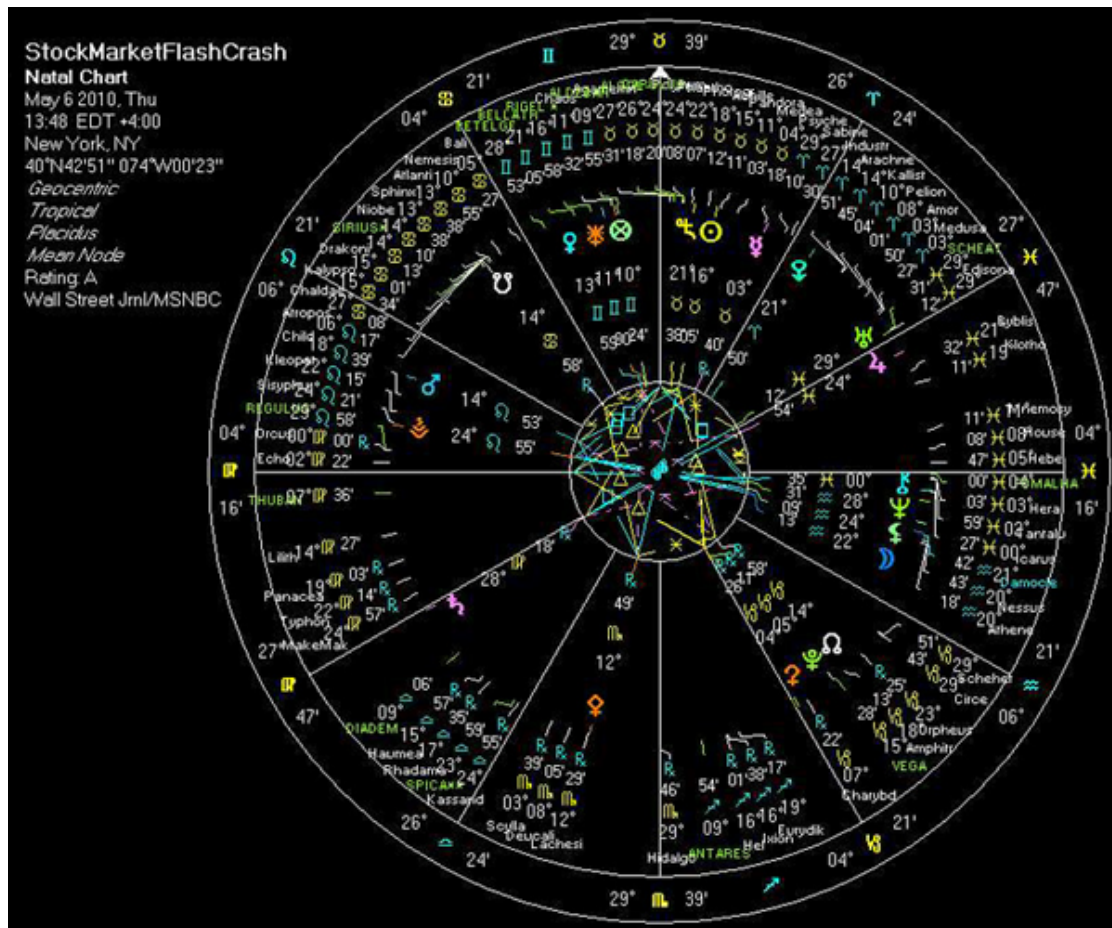


Figure 16: Natal Chart produced by rybn for their project *FLASHCRASH SONIFICATION*.

symbolic and metaphoric matter”.⁹⁷ Noise is to be found in this materiality of data, the same material that is located in places such as the NYSEs datacenter, and the same material that can be translated into pressure waves in the air. Paired with the sonification on their website is the image seen in Figure 16, a “Natal Chart” of the stock market that suggests that the divination of prices can be done through the consultation of astrological charts. This is a clear comment on contemporary financial discourse, as rybn argues that “news and media try to interpret the obscure behavior of ‘the markets’ as in the ancient practising of Haruspicy”, or divination through

⁹⁷rybn, E-mail interview with the author.

the entrails of sacrificed animals, with the image meant as “an attempt to criticize the degree of mysticism that finance has reached”⁹⁸.

While not explicitly intended by rybn, *FLASHCRASH SONIFICATION* also recalls *Black Shoals Stock Market Planetarium* (2002–2004) by Lise Autogena, Joshua Portway, Cefn Hoile, and Tom Riley, an installation consisting of an overhead projection of stock market data in the form of constellations that are constantly changing due to the calculations of artificial-life creatures who “feed” on the joint market activity of related companies. While the name of the piece references the Black-Scholes-Merton equation discussed earlier in this chapter, the project itself is about stock market valuations and not derivatives per se. *Black Shoals* has garnered much critical attention in subsequent years, specifically its attempt to understand the constructed nature of the financial system via the feedback dynamics of its alife creatures.⁹⁹ However, I think it is important to delineate the ways in which *FLASHCRASH SONIFICATION* differs from *Black Shoals*, specifically with respect to funding and support. Lise Autogena notes that *Black Shoals* raised around £70,000 and required special agreements from Reuters for access to its data feed and access to the “sensitive closed data handling systems” of the Copenhagen Stock Exchange.¹⁰⁰ *FLASHCRASH SONIFICATION*, on the other hand, is of a piece with rybn’s practice of using publicly available financial data, either published by corporations such as Nanex as in *FLASHCRASH SONIFICATION*,

⁹⁸rybn, *E-mail interview with the author*. Paul Crosthwaite offers a reading of the “financial thriller” genre through themes of waste, expenditure, and sacrifice; see Paul Crosthwaite, “Blood on the Trading Floor,” *Angelaki* 15, no. 2 (2010): 3–18.

⁹⁹Brian Holmes, “Is it written in the stars? Global finance, precarious destinies,” *ephemera: theory & politics in organization* 10, nos. 3/4 (2010): 222–233.

¹⁰⁰Lise Autogena, “Lise Autogena,” n.d. Accessed July 3, 2013, <http://research.ncl.ac.uk/sacs/projects/Autogena4.html>.

or scraped from sites such as Yahoo! Finance with repeated requests masked by IP proxies¹⁰¹. Access to market data is big business, and thus it is important to ask in what ways a project like *Black Shoals*, with its necessary interrelationships with major market producers, can function as a critical intervention, no matter the sophistication of its “allegory of the trader’s condition”, in the words of Brian Holmes.¹⁰²

Additionally, I disagree with Rita Raley’s interpretation of *Black Shoals*, specifically her contention that it is a “socially engaged, participatory, and pedagogical intervention into the discourse on financial markets”.¹⁰³ As has been mentioned in this chapter, evolutionary approaches to finance have percolated within the discourse of financial economists for decades; Raley notes this tendency as well. Moreso, the rhetoric of *Black Shoals*’ generative techniques sit comfortably close to those of Hayek’s discussed earlier; in the words of *Black Shoals*’ artificial life programmer Cefn Hoile, the “organisms” are produced by a “decentralised evolutionary process—a result of limited resource availability combined with co-evolutionary interactions”—in other words, via processes that are similar to those of Hayek’s market.¹⁰⁴ This is perhaps only a parallel tendency, in line with a particular zeitgeist associated with a-life research at the turn of the century; nevertheless, the historical antecedents of this within economic thought need to be noted. To do so might enable us to question whether or not the insight Raley draws from *Black Shoals* (“we are always caught within a paradigm that is too complex and that in effect manages

¹⁰¹An exception to this is ADM8 discussed above, as it required direct access to the market in order to execute the trades.

¹⁰²Holmes, “Is it written in the stars? Global finance, precarious destinies,” 224.

¹⁰³Rita Raley, *Tactical Media* (Minneapolis: University of Minnesota Press, 2009), 149.

¹⁰⁴Cefn Hoile, *Black Shoals: Evolving Organisms in a World of Financial Data*, n.d. 1.

us”) is all that we can hope for within art that engages with financial markets¹⁰⁵.

FLASHCRASH SONIFICATION is a layered comment on this state of affairs: a direct critique of the obscurantism of contemporary financial language; a foregrounding of the ways in which sacrificial, seemingly “wasteful”, loss of value is translated into meaningful discursive signs; and a noisy environment that pulls human perception into the timeframe of algorithms. In *FLASHCRASH SONIFICATION* sonic noise becomes a translation of the data from the market—abstract yet eminently material—into a different abstract form that does not immediately signify. Like the recording of Lichenstein from the pits, *FLASHCRASH SONIFICATION* suggests rather than indicates; listening to it cannot provide us with rational information regarding the dynamics of the Flash Crash. Instead it produces a dark foreboding of the mechanisms at work, the high-frequency pulses first recalling heartbeats that soon speed up beyond any ability for distinction. This darkness is heightened through what Steve Goodman might term “bass materialism”, or the tactility of the sub bass levels that are coupled to the increasing speed of the higher pulses at the end of the piece¹⁰⁶. By constructing *FLASHCRASH SONIFICATION* as slightly off-kilter, yet remaining within a certain genre of ordered elec-

¹⁰⁵Raley, *Tactical Media*, 149. Hoile refers to the tortoises of Grey Walter (*Machina Speculatrix*) in the naming of his creatures *Animaris Speculatrix*. Walter was immensely influential to the development of a certain strand of cybernetic thought, and cybernetics and the “cyborg sciences” in general were key to the development of postwar economics, as detailed by Mirowski, yet neither of these strands are noted by Raley. In a recent review of Andrew Pickering’s book on cybernetics, *The Cybernetic Brain*, a book that explores Walter’s work in detail, Mirowski noted the parallels between the cyberneticians Pickering studied and the thought of Hayek, ending on this apropos point: “neoliberalism is the background noise of modern culture, whether people are aware of it or not” (Philip Mirowski, “Minding the Cybernetic Gap,” *Technology and Culture* 53, no. 1 [2012]: 195).

¹⁰⁶Goodman defines bass materialism as “the collective construction of vibrational ontologies concentrated on low frequencies where sound overlaps tactility” (Goodman, *Sonic Warfare: Sound, Affect, and the Ecology of Fear*, 196). It should go without saying that this is a pun on George Bataille’s notion of “base materialism”.

tronic music, rybn comments on the inability for computation—and by extension, the market—to be the perfectly rational, ordered space it is ideally understood to be.

Noisy Accelerationism

Photonic Hypercapital digitizes
eschatology.

Ccru, "Swarmachines," n.d. Accessed July 3,
2013, [http:
//www.ccru.net/swarm1/1_swarm.htm](http://www.ccru.net/swarm1/1_swarm.htm)

It should be clear now what a mess noise makes of finance. Noise is the dual of information; yet people trading on noise can sometimes make more money and last longer in the market than those trading on information. Noise works to upend models of efficient markets. Noise as sound can indicate potential trading opportunities as well as being indispensable to the smooth functioning of the market. Noise as volatility or fluctuation as time approaches zero is a means for the continual accumulation of small profits. The intersection of informatic and sonic noise produces, on the one hand, vocal indications of fear and panic, and on the other, a dark, ghostly cloud from the onslaught of data. How do we understand these interferences, these contradictions that seem to exceed our existing frameworks? The ways in which we respond to this materiality of noise in flesh and machines will help construct our methodologies for addressing the imbrication of finance and contemporary life.

The acceleration discussed in the previous section—indexed perhaps most dra-

matically by the fact that Einstein's theory of special relativity is now a valid reference point for finance—provides one suggestion. In a historical materialist account, in order to reach a point where communism—or some other form of social relationship not mediated by the commodity form—can become possible, capitalism must first become extinct. Highlighting and exploiting the internal contradictions of capitalism then becomes one key part of the revolutionary project, of the process of dialectical materialism. But what if people could accelerate that process, thereby bringing capitalism to its foreseen end in less time? And what if that acceleration could use the very mechanisms of capitalism itself?

Such a tendency, latent within Marxist thought over the past century and a half, has only recently been given a name by the British philosopher Benjamin Noys: *accelerationism*.¹⁰⁷ Drawing on an intellectual lineage that begins most recently with the early 1970s work of Gilles Deleuze and Félix Guattari and Jean-François Lyotard, that resurfaces in the 1990s with the theory-fiction of Nick Land, and was resurrected during the most recent crisis, accelerationism is a theorization of the conditions and techniques for the hastening of the contradictions of capitalism in order to produce its ultimate downfall. Such techniques are predicated on a fundamentally anti-humanistic position, one that is weakly reflective of similar recent approaches in, for example, actor-network theory or object oriented ontology, but that radically explodes their implications. As Alex Williams, of the blog “splintering bone ashes” and a key interlocutor for Noys' term, writes, “The ‘blind acephelous polymorph’ that is capital must be embraced, but not from the point of view of some

¹⁰⁷Benjamin Noys, “Accelerationism,” October 20, 2008, accessed July 3, 2013, <http://leniency.blogspot.com/2008/10/accelerationism.html>.

naïve enthusiasm or sentiment of hope that markets can deliver utopia. Instead, as the way out of the binaries of a leftism which is utterly and irretrievably moribund, and a neo-liberal economics which is ideologically bankrupt, we must bend both together in the face of an inhuman and indefatigable capitalism, to think how we might inculcate a new form of radically inhuman subjectivation”.¹⁰⁸

Accelerationist reference points come from the early Deleuze and Guattari of *Anti-Oedipus* and the early Lyotard of *Libidinal Economy*. For Deleuze and Guattari the central conceit is the schizophrenia of capitalism: while it requires the reterritorialization of flows in order to capture surplus value and reinscribe the logic of Oedipus, it must simultaneously produce their deterritorialization in order to unleash desire: “Capitalism tends toward a threshold of decoding that will destroy the socius in order to make it a body without organs and unleash the flows of desire on this body as a deterritorialized field”.¹⁰⁹ In this interference of de- and reterritorialization, what is to be done? Writing from within the conflicts of the early 1970s over the relationship of the Communist Party to new social movements, the solution for Deleuze and Guattari was eminently *not* to be found within the formulations of Party politics. Rather, Deleuze and Guattari suggested that perhaps deterritorialization was not being pushed far enough:

But which is the revolutionary path? Is there one?—To withdraw
from the world market, as Samir Amin advises Third World coun-

¹⁰⁸splintering bone ashes, “Xenoeconomics and Capital Unbound,” October 19, 2008, accessed July 3, 2013, <http://splinteringboneashes.blogspot.com/2008/10/xenoeconomics-and-capital-unbound.html>.

¹⁰⁹Gilles Deleuze and Félix Guattari, *Anti-Oedipus: Capitalism and Schizophrenia*, trans. Robert Hurley, Mark Seem, and Helen R. Lane (Minneapolis, MN: University of Minnesota Press, 1983 [1972]), 33.

tries to do, in a curious revival of the fascist “economic solution”? Or might it be to go in the opposite direction? To go still further, that is, in the movement of the market, of decoding and deterritorialization? For perhaps the flows are not yet deterritorialized enough, not decoded enough, from the viewpoint of a theory and a practice of a highly schizophrenic character. Not to withdraw from the process, but to go further, to “accelerate the process,” as Nietzsche put it: in this matter, the truth is that we haven’t seen anything yet.¹¹⁰

But this ceaseless directionality towards ever more deterritorialized flows is tempered in *A Thousand Plateaus*:

You have to keep enough of the organism for it reform each dawn; and you have to keep small supplies of signifi-ance and subjectification, if only to turn them against their own systems when the circumstances demand it, when things, persons, even situations, force you to; and you have to keep small rations of subjectivity in sufficient quantity to enable you to respond to the dominant reality. Mimic the strata. You don’t reach the BwO [Body without Organs], and its plane of consistency, by wildly destratifying.¹¹¹

“...when the circumstances demand it”; “Mimic the strata”; these are not the phrases of an acceleration towards ultimate deterritorialization, but rather a statement of pragmatics in the dawning years of Reagan-Thatcher neoliberalism.

¹¹⁰Deleuze and Guattari, *Anti-Oedipus*, 239–240.

¹¹¹Gilles Deleuze and Félix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, trans. Brian Massumi (University of Minnesota Press, 1987 [1980]), 160.

Lyotard published *Libidinal Economy* shortly after, and partially in response to, *Anti-Oedipus*; he would later refer to it as his “evil book” and evidently it caused much trouble between him and his former Marxist colleagues and comrades from his time in *Socialisme ou Barbarie*¹¹². If possible, Lyotard’s evocations of desire are more intense than those of Deleuze and Guattari in *Anti-Oedipus*; writing becomes intensity, libidinality does not merely remain as potential: “Our danger, we libidinal economists, lies in building a new morality with this consolation, of proclaiming and broadcasting that the libidinal band *is good*, that the circulation of affects *is joyful*, that the anonymity and the impossibility of figures *are great and free*, that all pain is reactionary and conceals the points of a formation issuing from the great Zero...”¹¹³ The “circulation of affects” is already to be found within the bodily practices of the proletariat; here Lyotard deserves to be quoted at length:

Why, political intellectuals, do you *incline towards* the proletariat? In commiseration for what? I realize that a proletarian would hate you, you have no hatred because you are bourgeois, privileged smooth-skinned types, but also because you dare not say the only important thing there is to say, that one can enjoy swallowing the shit of capital, its materials, its metal bars, its polystyrene, its books, its sausage pâtés, swallowing tonnes of it till you burst—and because instead of saying this, which is *also* what happens in the desire of those who work with their hands, arses and heads, ah, you become a leader of

¹¹²Lyotard, quoted in Iain Hamilton Grant, “Introduction,” in *Libidinal Economy*, trans. Iain Hamilton Grant (Bloomington, IN: Indiana University Press, 1993 [1974]), xviii.

¹¹³Lyotard, *Libidinal Economy*, 11, emphasis in original.

men, what a leader of *pimps*, you lean forward and divulge: ah, but that's alienation, it isn't pretty, hang on, we'll save you from it, we will work to liberate you from this wicked affection for servitude, we will give you dignity. And in this way you situate yourselves on the most despicable side, the moralistic side where you desire that our capitalized's desire be totally ignored, forbidden, brought to a standstill, you are like priests with sinners, our servile intensities frighten you, you have to tell yourselves: how they must suffer to endure that! And of course we suffer, we the capitalized, but this does not mean that we do not enjoy, nor that what you think you can offer us as a remedy—for what?—does not disgust us, even more. We abhor therapeutics and its vaseline, we prefer to burst under the quantitative excesses that you judge the most stupid. And don't wait for our spontaneity to rise up in revolt either.¹¹⁴

Lyotard's vitriol is directed against those who would postpone revolution (the Party), postpone desire (the reterritorialization of Capital, in the language of Deleuze and Guattari), and postpone the enjoyment of the proletariat (the "political intellectuals"). In Lyotard's view this postponement needs to be burst open: "We desire the effects of conduction and the conduction of effects. Lysis, thesis."¹¹⁵

Noys notes that for Deleuze and Guattari (as we can understand from certain passages in *A Thousand Plateaus*), as well as for Lyotard (as evidenced in some texts from the 1980s and early 1990s), the move towards a slowing down of the

¹¹⁴Lyotard, *Libidinal Economy*, 115–116, emphasis in original.

¹¹⁵*Ibid.*, 259.

unleashing of desire might have reflected the realization that their earlier positions were becoming “congruent with capitalist flows”.¹¹⁶ Yet this accelerationism was to soon have another adherent within the work of the renegade academic Nick Land and his colleagues and students at the Cybernetic Culture Research Unit (C cru) at the University of Warrick in the mid-1990s. Amongst the hype of the potentials of the Internet and its professed ability for the deterritorialization of all traditional categories—race, ethnicity, gender, class, humanism—Land, along with the co-director of the C cru, Sadie Plant, produced a number of texts and performances that in their elusiveness reactivated the accelerationist tendencies of the earlier works by Deleuze, Guattari, and Lyotard¹¹⁷. Land’s dynamical evocations are a re-worked invocation of Nietzsche, Kant, Bataille, computational technology, viruses, drugs, and what he and Sadie Plant term the “cyberpositive”. Recalling Norbert Wiener’s valorization of negative over positive feedback, Plant and Land write that,

The modern Human Security System might even have appeared with Wiener’s subliminal insight that everything cyberpositive is an enemy of mankind. Evolving out of work on weaponry guidance systems, his was an attempt to enslave cybernetics to a general defence technology

¹¹⁶Benjamin Noys, *The Persistence of the Negative: A Critique of Contemporary Continental Theory* (Edinburgh: Edinburgh University Press, 2010), 8.

¹¹⁷For one of the few in-depth articles on the C cru, see Simon Reynolds, “Renegade Academia: The Cybernetic Culture Research Unit,” Originally published in 1999, November 3, 2009, accessed April 18, 2012, <http://energyflashbysimonreynolds.blogspot.com/2009/11/renegade-academia-cybernetic-culture.html>. Besides Land and Plant, the C cru also included, at various points, many writers, artists, and musicians who are well-known today: Steve Goodman, Kodwo Eshun, Luciana Parisi, Robin MacKay, and Mark Fischer, among others. The journal *Collapse*, which has been a key outlet for the development of “speculative realism”, could be considered a continuation of a similarly-named text published by the C cru in the 1990s.

against alien invasion. Cybernetics was itself to be kept under control, under a control that was not itself cybernetic. It is as if his thinking were guided by a blind tropism of evasion, away from another, deeper, runaway process: from a technics losing control and a communication with the outside of man¹¹⁸.

While Wiener understood the negative feedback of cybernetics as enacting a stabilizing force on systems, a position that resonates with his fundamental humanism that was key to his later writings, Plant and Land, following in the waves unleashed by Deleuze, Guattari, and Lyotard, moved to the other end of the binary, provocatively suggesting that positive feedback, though uncontrollable in principle, could fact enable a certain anti-humanism, one that allows for the “communication with the outside of man”.

Land released the cyberpositive in delirious works of theory-fiction that, depending on one's taste, are either the highlight or the doldrums of 1990s cultural theory. Land's texts, long available only in obscure journals that have long gone out of print, were recently published in an edited collection of his work, the release of which was the occasion for a symposium in 2010 around this question of accelerationism. It is here that we can reconnect to the questions of noise and finance that have been the topic of this chapter. Consider these two quotes regarding the potential of finance capital from his 1993 article “Machinic desire”:

¹¹⁸Sadie Plant and Nick Land, “Cyberpositive,” in *Unnatural: Techno-Theory for a Contaminated Culture*, ed. Matthew Fuller (London: Underground, 1994), n.p. This text is also available online; see Sadie Plant and Nick Land, “Cyberpositive,” 1994, accessed July 3, 2013, <http://www.sterneck.net/cyber/plant-land-cyber/index.php>.

The obsolete psychological category of “greed” privatizes and moralizes addiction, as if the profit-seeking tropism of a transnational capitalism propagating itself through epidemic consumerism were intelligible in terms of personal subjective traits. Wanting more is the index of interlock with cyberpositive machinic processes, and not the expression of private idiosyncrasy. What could be more impersonal—disinterested—than a haut bourgeois capital expansion servo-mechanism striving to double \$10 billion? And even these creatures are disappearing into silicon viro-finance automatisms, where massively distributed and anonymized human ownership has become as vacuously nominal as democratic sovereignty.

[...]

Markets are part of the infrastructure—its immanent intelligence—and thus entirely indissociable from the forces of production. It makes no more sense to try to rescue the economy from capital by demarketization than it does to liberate the proletariat from false consciousness by decortication. In neither case would one be left with anything except a radically dysfunctional wreck, terminally shut-down hardware¹¹⁹.

Land evokes Lyotard’s contempt for those who would “speak” for the proletariat while graphically noting the embeddedness of capital markets within society; the

¹¹⁹Nick Land, “Machinic desire,” *Textural Practice* 7, no. 3 (1993): 478, 480, reprinted as Nick Land, “Machinic Desire,” in *Fanged Noumena: Collected Writings 1987–2007* (Falmouth, UK: Urbanomic, 2011), 337, 340. On a personal note, in going back to this text of Land’s I realized that I quoted from it on my blog on the very day of the Flash Crash.

removal of markets would leave nothing but a “dysfunctional wreck”. Latent within these passages, as well as others in the text, is a foreboding tone towards the potential for transformation that removes accelerationism from the realm of choice. This is perhaps most evident in a later text from 1995 entitled “No Future”:

Mass computer commoditization de-differentiates consumption and investment, triggering cultural micro-engineering waves that dissociate theopolitical action into machinic hybridities, amongst increasingly dysfunctional defensive convulsions. Acephalization = schizophrenia: cutting-up capital by way of bottom-up macrobacterial telecommerce, inducing corporate disintegration. The doomed part of intensively virtualized technomic apparatuses subverts the fraying residues of anthropomorphic guidance. Control dissolves into the impossible.¹²⁰

This lack of control, this orientation towards Thanatos embedded within a cyber-positive system, is indexed by Land to, among other things, the dynamics of the market. Consider this fragment from “Meltdown,” a presentation from 1994:

Neoclassical (equilibrium) economics is subsumed into computer-based nonequilibrium market escalations, themed by artificial agencies, imperfect information, sub-optimal solutions, lock-in, increasing returns, and convergence. As digitally microtuned market metaprograms mesh with technoscientific soft engineering, cyber-

¹²⁰Nick Land, “No Future,” in *Fanged Noumena: Collected Writings 1987–2007*, 397.

positive nonlinearity rages through the machines. Cyclonic torsion
moans¹²¹.

My own evocation of Land through voluminous quoting from his work is meant to not only note a certain *prescience* in his writings but also, as with Lyotard, to re-present the dynamics of his writing, a dynamics that follows the noisiness of his referents. Land's writing resonates with the activity of computational technologies, of their fits and starts and seeming ability to act in ways that exceed their rational, ordered frameworks. And what are the "microtuned market metaprograms" but the algorithms of AT or HFT? The body of Land's work from the 1990s deserves its own re-activation during a time when the imbrication of computational technologies—of electronic trading, of mathematical formalism—seem to have run amok.

For those hewing to a program of humanism, Land's texts are an anathema; even amongst those (including myself) who desire a collapsing of human/non-human distinctions Land is troubling. In the aforementioned symposium on accelerationism, Ray Brassier noted both the philosophical difficulties Land gets himself into as well as how his project, mirroring Noys' position on Deleuze, Guattari, and Lyotard, merely replicates neoliberal ideology:

He [Land] has to instrumentalize neoliberalism in the name of some-
thing allegedly far darker and more potentially corrosive, but in the

¹²¹Nick Land, "Meltdown," in *Fanged Noumena: Collected Writings 1987–2007* (2011 [1994]), 447. Recently a tape recording of this presentation was made available online. The technical contributions in the original piece were contributed by the collective O(rphan)d(rift>). See Luke Robert Mason, "Nick Land's Academic Meltdown," May 3, 2011, accessed July 3, 2013, <http://virtualfutures.co.uk/2011/05/23/lands-academic-meltdown/>.

process it seems you end up...if your enemy's enemy is your friend, there comes a dangerous point where you forget the conditions under which you made this strategic alliance, because you can no longer see, you can no longer identify what the goal is any more. You end up endorsing and embracing a kind of neoliberal politics or ideology, and the pretence of instrumental distance, that this could just be the cunning of schizophrenic reason, quickly evaporates because it's not possible to dissociate praxis from identifiable ends any more.¹²²

But for me the problematic of using accelerationism as either political project, or a conceptual tool for the understanding of the recent financial crisis, rests on the logic of positive feedback. The cyberpositive approach assumes a dynamics of continual accumulation, of the ever-increasing acceleration based on the internal contradictions of capitalism. But this requires that positive feedback remains *positive*, that the dynamics do not oscillate between the negative and the positive poles. Such equivocation might erase any gains produced by cyberpositive accelerationism.

I would argue that the dynamics of financial noise outlined in this chapter show how such a system never remains only in the positive mode; recall the quick recovery of the market on the day of the Flash Crash. Cyberpositive feedback systems cannot remain there indefinitely as a result of the contribution of noise. In the language of Land, noise is itself a virus that prevents simple directionality of feedback. Like the dynamics of chaotic systems, small fluctuations can cause a switch into negative

¹²²Ray Brassier, "Accelerationism," Presentation at Accelerationism conference at Goldsmiths, September 14, 2010, accessed July 3, 2013, <https://moskvax.wordpress.com/2010/09/30/accelerationism-ray-brassier/>.

feedback, re-establishing stability. The eschatology of Land's texts indexes a desire; but desire remains wedded to material practices that are not entirely amenable to desire's own machinations. As I have shown in this chapter, as well as the previous ones, noise can be counted upon for only one thing: an excess that escapes containment within tactics or strategies of positive *or* negative determination. Noise needs to be understood within its dynamics of *both* cyberpositive and cybernegative systems, and thus its progressive micropolitical potentials need to be heard simultaneously with the possibility of near-instantaneous shifts towards regressive registers.

Part II

Speech, Voices, Noises

The chapters in Part I focused primarily on the discourses surrounding noise and its interferences with information theory, electronic music, and finance. Very little attention was given to sonic materials themselves; only with the move towards finance did we *hear* the sounds of the pits or artistic appropriations of financial information.

In this second part, "Speech, Voices, Noises", I turn to noisy interferences with the sounds of the voice, undertaking close listening of particular artistic and musical projects. This part also has more of an overtly political bent, as I attend to the potentials of novel vocal sounds in the construction of new forms of sociality, or the micropolitical possibilities of non-speech sounds. The next chapter considers *par-rhesia*, or "fearless" speech, updating Michel Foucault's important archaeology of the term for a world in which rational speech may not be the most direct way to engage in agonistic forms of democracy. The chapter that follows listens to the work of two contemporary women musicians who both use computational technologies to manipulate their voices. I hear in their work a micropolitics that responds not only to the vexed history of the female voice but also performs alternative configurations of humans and machines. Both chapters involve close listening to the projects under consideration, a listening that allows me to chart the dynamics of the noisy voice.

In both of these chapters, nevertheless, the informatic (the computational *how*) is never absent. In fact, without the ubiquity of information theory—and the settling of the early debates witnessed in Chapter 1—many of these projects would not have been possible. This does not mean, however, that the universal embedding of information theory within the design and construction of computational devices necessarily enumerates what is possible. Both chapters focus on artists and musi-

cians who construct much of their own hardware and software, showing how sonic expressions of noise continues to interfere with the informatic.

Chapter 4

Noise, *Parrhesia*, and the Enunciative Potentials of Performing Objects

Noise interferes—and continues to interfere—with the smooth functioning of systems, be they scientific, musical, or financial. In the cases considered so far the primary focus has been on the informatic: that is, analysis began by considering noise from the perspective of information theory, moving towards specific sonic exemplars such as early electronic music or the resonances between open-outcry and high-frequency trading. Here I choose to begin nearer the sounds themselves, and thus move closer to discursivity and vocal enunciations. The informatic is never far, however, as each situation I discuss in this chapter exists because of the influence of computational performing devices on the production of these enunciations.

In this chapter I consider noise from the perspective of *parrhesia*, a concept appearing in ancient Greek and Roman texts and discussed by Michel Foucault in a set of lectures presented over the last year of his life¹. In short, *parrhesia* means

¹See Michel Foucault, *Fearless Speech*, ed. Joseph Pearson, Foreign Agents (Los Angeles: Semiotext(e), 2001) and Michel Foucault, *The Courage of the Truth (The Government of Self and Others II): Lectures at the Collège de France 1983-1984*, trans. Graham Burchell (New York: Palgrave Macmillan,

“free” or “fearless” speech, but as we will see, *parrhesia* admits more nuance than such a straightforward translation would allow. The conditions whereby *parrhesia* could take place, the types of people who could be a *parrhesiastes* (the one who is capable of *parrhesia*), and the very types of “speech activities” allowed were all in question throughout the Greco-Roman periods considered by Foucault². The situations considered in this chapter will allow us to pose the question of *parrhesia* in the early years of the third millennium, and specifically how it might need to be expanded in light of new computational devices and their effect on speech activities.

The noise of *parrhesia* is due to the interferences these utterances cause in the smooth functioning of their intended discursive systems. While *parrhesia* was often a sanctioned activity, the words of the *parrhesiastes*, by definition, would often cause a disturbance or a perturbation in the dynamics of the *agora*, the relationships between the monarch and his advisors, or the relationships amongst individuals. The dual of *parrhesia* as a sanctioned activity was the concern that such speech is mere “chatter”, unwanted and unuseful material that impedes the orderly activity of the *polis*. Yet since these discursive systems are not “closed”—they admit utterances not enumerated *a priori*—preventing *parrhesia* requires some form of social control, be it the internal regulation of speech in a subject, or the disciplinary repression of speech by a state or a monarch. As such, debates about what constitutes “good” or “bad” *parrhesia* can be found through these texts of antiquity. The discussions surrounding acceptable *parrhesia* can be understood to resemble similar ones in the modern world (Foucault 2011 [2008]).

²Foucault prefers the phrase “speech activity” to the more common “speech act” of John Searle to make a point regarding differing levels of commitment in *parrhesia* and normal speech acts. See Foucault, *Fearless Speech*, 13.

lar debates found in earlier chapters regarding what is or is not acceptable noise, or what potential positive impacts noise might have.

Foucault primarily considers *parrhesia* from the perspective of speech activities; that is, embodied vocal situations involving a shared discursive language. Nevertheless, I believe *parrhesia* can be extended to other forms of vocal activities: the voices of robotic creatures or non-speech sounds. Thus, I prefer to use the word “enunciation” to consider the whole gamut of situations involving what we might term speech and non-speech. This focus on enunciation draws from the shared concerns of Félix Guattari, specifically his elaboration of collective assemblages of enunciation. For Guattari,

Enunciation is like an orchestra conductor who on occasion accepts a loss of control over the musicians: at certain moments, it is articulatory pleasure or rhythm, it is an inflated style that begins to play a solo and to impose it upon the others. Let us underscore that if an enunciative lay-out can entail multiple social voices, it also engages pre-personal voices susceptible of inducing an aesthetic ecstasy, a mystical effusion, or an ethological panic—such as an agoraphobic syndrome—as well as an ethical imperative.³

Thus enunciations are more than discursive speech: they are not localized in an individual, but within an assemblage of components that are affectual (“affect is not a massively elementary energy but the deterritorialized matter of enunciation”).⁴

³Félix Guattari, “Ritornellos and Existential Affects,” *Discourse* 12, no. 2 (1990): 74.

⁴*Ibid.*, 77.

Moving towards the language of assemblages of enunciation rather than speech and non-speech allows us to consider the dynamical interaction of components that enable certain types of vocalizations to occur—or to be suppressed. When considered in light of the “ethical imperative”, enunciations can thus become *parrhesia* as I will outline below.

Considering vocalizations from the perspective of enunciations also enables one to engage with how language in contemporary Western societies is made solid, closed to openings to other nondiscursive, nonsignifying potentialities: “Subjectivity is standardised through a communication which evacuates as much as possible trans-semiotic and amodal enunciative compositions”.⁵ This is not an either/or proposition; conventional language is not to be dropped in favor of grunts or howls. Rather, it is how to both find a place within contemporary society for such forms of communication as well as reactivating the poetics of common language. Possibilities for both exist within new communicative technologies, and thus Guattari’s comments on their potential is applicable to the consideration of computational technologies:

It is certainly worthwhile reconstituting collective means of communication and action appropriate to a historical situation which has radically devalued old ideologies, social practices and traditional politics. In this respect, we should note that it is entirely possible that the new communication technologies will contribute to a renewal of similar means of elaboration and intervention.⁶

⁵Guattari, *Chaosmosis*, 104.

⁶*Ibid.*, 120.

Nevertheless, it is not the technologies themselves that create new forms of “communication and action”; rather it is through “[n]ew collective assemblages of enunciation” that work through “fragmentary ventures, at times risky initiatives, trial and error experiments”.⁷

This leads to the additional wrinkle in the use of *parrhesia* in the projects I engage with in this chapter. Each project *requires* the use of objects in order for *parrhesia* to take place. These objects act as unruly doubles of the speaker, or displace the speaker in order to place him or her in a place safe from state control. In order to do this the user of the objects must cede some control over their self-presentation, over the dynamics of their interaction with the public. Yet in nearly all of the examples of *parrhesia* considered by Foucault objects are absent; the speech occurs “unmediated” between a person and the *polis* or amongst individuals. To deal with this complication, and in light of the potential of computational “communication technologies,” I consider the objects involved in these situations of *parrhesia* as *performing objects* to focus on their potential joint agency with their users. The concept of “performing objects” was developed by Frank Proschan in the context of the semiotic analysis of puppetry and other forms of object performance in the theatre. According to Proschan, performing objects are “*material images of humans, animals, or spirits that are created, displayed, or manipulated in narrative or dramatic performance*”⁸. Expanding Proschan’s definition, the performance theorist and puppeteer

⁷Guattari, *Chaosmosis*, 120.

⁸Frank Proschan, “The semiotic study of puppets, masks, and performing objects,” *Semiotica* 47, nos. 1/4 (1983): 4, emphasis in original. Even though Proschan focuses on iconicity, others he cites do not hold as true to this definition. Proschan draws extensively from the Prague Linguistic Circle, including from Roman Jakobson and Petr Bogatyrev, in their analysis of Russian folk theatre. Jindrich Honzl, another member of the Prague Circle, noted that an actor could potentially be made of a piece of wood: “If the wood moves about and its movements are accompanied by words, then such a piece of

John Bell notes that “the term performing object has a broader scope and includes techniques of performance not normally labeled puppetry which nonetheless share the same basic approach” with the objects themselves “appear[ing] as one of the traditional forms of puppet theatre, or as a new form of abstract, found-object, or mechanical theatre.”⁹ Thus I propose to further expand the definition of performance and performing object beyond that suggested by Bell. The objects below each perform because of both their programming and their use by individuals. We will discover as well how *parrhesia* is a form of performance in public. Thus performing objects, enunciations, and *parrhesia* come together into new collective assemblages that potentially enable the reconfiguration of psychological and social machines.

***Parrhesia* Across the Millennia**

In order to understand the potentials—and pitfalls—of working with the concepts and practices of *parrhesia* in the twenty-first century, it’s important to understand Foucault’s approach to *parrhesia* in some detail. Foucault characterizes *parrhesia* as requiring frankness, truth, danger, criticism, and duty. The frankness of the *parrhesiastes* is because he must “open his heart and mind completely to other people through his discourse” via the “most direct words and forms of expression he can

wood can represent a character in the play, and the wood becomes an actor” (Proschan, “The semiotic study of puppets, masks, and performing objects,” 15). Another member of the Prague Circle, Jirí Veltruský, shows “how thing and man can change places, how a man can become a thing and a thing a living being. We can thus not speak of two mutually delimited spheres; the relation of man to object in the theater can be characterized as a *dialectic antimony*” (ibid., 16, emphasis in original). Thus the boundaries between things and objects can break down; transitions between the two can occur in a dynamic process. It is important to note that even for Honzl, words must be accompanied with the movement of the wood in order for it to become a character.

⁹John Bell, “Puppets and Performing Objects in the Twentieth Century,” *Performing Arts Journal* 19, no. 2 (1997): 30, 29.

find”¹⁰. Speaking the truth is the goal of the *parrhesiastes*, but this is a truth based on the *courage* of the *parrhesiastes* rather than on contemporary standards of evidence. This is a moral truth rather than a scientific one. The courage of the *parrhesiastes* comes from the fact that he is in some level of danger: *parrhesia* can occur only when there is a difference in power between the *parrhesiastes* and the person to whom he speaks. In the *agora* this danger might merely be one of status; in the game with a monarch, it might be linked to one’s own life. The danger arose because *parrhesia* is a form of criticism of the interlocutor or self-criticism of the speaker, situations that as a result of the unequal relationship between the interlocutor and the speaker could result in exile or death. The speech of the *parrhesiastes*, however, is never forced; the *parrhesiastes* speaks out of a sense of duty, an inability to keep silent¹¹.

Foucault considers *parrhesia* from a close reading of texts covering a thousand years of history, from the fifth century BC through the fifth century AD, highlighting the dynamics of the five aspects of *parrhesia* just mentioned. *Parrhesia* is understood as being connected to the distinct fields of rhetoric, politics, and philosophy, with Foucault focusing primarily on the latter two. In the political domain, *parrhesia* is first, that which makes the *agora* possible (“it is a requisite for public speech, takes place between citizens as individuals, and also between citizens construed as an assembly”) and second, during the Hellenistic period, as the necessary component of the relationship between the monarch and his advisors (“it is the advisor’s

¹⁰Foucault, *Fearless Speech*, 12. Foucault notes that given the oppressed role of women within Greek society most *parrhesiastes* were men (and only citizens at that), although he does discuss Electra as a *parrhesiastes* in the eponymous play.

¹¹For more on these characteristics see *ibid.*, 12–20.

duty to use *parrhesia* to help the king with his decisions, and to prevent him from abusing his power").¹² Later *parrhesia* is considered as a philosophical term related to the care of the self or as an "art of life".¹³

Politically, the use of *parrhesia* results in an aporia regarding its role within democratic institutions:

...the problem is one of recognizing who is capable of speaking the truth within the limits of an institutional system where everyone is equally entitled to give his opinion. Democracy by itself is not able to determine who has the specific qualities which enable him to speak the truth (and thus should possess the right to tell the truth). And *parrhesia*, as a verbal activity, as pure frankness in speaking, is also not sufficient since negative *parrhesia*, ignorant outspokenness, can also result.¹⁴

Since *parrhesia* is given to all citizens, even the "worst" ones, it becomes a danger to democracy itself. The real problem of *parrhesia* in a democracy is that it entitles everyone to his own definition of *bios* (life) thereby preventing a shared *logos*:

Freedom in the use of *logos* increasingly becomes freedom in the choice of *bios*. And as a result, *parrhesia* is regarded more and more as a personal attitude, a personal quality, as a virtue which is useful

¹²Foucault, *Fearless Speech*, 22.

¹³Ibid., 23.

¹⁴Ibid., 73.

for the city's political life in the case of positive or critical *parrhesia*, or as a danger for the city in the case of negative, pejorative *parrhesia*.¹⁵

This personal quality of *parrhesia* becomes more pronounced when it occurs in the context of a monarchic situation: successful use of *parrhesia* depends more and more on the personal qualities of the monarch, "a choice of *bios*", rather than the shared beliefs of the citizens in the *agora*.¹⁶

Parrhesia as a component of the care of the self can be found within its philosophical appearances, and specifically in the construction of a resonance between *bios* and *logos*. In Foucault's reading of the *Laches* of Plato, Socrates is a *parrhesiastes*, not for his speech in a political situation, but rather for his advice within the realm of personal relationships. For in this dialogue people of higher standing than Socrates are evaluating him as a potential pedagogue. Important to this choice is whether there is an "ontological harmony where the *logos* and *bios* of such a person [Socrates] is in harmonic accord".¹⁷ This harmony (phrased in a musical sense as necessarily in the Dorian mode) observed in Socrates thus enables him to act as a pedagogue to "lead the interlocutor to the choice of that kind of life (*bios*) that will be in Dorian-harmonic accord with *logos*, virtue, courage, and truth".¹⁸

For Foucault, this transition from political to philosophical *parrhesia* found in the Socratic dialogues is an important shift into a set of practices rather than a concept or a theme. This is important, because *parrhesia* becomes less an attempt to convince someone or to change his mind, but rather a set of practices that result

¹⁵Foucault, *Fearless Speech*, 85.

¹⁶Ibid., 86.

¹⁷Ibid., 100.

¹⁸Ibid., 101, emphasis in original.

in the changing of one's *life*. This means, then, that the relationship between *parrhesia* and truth becomes embedded within questions about the self, specifically self-knowledge. As such, the location of *parrhesia* extends far beyond the *agora* or the monarch's chambers, while not entirely losing its political potentials¹⁹.

Parrhesia as a philosophical practice encompasses both the sphere of relationships as well as technologies of self-examination. Within human relationships Foucault distinguishes three areas: community life, the public, and personal relationships. In a reading of an Epicurean fragment, Foucault sees *parrhesia* is a particular form of leadership, "a *techné* comparable both to the art of medicine and to the art of piloting a boat".²⁰ In this form of *parrhesia* it is the "philosopher's art of governing himself and acting as a kind of 'spiritual guide' for other people".²¹ It's important to remember, of course, that cybernetics comes from the Greek *kybernētēs* meaning steersman, governor, or pilot. In a sense this form of *parrhesia* resonates, perhaps uncomfortably, with our later understanding of cybernetics as a set of techniques of regulation or governing.

The Cynics were Foucault's source for philosophical *parrhesia* in public life; this occurred through forms of critical preaching, scandalous behavior, and provocative dialogues.²² The critical speech of the Cynic in public was meant to foreground the "natural life", the one that is not beholden to the whims of arbitrary rules or social mores.²³ This was occasionally embodied through scandalous behavior that questioned the relationships between the ruler and his subjects or the supposed

¹⁹For more on these changes, see Foucault, *Fearless Speech*, 105–107.

²⁰*Ibid.*, 110, emphasis in original.

²¹*Ibid.*, 112.

²²*Ibid.*, 120.

²³*Ibid.*, 121.

“natural” domains of arbitrary rules. This enabled the Cynic, through this form of *parrhesia* (which did not necessary need to be based on speech) to “question collective habits, opinions, standards of decency, [or] institutional rules.”²⁴ Finally, the Cynics, through the reversal of roles, engaged in dialogues that were meant to cause the interlocutor to come to a new form of self-realization, “to lead the interlocutor to *internalize* this parrhesiastic struggle—to fight within himself against his own faults.”²⁵

Within personal relationships, a good *parrhesiastes* is not necessarily a good friend; rather, this is a person who must be neutral in order to competently evaluate what he is being told: “A good truth-teller who gives you honest counsel about yourself does not hate you, but he does not love you either.”²⁶

Finally, Foucault considers *parrhesia* as a technology of the self through situations of solitary self-examination, self-diagnosis, and self-testing. A key metaphor used here is that of an artist or a sculptor “who from time to time stops working, examines what he is doing, reminds himself of the rules of his art, and compares these rules with what he has achieved thus far.”²⁷

Foucault’s exegesis of the different forms of *parrhesia* in *Fearless Speech* does not venture beyond the fifth century AD. In his final year-long seminar at the Collège de France, however, Foucault foregrounds the potential resonances of *parrhesia* with contemporary practices. While he believes that *parrhesia* has “precisely disappeared as such,” Foucault does suggest that there are three modalities on which

²⁴Foucault, *Fearless Speech*, 120.

²⁵Ibid., 133, emphasis in original.

²⁶Ibid., 141.

²⁷Ibid., 166.

parrhesia is “grafted”:

Revolutionary discourse plays the role of parrhesiastic discourse when it takes the form of a critique of existing society. Philosophical discourse as analysis, as reflection on human finitude and criticism of everything which may exceed the limits of human finitude, whether in the realm of knowledge or the realm of morality, plays the role of *parrhesia* to some extent. And when scientific discourse is deployed as criticism of prejudices, of existing forms of knowledge, of dominant institutions, of current ways of doing things—and it cannot avoid doing this, in its very development—it plays this parrhesiastic role.²⁸

More directly for the matters at hand, Foucault suggests that the emergence of the artist in modernity—specifically, the artistic life as a “manifestation of art itself in its truth”—is the locus of Cynicism in modern life.²⁹ For Foucault, “art has been the vehicle of Cynicism in the modern world” because “art itself [...] is no longer one of ornamentation, or imitation, but one of laying bare, exposure, stripping, excavation, and violent reduction of existence to its basics.”³⁰ Art becomes a “site of the irruption of the basic, stripping existence bare.”³¹ As a result of this it is in “art that the most intense forms of a truth-telling with the courage to take the risk of offending are concentrated.”³²

²⁸Foucault, *The Courage of the Truth (The Government of Self and Others II): Lectures at the Collège de France 1983-1984*, 30.

²⁹Ibid., 187.

³⁰Ibid., 188.

³¹Ibid.

³²Ibid., 189.

Within these gestures towards the potential locus of *parrhesia* in modern art Foucault limits his references to high modernists such as Édouard Manet, Francis Bacon, Samuel Beckett, Charles Baudelaire, and William Burroughs.³³ Whither *parrhesia* in the late twentieth and earlier twenty-first centuries, then? Importantly, in the forms discussed by Foucault, *parrhesia* was a set of practices limited primarily—essentially—to men, and to men who were citizens. This of course prevents women, slaves, immigrants—non-citizens in general—of being *parrhesiastes*. Additionally, as the photographer and cultural theorist Ahmad Hosni notes, Foucault's discussion of *parrhesia* says little about the ethics of the practice, thereby admitting any form of political discourse far out of the political mainstream, including the far left and far right.³⁴

Nevertheless, *parrhesia* is a potentially useful set of practices to consider, assuming they are suitably transformed for the exigencies of the present day. For the use of *parrhesia* foregrounds important questions that remain with us today: what is truth, who has the ability to speak the truth, and in what situations? These types of questions are all the more important in a world where everybody is assumed to have the same access to media technologies and thus to their own potential to challenge the more powerful—a claim that is without a doubt false. Perhaps most intriguing in the use of *parrhesia* is its framing as a perturbation into the smooth functioning of discourse: a noise that aims to correct in some way the functioning of the system. *Parrhesia* then can be construed as a set of practices that enables certain

³³Foucault, *The Courage of the Truth (The Government of Self and Others II): Lectures at the Collège de France 1983-1984*, 188.

³⁴Stephanie Bailey et al., eds., *Masquerades of Truth (PARRHESIA: Technologies of Truth)* (London, 2012), 29.

individuals or groups of people to intervene within a system or set of systems. And thus *parrhesia* consists of the whole set of activities needed to prepare the ground and space for the *parrhesiastes* to engage in new enunciations, discursive or not. As Hosni suggests,

It would be better to think of parrhesia without Foucault. I take it as a pretext for a speculative opinion and a pre-text for what could come next; post-Foucault, post-parrhesia. We need to translate parrhesia into the parlance of contemporary political theory. There is something essentially political there. It is not listed in the concept's active components. No, it is not criticism. It is not duty, and definitely not a transcendental truth. It is essentially the condition of disagreement, of antagonism that marks the parrhesiastic moment. There is always a moment of friction, of tension, where new knowledge stems into being, a moment of turning-against that is the true locus of parrhesia and politics.³⁵

Taking Foucault's cue regarding certain modernists as *parrhesiastes* we can examine a set of situations that exhibit this particular intersection of *parrhesia*, Cynicism, and art. Through this we can extend *parrhesia* beyond the definitions drawn out by Foucault and into the nexus of humans and machines. And via Hosni's explanations we might be able to understand moments of friction and tension as the real power of *parrhesia* —interventions that create "new knowledge" or new truths— via their noisy interferences within an existing system. As we have seen in other

³⁵Bailey et al., *Masquerades of Truth (PARRHESIA: Technologies of Truth)*, 29.

chapters, noise is more than a simple disruption that contributes nothing of novelty; in fact, noise is oftentimes a vital component in the construction of new forms of knowledge, new ways of knowing. *Parrhesia* enables one to pull these aspects of noise into a more explicitly political realm while at the same time engaging with the enunciative potentials of noise.

Prosthetic Performing Objects and the *Parrhesiastes*

Krzysztof Wodiczko is an artist who was originally trained as an industrial designer. Currently teaching at the Harvard Graduate School of Design, Wodiczko has additionally taught at the Massachusetts Institute of Technology, serving as director of the Center for Advanced Visual Studies. He came to these positions in the United States as a refugee from Poland via time teaching and working in Canada. Wodiczko is well-known for his large-scale projections that use both provocative imagery and personal testimony to re-activate monuments³⁶. I am interested, however, in examining a different set of projects that were developed in the 1990s and that belong to a series entitled *Immigrant Instruments*. This series continues from Wodiczko's earlier interest in the intersection of humans and the built environment, and specifically the role of the artist/designer as someone who can intervene within this space. The vehicles he developed—*Homeless Vehicle Project* (1988–1989) and *Poliscar* (1991) (Figure 17)—not only worked to upend common understandings

³⁶For a detailed account of these projects see Duncan McCorquodale, ed., *Krzysztof Wodiczko* (London, UK: Black Dog Publishing Limited, 2011), 46–145, 264–305.



Figure 17: Krzysztof Wodiczko: *Homeless Vehicle Project* (1988–1999, left); *Polis-car* (1991, right)

of the homeless and homelessness, but also demanded a certain attention and insisted that one address the question as to why these vehicles need to exist. Beyond the ways in which Wodiczko entered into discussions with the homeless in the design of the vehicles—a common tactic within commercial design and beginning to be undertaken within socially-conscious design at the time—the objects themselves attest to their liminal nature: neither solution nor mere adornment, the vehicles and their appointed caretakers are brought to marginal visibility from the undifferentiated background.

Consider one of the *Immigrant Instruments*, *Alien Staff* (1992–1996; Figure 18). The device, meant to evoke the staff of the wanderer or shepherd, functions as a mediator between an immigrant and the public, an item that provokes further discussion. Atop the staff is small video screen—a size that demands close proximity to the immigrant for viewing—displaying pre-recorded and pre-edited clips that interfere, constructively or destructively, with the presence of the immigrant holding the staff. Further down the staff is a reliquary holding objects important for the immi-



Figure 18: Krzysztof Wodiczko: *Alien Staff* (1992–1996), used by Adul So and Hamed Sow in Stockholm

grant's travel: visas, passports, and photographs that document his or her passage from one locale to another. The form of the staff and the ways in which the objects inside are arranged and displayed gestures towards the staff's role as more than a mere tool for communication; in the words of Wodiczko, "*Alien Staff* becomes a sacred object. It is an immigrant's companion and a historical (and 'storical') double, displacing displacement and spreading communicative cure"³⁷. The ambivalent

³⁷Krzysztof Wodiczko, "Identity and Community: Alien Staff," in *ibid.* The staff's role as more than a communicative device was raised in conversations with members of the public:

Reaction: But what's the point? Is it originality, or that when you introduce yourself with it [the staff], you want people to get to know you?

Patrica Pirreda [immigrant living in Paris]: No, it's for people to ask questions. And they do ask questions.... My own goal is to be able to express this. My goal is to participate in a voyage, a voyage beyond borders. I have crossed borders. There have

role of the staff mirrors the elusive position of the immigrant: neither here nor there, sometimes visible and sometimes not, pushed to answer the question “Where are you from?” with a definitive answer. In the words of Wodiczko again, “[*Alien Staff*] is designed as public-speech-act equipment, which allows the singular immigrant to open up his or her own critical history of displacement to everyone whom it may (or even may not) concern, to open up to the ‘other’ and to the world the complexity of the often unstable and multiple configurations and reconfigurations of identities inhabiting the immigrant’s mind”.³⁸ This is the immigrant multiple, a position that is perhaps more clear to those who have undergone displacement, but is in fact true for everyone³⁹. Thus a side-effect of the *Alien Staff* and the *Immigrant Instruments* in general is to bring into awareness the fragmentation of our identities and the possibilities (and boundaries) of their potential reconfiguration⁴⁰.

A second instrument from the series, *Porte-Parole* (1993; Figure 19) presents this exact point, and further highlights the interconnection between people and

been plenty of fractures within myself. And this is another voyage I am making. I am trying to see if I can cross borders....

Ellipses present in the original. See McCorquodale, *Krzysztof Wodiczko*, 238.

³⁸Wodiczko, “Identity and Community: Alien Staff,” 221.

³⁹This is a play on Annemarie Mol’s notion of the “body multiple”, a reference to the multiple realities of the body through the enactment of different practices within a hospital. While her context is rather different than the one considered here, it resonates with the role of these performing objects in enacting multiple representations:

If practices are foregrounded there is no longer a single passive object in the middle, waiting to be seen from the point of view of seemingly endless series of perspectives. Instead, objects come into being—and disappear—with the practices in which they are manipulated. And since the object of manipulation tends to differ from one practice to another, reality multiplies.

See Mol, *The Body Multiple: Ontology in Medical Practice*, 7.

⁴⁰For an account of how these fluid identities are reconfigured in the nascent online cultures of the 1990s, see Sherry Turkle, *Life on the Screen: Identity in the Age of the Internet* (New York: Touchstone, 1995).



Figure 19: Krzysztof Wodiczko: *Porte-Parole* (1993)

computational objects. Instead of a device that acts as a mediator, in *Porte-Parole* one's speech is replaced by the "mouthpiece", the blocking of sound from the mouth via the unnatural placement of the instrument in front of it. The actual mouth is replaced by a video double of it, pre-recorded and potentially manipulated by the immigrants. The sound comes from a speaker next to the head, rather than from the mouth itself. Like in the *Alien Staff*, the small size of the screen requires people to come close to the instrument, and thus to the person. According to Wodiczko, with *Porte-Parole*, "The user himself or herself is no longer delegating power to the instrument, but is integrated organically with it, transforming him or her into a kind of cyborg, a virtual subject. [...] [*Porte-Parole*] is an instrument whose function is to empower those who are deprived of power".⁴¹

As with *Alien Staff*, a key aspect of the piece are the preparations the immi-

⁴¹Krzysztof Wodiczko, "Mouthpiece (*Porte-Parole*)," in McCorquodale, *Krzysztof Wodiczko*, 228.

grants make prior to using the instruments in public: “Those who are ready to negotiate these psycho-political roles need this equipment, an artifice or prosthesis, to begin this demanding process of fearless speech.”⁴² This includes the choices of what speech to make and how to present it. In *Porte-Parole*, this additionally includes potential visual manipulations of the recordings, as one person chose to warp the video into spirals and swirls. This further heightens the disconnect between the assumed stable self—a fiction—and the one that is multiple, fragmentary, and often in flux. Yet unlike bureaucracy, which sees from the perspective of paperwork only a few components of this self, with *Alien Staff* and *Porte-Parole* the immigrant is in charge of their own representation. In the words of the art historian Ewa Lajer-Burcharth, “Thus, while they provide the strangers with only a piecemeal self-image and a fragmented identity, the key importance of these instruments is that they enable their users to author it, to be the bricoleurs of their selves, provisional and incomplete as such selves may be.”⁴³ And it is precisely this aspect of *editing* that, through an attention to choices of words or the ordering of phrases, enables the immigrants to turn “speech into a manageable scope and form that is available to anyone” according to Wodiczko.⁴⁴ In charge of their speech, of what they choose to reveal, those who use the *Immigrant Instruments* can shape a new presentation or performance of their identities.

The mention of “fearless speech” is a direct reference to *parrhesia*, an important influence for Wodiczko along with the theories of agonistic democracy put

⁴²Patricia C. Phillips, “Creating Democracy: A Dialogue with Krzysztof Wodiczko,” *Art Journal* 62, no. 4 (2003): 38.

⁴³Ewa Lajer-Burcharth, “The Global Wanderer,” in McCorquodale, *Krzysztof Wodiczko*, 215.

⁴⁴Phillips, “Creating Democracy: A Dialogue with Krzysztof Wodiczko,” 38.

forth by Chantal Mouffe. In contrast to deliberative forms of democracy based on consensus such as those put forth by John Rawls, Mouffe posits the necessity of what she calls “agonistic pluralism,” or the active contestation of positions that may not resolve into consensus⁴⁵. While Mouffe does not address *parrhesia* per se, for Wodiczko it is intersection of agonism, *parrhesia*, and the addressing of trauma that makes active participation in public speech possible. And unlike Mouffe, Wodiczko understands that agonism requires the speaker to be prepared: “A fundamental question is how to prepare this ‘fearless speaker’ to participate in the agora or contemporary public space. And what are our expectations for the fearless speaker? Should she speak from her own experience?”⁴⁶ The *Immigrant Instruments*—through the processes necessary for their construction, through the formal aspects of their use—ensure that the immigrant does not enter into the acts of *parrhesia* without prior training. For it is not the case that any kind of speech is *parrhesia*, as we have just learned. Indeed, given the risk involved in *parrhesia*, it is

⁴⁵Responding to the rather perplexing re-evaluation of the work of Carl Schmitt in recent decades, Mouffe reworks his well-known “friend/enemy” distinction.

...I propose to distinguish between two forms of antagonism, antagonism proper—which takes place between enemies, that is, persons who have no common symbolic space—and what I call “agonism”, which is a different mode of manifestation of antagonism because it involves a relation not between enemies but between “adversaries”, adversaries being defined in a paradoxical way as “friendly enemies”, that is, persons who are friends because they share a common symbolic space but also enemies because they want to organize this common symbolic space in a different way.

See Chantal Mouffe, *The Democratic Paradox* (New York: Verso, 2000), 13, 80–107. Recently Carl DiSalvo has used Mouffe’s explication of adversaries to argue for an “adversarial design”: “In labeling an object as adversarial, I mean to call attention to the contestational relations and experiences aroused through the designed thing and the way it expresses dissensus” (DiSalvo, *Adversarial Design*, 7). For DiSalvo, adversarial design includes online projects that reveal hegemony, agonistic encounters with social robotics (including the work of Kelly Dobson, discussed below), and new collectivities formed through ubiquitous computing.

⁴⁶Phillips, “Creating Democracy: A Dialogue with Krzysztof Wodiczko,” 34.



Figure 20: Krzysztof Wodiczko: *Ægis* (1999–2000), in use by Kelly Dobson

all the more important to construct situations that enable certain types of speech to be heard in order to become a *parrhesiastes*: “If we wish to bring these unheard, invisible, and uninvited speakers to public space, then how are we to do this? We could give a microphone or loudspeaker to these people, but we may hear nothing. So the question is, what kind of conditions must be created for these individuals be heard? What is required for them to have some impact?”⁴⁷ The prosthetic computational device—a device that can manipulate what is said, how it appears and is heard—becomes intertwined with the embedding of the immigrant within the public space. Without the devices *parrhesia* may not take place. With them *parrhesia* occurs, the devices performing with their companions in public.

Yet there are others who are not presently immigrants and who may need such

⁴⁷Phillips, “Creating Democracy: A Dialogue with Krzysztof Wodiczko,” 36.

devices to speak. In *Ægis* (1999–2000; Figure 20), Wodiczko and his collaborators constructed an instrument that enables the wearer to present multiple contradictory aspects of their existence. Referencing the cloak Athena used for protection, *Ægis* has two screens that unfold from behind the wearer like angel's wings. Each screen displays a pre-recorded video that offers competing responses the question "Where are you from?", but from the perspective of someone who is not necessarily an immigrant. Responding to pre-determined vocal cues the instrument selects different clips to be shown on the wings/screens. *Ægis* foregrounds the complications in responding to questions regarding one's past, highlighting the power relations inherent in such an encounter. While wearing *Ægis* one is protected by the activity of the instrument: instead of providing stock answers the wings/screens emit different answers created in private. The instrument takes over, each wing potentially contradicting the other, along with the wearer himself or herself. Thus like the immigrant who carries the *Alien Staff*, the wearer of *Ægis* "resembles that of an angel or prophet" performing "an angelic or prophetic mission in today's migratory and alienating world. They are messengers of a better world to come as well as critics of the unacceptable world in which they live"⁴⁸

With the *Immigrant Instruments* and *Ægis*, Wodiczko foregrounds the complicated relationships between immigrants, the public, and technologies of representation. Indeed the *Immigrant Instruments* function again within this liminal space whereby it becomes impossible to definitively determine the boundary between the immigrant or the object, with both blurring together through their co-construction

⁴⁸Krzysztof Wodiczko, "Ægis: Equipment for a City of Strangers," in McCorquodale, *Krzysztof Wodiczko*, 254.

of situations of *parrhesia*. The instruments thus “function” not in the recognizable ways of industrial design, but rather in the space of *interrogative* design: “Interrogative design questions the very world of needs of which it is born”⁴⁹. The form of these devices produced by interrogative design is key: “The appearance of interrogative design may ‘attract while scandalizing’—it must attract attention in order to scandalize the conditions of which it is born. Implicit in this design’s temporary character is a demand and hope that its function will become obsolete.”⁵⁰ The oppressive covering of the mouth in *Porte-Parole* connotes the silencing—external or internal—of an immigrant’s voice. Yet because the covering contains a video screen the voice can still be seen and heard, but this time constructed prior to wearing the instrument in public. Statements and responses can be prepared in advance with the wearer delegating the enactment to the instrument itself. This contrived situation is necessary because of the dangers—psychological or social—of *parrhesia*.

Thus the instruments enable one to let the instrument speak—albeit an instrument already charged with certain desires and speech of the wearer. For Wodiczko these instruments “reside between performance, industrial design, and some action.”⁵¹ The objects perform in their role as fragments of their user, fragments that never coalesce into a complete whole. Perhaps seen and heard most dramatically in *Ægis*, the fragmentary nature of our existence challenges a mode of democracy

⁴⁹Krzysztof Wodiczko, “Interrogative Design,” in *Critical Vehicles: Writings, Projects, Interviews* (Cambridge, MA: MIT Press, 1994), 16. The industrial designer Victor Papanek, important to the thought of Wodiczko, notes how designers are taught to respond to culturally-defined *wants*, rather than the actually-existing *needs* of society. Many of these needs are well-known, such as the paucity of well-designed products for the disabled. See Victor Papanek, *Design for the Real World: Human Ecology and Social Change* (New York, NY, USA: Pantheon Books, 1971 [1970]).

⁵⁰Wodiczko, “Interrogative Design,” 17.

⁵¹Phillips, “Creating Democracy: A Dialogue with Krzysztof Wodiczko,” 38, 46.

based on consensus: if our identities are fragmentary and conflicting, how can we ever assume that consensus will occur amongst many individuals? The instruments participate in a form of agonism predicated on the practice of *parrhesia* through their performances with their users. *Parrhesia* becomes possible for these people through their joint performances with the instruments.

What Happens When the *Parrhesiastes* Is Not Human?

In the work of Wodiczko the objects act as mediators between the *parrhesiastes* and the public. His prostheses do not displace the human from the encounter but rather transform the types of speech possible. Yet there now exist situations where Wodiczko's prostheses may not be enough to prevent bodily harm to the *parrhesiastes*. Might there be a way to enable *parrhesia* through the actions of a robotic agent, a stand-in for a human *parrhesiastes*? What happens to the quality of speech when a human meets a non-human *parrhesiastes*?

The IAA is a tactical media collective founded in 1998 as a “technological research and development organization dedicated to the cause of individual and collective self-determination. Our mission is to study the forces and structures which affect self-determination and to provide technologies which extend the autonomy of human activists.”⁵² By reappropriating the imagery, rhetoric, methodology, and technology of research institutions (such as universities, industry, and the military)

⁵²Institute for Applied Autonomy, “Mission,” n.d. Accessed July 3, 2013, <http://www.appliedautonomy.com/mission.html>.



Figure 21: IAA: *Little Brother* (1999), still from <http://vimeo.com/6070459>

IAA attempts to not only annex the legitimacy of these institutions, but also provide easy-to-understand descriptions of novel technological artifacts to those unaffiliated with these organizations. Many of IAA's projects exist in order to protect activists from unwanted surveillance or arrest via the use of technologies, such as robotics, to project a form of social authority while simultaneously masking the real operator of the device.

Little Brother (1999; Figure 21) is a robotic pamphleteer designed to distribute activist messages in locations where humans would otherwise be prevented from doing so, such as in malls or privately-owned "public" parks. *Little Brother's* mechanism is relatively simple: an aluminum "body", basic direction finding through sonar that controls the movement of the head, and a set of pre-recorded phrases stored on a readily available voice recording chip. More important than the tech-

nical construction however is the design of *Little Brother* itself. IAA describe in a tongue-in-cheek manner the robot's "cuteness factor", suggesting that its "utility is not driven by technological sophistication, but rather by its aesthetic appeal."⁵³ IAA constructed *Little Brother* with large eyes and head and a diminutive body specifically to enhance this "cuteness factor"⁵⁴. According to IAA, *Little Brother* is necessary for three reasons: the spreading of activist messages in public space has to compete in a noisy environment with many other forms of leafletting, causing pedestrians to avoid anyone spreading literature on the street; activists are "notoriously flaky" and "inefficient", making the distribution of the desired messages less than ideal; and the replacement of public, governmentally-owned spaces with private ones (such as malls and parking lots) means the distribution of political speech is no longer governed by free-speech statutes. IAA conducted "field research" with *Little Brother* and found that not only was its "cuteness factor" higher than a human pamphleteer, but the use of a robot—an object associated with high research and/or the military—created a "Trojan Horse" situation enabling the surreptitious distribution of material⁵⁵.

⁵³Institute for Applied Autonomy, "Pamphleteer: A Propaganda Robot for Cultural Resistance," n.d. Accessed July 3, 2013, <http://appliedautonomy.com/pamphleteer.html>.

⁵⁴In *Alone Together: Why We Expect More from Technology and Less from Each Other*, Sherry Turkle notes how new forms of social robotics aim to use something like "cuteness" to draw people into new types of relationships with computational objects. Through detailed ethnographic research, Turkle shows how social robots potentially provide new forms of companionship while simultaneously raising questions surrounding intimacy and complicity: "Our new encounters with sociable robots ...provoke responses that are not about these machines' capabilities but our vulnerabilities." See Sherry Turkle, *Alone Together: Why We Expect More from Technology and Less from Each Other* (New York: Basic Books, 2011), 20, 21–147.

⁵⁵Institute for Applied Autonomy, "Pamphleteer: A Propaganda Robot for Cultural Resistance." The text from which these quotes from was written by IAA in the form of a standard engineering research article in part to highlight the language and rhetoric used within these domains. It is highly unlikely that the members of IAA believe these terms apply to *all* activists.



Figure 22: IAA: *Graffiti Writer* (1999), still from <http://vimeo.com/6070459>

Prior to the testing of *Little Brother*, IAA and Critical Art Ensemble (CAE) had proposed the concept of “contestational robotics”, or the design, construction, and distribution of robotics projects that can be used in an agonistic fashion within public—and not-so-public—spaces. Contestational robotics depart from conventional robotics by not so much in their materials or plans, but rather in their framing. Indeed, IAA and CAE note that what disaster, military, and contestational robots share is the ability to “insinuate themselves into situations that are mortally dangerous or otherwise hazardous to humans”.⁵⁶ This ability arises because of telepresence, the manipulation or direction of an object from a remote location. All of these aspects come into play with IAA’s *GraffitiWriter* (1999; Figure 22),

⁵⁶Critical Art Ensemble and Institute for Applied Autonomy, “Contestational Robotics,” 1998, accessed July 3, 2013, <http://www.appliedautonomy.com/objectors.html>.

a remote-controlled robot that uses computer-actuated spray-paint cans to surreptitiously print activist messages in dangerous locations⁵⁷. Built upon commodity radio-controlled (RC) cars and using off-the-shelf electronics components, IAA designed *GraffitiWriter* to be cheap (so that its capture or loss would not represent a significant financial loss to the collective) and easy-to build (so that amateurs could construct their own without specialized knowledge), two aspects of do-it-yourself (DIY) culture common to anarchist strains of activism within which IAA and some other tactical media collectives operate.

GraffitiWriter has been used in many locations around the world, including the grounds of the US Capitol and onstage during the awards ceremony of Ars Electronica in 2000⁵⁸. In conjunction with an exhibition in Philadelphia in 1999, IAA claimed that *GraffitiWriter* was used by construction workers, a girl scout troupe, and the general public, with no-one being arrested for vandalism. Kay Saracera (a pseudonym of one of IAA's members) described how this could occur:

By making GraffitiWriter publicly available we accomplish several goals. On the one hand, we are encouraging people to be expressive, to share their thoughts with their communities. Secondly, we are

⁵⁷A plan for an early prototype of *GraffitiWriter* can be found in Critical Art Ensemble and Institute for Applied Autonomy, "Contestational Robotics." The posting of this on the <nettime> mailing list caused Bruce Sterling to write that he would "be willing to pay no-kidding, American deep capitalist dollars for a gizmo like that! It has commodity fetish appeal! It would jump off the shelves at Computer City and Radio Shack." Such a comment illustrates one of the key points of IAA's practice, the "commodity fetish appeal" of accessible robotics projects and the ways in which they could have inserted themselves into the popular imaginary. See Bruce Sterling, "Contestational Robotics," September 5, 1998, accessed July 3, 2013, <http://www.nettime.org/Lists-Archives/nettime-1-9809/msg00015.html>.

⁵⁸The Ars Electronica event was meant to protest the free-speech policies of Austria and the attacks upon the now-defunct public_netbase, an online source for dissident materials. The awards ceremony was presented on live television. See <http://www.appliedautonomy.com/artbyteletter.html>.

exploring the possibilities of using new technologies to create public spectacles which can alter people's conception of the world around them. If we were to go into a park and hand people cans of spray-paint, no one would write anything because we've been conditioned to believe that graffiti is destructive—not to mention illegal. However, by using a robot, it suddenly seems acceptable behavior to paint all over the ground. In a sense, we are using the robot to create, at least temporarily, a space for free action and expression in the middle of the city, and in broad daylight.⁵⁹

Here it is not the “cuteness factor” that pushes people over the threshold of contact, but rather a form of fun, of play, the framing of which enables people to undertake an action that is nominally illegal. *GraffitiWriter*, built upon RC cars with their simple controls and connotation as simply “toys”, potentially enables a contestational form of speech by those unable to afford the risk of graffiti in a different set of circumstances. This is only “potential”, of course, as nothing in the construction of *GraffitiWriter* requires *parrhesiastic* speech.

This issue would come to the fore a few years after the deployment of *StreetWriter* (2001, 2004; Figure 23), the natural upscaling of *GraffitiWriter*. *StreetWriter* enabled the spray-painting of messages from a moving vehicle, producing written speech visible from aircraft and tall buildings while also greatly increasing the possible length of text used. In 2009, however, there appeared the “Chalkbot”, itself an upscaled version of *StreetWriter* developed by Deeplocal (a

⁵⁹Institute for Applied Autonomy, “Robotic Insurrection in Philadelphia Streets,” August 20, 1999, accessed July 3, 2013, <http://www.appliedautonomy.com/phillypr.html>.



Figure 23: IAA: *Street Writer* (2001, 2004), still from <http://vimeo.com/6070459>

Pittsburgh, PA branding studio) for Nike and Wieden+Kennedy Portland, an advertising agency. Chalkbot was deployed during the Tour de France in conjunction with Livestrong, the cancer charity founded by Lance Armstrong. Chalkbot enabled remote participants to enter messages of “cancer survival” to a website; the messages were then printed on the road and GPS-tagged photos of the messages-as-chalk were e-mailed to the participants⁶⁰. According to IAA, some of the developers of Chalkbot were “close associates”. Noting that they claimed no ownership over the idea, IAA did suggest that the lack of acknowledgement of the DIY-roots of Chalkbot were of a piece with contemporary corporate development, writing that “It is unfortunate that as they [the associates] enriched themselves, they were unable

⁶⁰For a video on the making and use of Chalkbot, see <http://vimeo.com/11849530>.

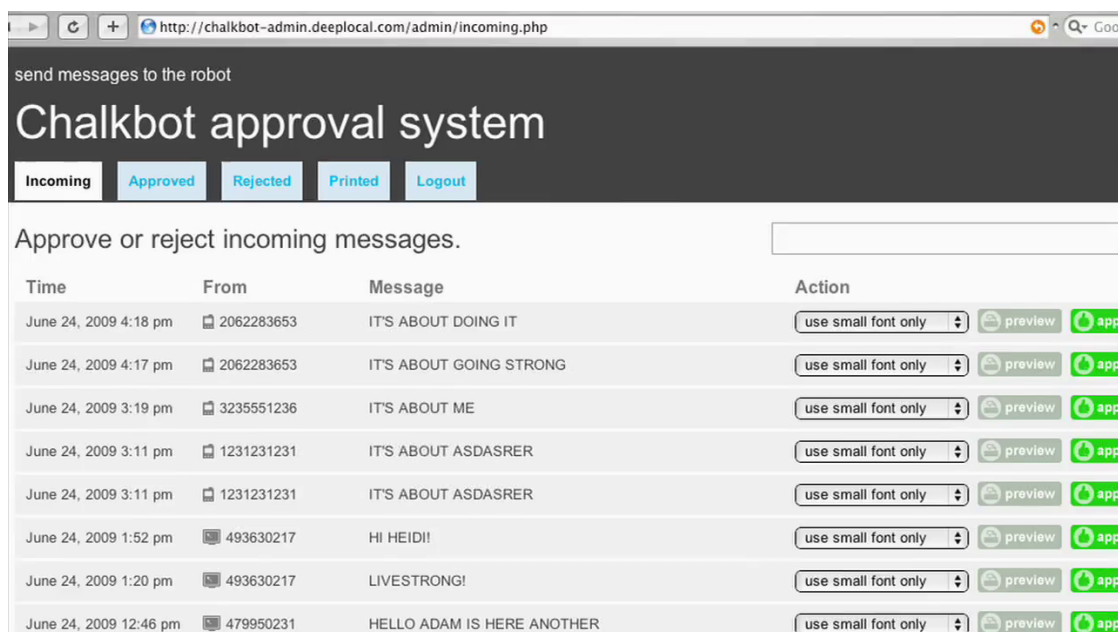


Figure 24: Chalkbot approval system, still from <http://vimeo.com/11849530>

to also enrich the communities that nurtured their own development.”⁶¹

More germane to my interests, however, is a series of images from the video documenting Chalkbot. Seemingly innocuous, the sequence shows the administrative interface for the robot, entitled the “Chalkbot approval system” (Figure 24). On this page that allows an administrator to “send messages to the robot”, one also has the ability to approve or reject the messages to be spray-painted in chalk on the road. A moderator, therefore, sits in between the speech from the participant and its appearance in physical form. The necessity of a moderator in a circa-2009 project that is open to anyone on the Internet is clear. Nevertheless, this interface encapsulates the primary difference between the projects of IAA and Chalkbot, and is what enables *parrhesia* with IAA’s projects and not by default with Chalkbot. For IAA is clear on this point: “IAA agents act only as facilitators—both the message

⁶¹Institute for Applied Autonomy, “Nike Chalkbot Rips-off Streetwriter,” July 7, 2009, accessed July 3, 2013, <http://www.appliedautonomy.com/chalkbot.html>.

content and the actual operation of *GraffitiWriter* is left in the hands of ‘civilians’.⁶² Thus, in the deployment of *GraffitiWriter* and *StreetWriter*, IAA did not exert editorial control. Chalkbot, on the other hand, is constructed with editorial control in mind, both in terms of the messages themselves as well as the location of the printed messages. There is something about *scale* here that seemingly necessitates the control of messages to prevent “interesting” speech from being drowned out by spam. Perhaps, then, it is the relationships made between members of IAA and the public that primarily shapes the types of speech made with *GraffitiWriter* and *StreetWriter* versus Chalkbot. In fact, in the hands of IAA it is likely that Chalkbot would similarly employ a moderator but with a different set of constraints.

The relationship between Chalkbot and the work of IAA raises two issues important to the consideration of *parrhesia*. The first is the precise kind of speech conveyed through the intersection of humans and these machines. It is clear that the purpose of Chalkbot was to spread positive messages regarding battles with cancer. In the hands of IAA, *GraffitiWriter* and *StreetWriter* were used to spread seemingly subversive content, such as the URL for a disdained online repository of texts

⁶²Institute for Applied Autonomy, “Robotic Insurrection in Philadelphia Streets.”

or “Robots Must Not Kill” before the first DARPA Grand Challenge⁶³. In the case of *Little Brother*, video documentation show the distribution of Society of Reproductive Anachronisms pamphlets, a project of CAE⁶⁴. It is less clear, however, what texts the public chose to write with *GraffitiWriter* and *StreetWriter*. The video documentation of the projects indicate that the aforementioned Girl Scout Troop wrote “Girl Scouts Rule!”, but the messages of others are not listed and are difficult to discern. Thus we are faced with the same conundrum that bedeviled the Greeks and Romans with respect to *parrhesia*: what types of speech can be considered *parrhesia*, and what types of speech are mere chatter? Does giving *parrhesia* to all citizens mean there is no chance for a shared *logos* given wildly varying definitions of *bios*? It is clear that involving a non-human mediator does not provide a means for adjudicating these questions.

Yet it is precisely this involvement of the *non-human* that leads to the second key issue. In the texts discussed by Foucault *parrhesia* could only take place because the enlightened behavior of the monarch would not result in the death of the *parrhesiastes*; or, the interlocutor of the *parrhesiastes* would not violently retaliate as a result

⁶³Begun in 2004, the DARPA Grand Challenge is a competition to develop fully autonomous vehicles. For more information on the 2004 challenge, see <http://archive.darpa.mil/grandchallenge04/>. The phrase IAA chose to spray-paint is a restatement of Isaac Asimov’s Three Laws of Robotics:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

⁶⁴The website for this project can be found at <http://critical-art.net/Original/sra/SRAweb/index.html>.

of the frank speech. In certain respects these sanctioned locations for fearless speech have withered away from our public spaces, with IAA raising this precise aspect of speech-in-public as a rationale for the development of *GraffitiWriter*. It becomes sadly necessary to provide a stand-in, an avatar so-to-speak, of the *parrhesiastes* when basic compacts regarding both civility and types of speech are no longer valid. The simplicity of IAA's projects enable these stand-ins to be constructed by those with limited technical knowledge. A simple form of telepresence thus becomes the modality through which *parrhesia* occurs. Such a necessity should give us pause. *Little Brother*, *GraffitiWriter*, and *StreetWriter* exist—and provide a vital function of preventing harm to come to activists—in response to needs that should not exist. The distancing of humans in communication is the real issue at hand. Perhaps the further use of IAA's projects will obviate their necessity.

***Parrhesia* and Non-Speech Enunciations**

The projects of Wodiczko and IAA have all involved performing objects that enable their human interlocutors to engage in forms of discursive enunciations: that is, normal speech, with recognizable phonemes or syllables strung together in a discernible fashion. Such enunciations fit squarely into the possibilities of *parrhesia* delineated by Foucault: *parrhesia* as a discursive activity; the measured, rational exchange of truth. Perhaps, however, aspects of our contemporary moment prevent such exchanges from taking place. The necessity of IAA's distancing of the human from the places of *parrhesia* suggests that this could be the case. The wariness one might feel with the projection of a *parrhesiastes* onto a robotic actor raises the pos-

sibility that speech may not be the best way of conveying contemporary truths, that a different form of vocal enunciation might be necessary.

Listen to and consider the work of Kelly Dobson, an artist and professor at the Rhode Island School of Design who has studied at both Cornell (BFA) and at MIT (MVis, MS, and PhD). Her work is nominally about the relationship between humans and objects. But in Dobson's case, the objects are termed *machines*: large electro-mechanical structures like cranes, and smaller, domestic objects such as blenders and custom-designed electromechanical devices. While the question of biography and the artist is a vexing one, it is important to note that Dobson ascribes much of her interest in the intersection between machines and the voice to early experiences:

I would lie on the wooden floor of our small apartment as a child, my ear pressed airtight against the smooth surface, listening to the heating and plumbing, the humming, creaking adjustments, and footsteps and voices of neighbors, all mixed together, a living machine that I was contained by and held by.

[...]

I had sung with staplers and crows in high school and college, in folk punk bands and sound ensembles. As I began singing with machines I became reflective about having always been interested in my voice during unusual circumstances only. In regular circumstances I was extremely uncomfortable using my voice. Debilitatingly shy.⁶⁵

⁶⁵Kelly Dobson, "Machine Therapy" (PhD diss., Massachusetts Institute of Technology, 2007),

Dobson's practice importantly brings together the psychological and the social, showing how they are intimately intertwined. Dobson remarks on the porous boundaries between assumed separate realms: for example, inner, psychological space and the outside social world, or the difficulty in distinguishing whether an object is or is not part of you.

This latter contrast is related to the British psychoanalyst D. W. Winnicott's notion of the "transitional object". According to Winnicott, infants have difficulty in distinguishing between "me" and "not-me"; early on, an infant understands "me" to include an attachment to his/her mother. At a later stage of development the infant begins to realize s/he is separate from the mother; such a realization can bring on periods of anxiety or frustration, leading to the use of a "transitional object" that stands in for the mother. The transitional object—a blanket, teddy bear, doll—is the first "not-me" possession of the child:

I have introduced the terms "transitional objects" and "transitional phenomena" for designation of the intermediate area of experience, between the thumb and the teddy bear, between the oral erotism and the true object-relationship, between primary creative activity and the projection of what has already been introjected, between primary unawareness of indebtedness and the acknowledgment of indebtedness ("Say: 'ta'").⁶⁶

Even so, the child still has difficulty in distinguishing between himself/herself and

17.

⁶⁶D. W. Winnicott, *Playing and Reality* (New York: Routledge, 1971), 2–3.

the transitional object. Later, however, the child becomes able to make this separation and often casts-off the no-longer-needed transitional object:

Its fate [the transitional object] is to be gradually allowed to be de-cathected, so that in the course of years it becomes not so much forgotten as relegated to limbo. By this I mean that in health the transitional object does not “go inside” nor does the feeling about it necessarily undergo repression. It is not forgotten and it is not mourned. It loses meaning, and this is because the transitional phenomena have become diffused, have become spread out over the whole intermediate territory between “inner psychic reality” and “the external world as perceived by two persons in common”, that is to say, over the whole cultural field⁶⁷.

While Winnicott suggests holding on to the transitional object into adulthood can lead to psychosis, for him certain qualities of the *experience* of the transitional object are key to play and creativity in the adult: “The place where cultural experience is located is in the *potential space* between the individual and the environment (originally the object).”⁶⁸ The “potential space” comes directly from these experiences with transitional objects as an infant: “From the beginning the baby has maximally intense experiences *in the potential space between the subjective object and the object*

⁶⁷Winnicott, *Playing and Reality*, 7. The reference to “go inside” might be to Freud’s “Mourning and Melancholia”; for Freud, in melancholia (in contrast to “normal” mourning), the object of the melancholia is allowed to be internalized, causing the person to be unable to make a distinction between the loved object of the melancholia (in Freud’s case, always a person) and himself/herself. See Sigmund Freud, “Mourning and Melancholia,” in *The Standard Edition of the Complete Psychological Works of Sigmund Freud*, ed. James Strachey (London, UK: The Hogarth Press, 1953-1974 [1917] [1915]), 239–258.

⁶⁸Winnicott, *Playing and Reality*, 135, emphasis in original.

objectively perceived, between me-extensions and the not-me. This potential space is at the interplay between there being nothing but me and there being objects and phenomena outside omnipotent control”.⁶⁹

Dobson proposes that the concept of the “transitional object” be pushed further into the realm of the adult, coining the term “transobject” to refer to that which makes possible what she called the “endo-exo dance”, or the elusive movement between experiencing an object as part of you or as separate from you.⁷⁰ Dobson’s oeuvre choreographs this dance through the design and use of specific objects; the dance could be understood as analogous to the “potential space” where Winnicott locates cultural experience. Additionally, Dobson suggests that in the work of Joan Jonas, Pina Bausch, Lygia Clark, and Wodiczko, the slipperiness of the ontological status of objects causes us to experience a questioning of the everyday⁷¹.

Dobson’s master’s thesis in visual studies at MIT, entitled *BOOM* (2000), begins her move away from the discursive (see Figure 25). During a time of massive infrastructural projects within the Boston area, including the largest civic project of the time, the Big Dig, Dobson was entranced by the sounds of the construction machines, their extreme sound and power to modify the landscape of the city. Dobson would return to these machines and scream with them in order to channel both her desires and those of the equipment:

⁶⁹Winnicott, *Playing and Reality*, 135, emphasis in original.

⁷⁰Dobson, “Machine Therapy,” 66.

⁷¹*ibid.*, 41–51. Importantly, Dobson was a member of Wodiczko’s Interrogative Design Group during the late 1990s while the members were developing some of the prostheses mentioned earlier. Dobson is often seen in documentation of *Ægis* (1998). In her essay on *Ægis* and Wodiczko’s other instruments, the art historian Rosalyn Deutsche writes that, “Like the transitional object, [the instruments] facilitate a journey of progress toward separation, couple fantasy and social reality, and embody a hope that they will one day lose meaning for their users” (Rosalyn Deutsche, “Sharing Strangeness: Krzysztof Wodiczko’s *Ægis* and the Question of Hospitality,” *Grey Room*, no. 6 (2002): 37).



Figure 25: Kelly Dobson: *BOOM* (2000), image from Dobson, “Machine Therapy,” 71

In *Boom* the machines are transitional objects. This is one aspect. They are expressive beasts I channel. This is another aspect. They are screaming in the city of the things they have witnessed and laughing and bellowing cries cut through streets, through buildings, through garage doors, apartment windows, into the earth, the thickest steel and stone, down in sewers, along power lines, gas lines, phone lines, lines of people, lines of traffic, screeching, hissing, whispering, vomiting, looking for something. [...] The motor singing, coupled with my vocalizations, allows me to hallucinate that I am actually driving the machine with my voice. To some extent, I am. This may be con-

sidered mad, but it is also true. And this is part of the third area of existing, creative play, cultural life.⁷²

Dobson noted that this experience with the construction machines altered her relationship with the city: “I moved away from the normal relationship of a person in the city, namely being against the disturbing sounds of the machines yet passive and begrudgingly submissive, to a relationship in which through moments of appropriation and commingling at the visceral and experiential levels, I remade my conceptions and connection with the machines and their affects.”⁷³ Importantly, these experiences were not only between her and the machines, but also between her and the construction workers, noting that they would point her towards other machines with interesting sounds, as well as admit that they were making these sounds themselves.⁷⁴ Thus *BOOM* works as a contrast to simplistic notions of acoustic ecology that would remove these machines from the soundscape *tout court*; the vocalizations of Dobson and the construction workers foreground other potentials of experience that do not rely on a passive acceptance of the sounds themselves. And this experience is a *sounding* of a certain form of truth: a truth that, though its re-sounding amongst the din of a construction site might blend in to its background, but whose activation of the air leaves a physical trace of a voice making manifest its connection to the built environment.

But what if these sounds could be stored and later released in another location?

And what if the sounds were not those that mimic machines, but rather unadul-

⁷²Kelly Dobson, “BOOM” (master’s thesis, Massachusetts Institute of Technology, 2000), 8.

⁷³Dobson, “Machine Therapy,” 72.

⁷⁴Ibid., 18, 72.



Figure 26: Kelly Dobson: *ScreamBody* (1998–2004), image from Dobson, “Machine Therapy,” 75

terated screams? In *ScreamBody* (1998–2004), Dobson created what she calls a “Wearable Body Organ (WBO)” that enables one’s scream to be silenced and later released (see Figure 26). The design of *ScreamBody* is meant to reference a set of external lungs that are kept close to the body. *ScreamBody* functions to address an unmet need that exists but should not, that of releasing anguish in situations that our society considers to be inappropriate⁷⁵. The video documentation for *ScreamBody* shows Dobson screaming into the WBO within an interior “public” space, and later releasing it outside near a busy thoroughfare⁷⁶. The scream, now released, enters into a new type of public space, an act that demands attention and raises questions from those nearby. The release of the scream is an act of *parrhesia* —its unexpected sounding a potentially dangerous act that could lead to unwanted institutionalization but whose very irruption into the everyday announces a truth that would otherwise be silent. What the precise components of this truth are cannot

⁷⁵These needs are poorly defined, yet are just as ignored as the more apparent needs discussed by Victor Papanek. See footnote 49.

⁷⁶see <http://web.media.mit.edu/~monster/screambody/>.

be understood from the scream itself. But its activation of the air produces a situation not unlike the disturbances of the Cynics discussed by Foucault; while not scandalous behavior *per se*, the scream-in-public does question the standard rules of behavior.⁷⁷

Important for Dobson was the *visibility* of *ScreamBody* and the other WBOs:

Also a public performance based series, WBOs are designed to be visible and worn and used in public (as well as private) everyday life. Their visibility and use in public becomes something of a personal performance that announces the very needs they address, questions the situations we are in that result in such needs. This form of acknowledgment represents the needs through a material, tangible form that can be negotiated with and through.⁷⁸

Elsewhere, in discussing the potential series of WBOs—HoldBody, CryBody, EatBody, FightBody, HideBody, HouseBody—Dobson notes that the WBOs are “critical social activists. Each apparatus acts to call reflexive attention to the social repression addressed by the very need for the existence of the device.”⁷⁹ Thus not only is the scream—the sonic aspect of *ScreamBody*—an act of *parrhesia*, but so is the wearing of the WBOs themselves. Consider another WBO, *HoldBody* (2005), a “cozy cushiony straightjacket of sorts” “for situations where one wants to hold and comfort, or be held and comforted, but is not able to do so with a person in the

⁷⁷Foucault, *Fearless Speech*, 122.

⁷⁸Dobson, “Machine Therapy,” 76.

⁷⁹Kelly Dobson, “Wearable Body Organs: Critical Cognition Becomes (Again) Somatic,” in *Proceedings of Creativity & Cognition 2005* (2005), 259.



Figure 27: Kelly Dobson: *HoldBody* (2005), image from Kelly Dobson, “Wearable Body Organs: Critical Cognition Becomes (Again) Somatic,” in *Proceedings of Creativity & Cognition 2005* (2005), 260

immediate environment” (see Figure 27).⁸⁰ In both cases the design of the WBOs themselves make the needs visible: truth is announced via form. Yet it is the activation of this form through its use that strengthens the acts of *parrhesia*; through the use of, for example, *ScreamBody* in a public space, new truths become manifest in the sounds heard and the engagement with a rather odd device. The use and appearance of the WBOs work to eventually negate their necessity through the addressing of the needs underlying their development. In short, the noisiness of the vocalizations in *BOOM*, along with the irruption of screams enabled by *ScreamBody*,

⁸⁰Dobson, “Wearable Body Organs: Critical Cognition Becomes (Again) Somatic,” 260.

foreground new forms of affective *parrhesia* enabled by computational performing objects that create new assemblages of enunciation between individuals, machines, and the public⁸¹.

***Parrhesia* and the Noise of the Unwanted**

A recent book by Franco “Bifo” Berardi—key activist and writer of Italian Autonomism, theorist of semiocapitalism, and friend and colleague of Guattari—reactivates Guattari’s insistence that contemporary language has evacuated trans-semiotic and amodal enunciations. Writing in the wake of the financial crisis, Bifo suggests that poetry is a necessary, powerful response to the automation of language within the contemporary economic sphere: “Poetry is the here and now of the voice, of the body, and of the word, sensuously giving birth to meaning. [...] We have to start a process of deautomating the word, and a process of reactivating sensuousness (singularity of enunciation, the voice) in the sphere of social communication”⁸². According to Bifo, financialization—the on-going processes that turn anything into a mathematical construct to be traded, more and more often by computer algorithms

⁸¹In her recent *Depression: A Public Feeling* Ann Cvetkovich, through a close attention to the affective potentials of certain forms of contemporary craftwork by artists such as Sheila Pepe and Allyson Mitchell, notes that such practices might, following Foucault, “provide a model for new ways of inhabiting the disciplinary regimes that constitute the modern self.” Cvetkovich believes that an attention to the “utopia of ordinary habit”—the repetitive activities of yoga, running, or craftwork such as knitting and crochet—might provide a ground for new forms of practice that respond to the deadening despair of political depression. Additionally, this utopia “reconceives the rational sovereign subject as a sensory being who crafts a self through process and through porous boundaries between self and other, and between the human and the nonhuman (including animals and things)” (Ann Cvetkovich, *Depression: A Public Feeling* (Durham, NC: Duke University Press, 2012), 191–192). I believe that Dobson’s WBOs extend Cvetkovich’s utopias into the realm of computational performing objects.

⁸²Franco “Bifo” Berardi, *The Uprising: On Poetry and Finance*, Intervention Series 14 (Los Angeles: Semiotext(e), 2012), 21.

as we have seen—erases the poetic potentials of language. In conjunction with this has been the acceleration of time into smaller and smaller fragments—again, something seen in the discussion of HFT in Chapter 3—as well as the production of precarity through the loss of state and corporate guarantees to work and welfare. In response, Bifo notes the need for a new “sensibility”, an “ability to understand what cannot be verbalized.... In order to reactivate sensibility, art and therapy and political action have to all be gathered”.⁸³ Important to this reactivation of sensibility and poetry is an understanding of the activities of the Cynics and their practices of *parrhesia*. While contemporary cynicism is based on “lip service, moral unreliability, and conformist subjugation to those in power”, the Cynics of Foucault’s texts engage in a “rigorous truthfulness” and possess a “disdain for power”.⁸⁴ Even so, both have an “awareness of the ambiguous nature of language, and an ability to suspend the relation between language and reality, particularly in the ethical sphere”.⁸⁵

It is thus potentially through a reactivation of these aspects of ancient Cynic *parrhesia*—what Bifo, through a reading of Peter Sloterdijk, prefers to term *irony*—that we can break the stranglehold of financialization on language. From Wodiczko’s interrogative instruments that help to construct fragmentary selves, to IAAs robotics that distance the *parrhesiastes* from harm, to Dobson’s WBOs that sound affective experiences within public spaces, the vocal noises become intertwined with the communicative noises produced within the existing social machines. The voices, the enunciations, are unwanted, an interference within the social machines that are altogether assumed to be smoothly functioning. Yet the existence of these projects,

⁸³Berardi, *The Uprising: On Poetry and Finance*, 143.

⁸⁴*Ibid.*, 159.

⁸⁵*Ibid.*, 159–160.

and the necessity of interrogative design, foregrounds the unseen, unheard, undesirable problematics many would prefer to ignore. Dynamically, these noises—sonic and social—come about through the performative actions of the assemblages of the objects and individuals. Without the somewhat unpredictable activity of the performing objects the enunciations would lose a key component of their noisy characteristic. It is this constellation of performing object, individual, and the voice that forms the assemblages of enunciations that then create these interferences within social fields. The interferences become, for a few moments at least, unable to be evacuated of their amodal and trans-semiotic potentials by processes of recuperation—assuming there is not an intermediary selecting speech based on a normalizing criterion. *Parrhesia* is thus transformed into something beyond rational discursive truth, an affective *parrhesia* that occurs as a result of the joint activity of humans and machines, a poetic *parrhesia* that demands to be understood in a register other than that of efficiency.

Chapter 5

Some Micropolitics of Noisy Voices

Perhaps there are other ways of causing noisy interferences within semiotic systems besides the conjunction of humans and computational performing objects. Maybe we can consider vocal political interventions that gesture towards *parrhesia*—not explicitly functioning as *parrhesiastic* speech but rather within a *micropolitical* register through the computational manipulation of the *voice*. In what ways does this attention to the voice help complicate long-standing philosophical discourses surrounding presence and the relationship between a voice and the body from which it comes? And how might such manipulation further extend artistic and poetic responses to the commodification, or, in the words of Berardi, the financialization of language?

This chapter discusses the performance, compositional, and production practices of Maja Ratkje and Holly Herndon. Taken together, the works I consider stretch over a decade (2002–2012) marked by contradictions in the domains of the voice and sound: the experience of significant shifts in the ways in which music is constructed, shared, and heard, leading to a certain new level of access to the

means of sonic production, but at the same time complicating the dynamics of remuneration; and, in conjunction with the domains of the two musicians under consideration, the widespread development of a vibrant set of “noise” music practices the world over that have contributed to the development of new listening regimes while also in the best of situations foregrounding the position of women within a longstanding history of experimental sound. Moving from this level of generalization, I will listen closely to the works of Ratkje and Herndon in order to highlight the dynamics of their temporal unfolding, the ways in which they produce their own interferences in how we hear the voice beyond rational signification, beyond the gendered representative of genred dance music, beyond the discursive conveyor of truth. Rather, I consider how the vocal practices heard in the works of Ratkje and Herndon offer yet another micropolitical intervention into a regime of signs that attempts to commodify all vocal utterances. While Ratkje and Herndon’s projects exist at the level of physical commodity—as CD, as collectors vinyl, as digital download, as online video clip—the dynamics of their sounds exceeds each particular medium.

I begin by reviewing some of the philosophical discourses surrounding the voice, highlighting recent work in feminist and queer scholarship that points to the intersection of the voice and technology as a way of recuperating the *sounds* of the voice in a world post-phonocentrism. I then turn to a close listening of Maja Ratkje’s oeuvre as a solo performer, as a member of Fe-Mail, and as part of the collective SPUNK. Ratkje’s projects span a wide variety of media and compositional practices but converge on an interest in the potentials of the voice. I listen to a recent album by Holly Herndon that moves through a set of disparate genres via a set of vocal

manipulations that perform new types of technological transformations. Herndon credits cyborg and post-human thematics in the development of her compositional practice, and I thus connect this to the question of a micropolitics of vocal manipulation. Along with Ratkje, I consider how these sound works suggest possible interferences within contemporary semiotic systems.

Some Philosophies of Voice

In recent years the voice has sounded within academic discourse. A series of philosophical reflections have brought attention to the role of the voice outside or alongside speech and language in the wake of Jacques Derrida's critiques of phonocentrism and logocentrism¹. Others have focused on the intersection of the voice and various forms of analog and digital technologies². Finally, recent works have re-

¹See, for example, Adriana Cavarero, *For More Than One Voice: Toward a Philosophy of Vocal Expression*, trans. Paul A. Kottman (Stanford University Press, 2005 [2003]); Steven Connor, *Dumbstruck: A Cultural History of Ventriloquism* (Oxford and New York: Oxford University Press, 2001); Jacques Derrida, *Of Grammatology*, trans. Gayatri Chakravorty Spivak (Baltimore, Maryland, USA: Johns Hopkins University Press, 1997 [1976]); Jacques Derrida, *Speech and Phenomena and Other Essays on Husserl's Theory of Signs*, trans. David B. Allison (Evanston, IL: Northwestern University Press, 1973); Mladen Dolar, *A Voice and Nothing More* (Cambridge, MA, USA: MIT Press, 2006). I discuss the texts by Cavarero, Derrida, and Dolar in more detail below.

²See, for example, Kay Dickinson, "'Believe'? Vcoders, Digitalised Female Identity and Camp" [in English], *Popular Music* 20, no. 3 (2001): 333–347; Don Ihde, *Listening and Voice: Phenomenologies of Sound* (State University of New York Press, 2007); Freya Jarman-Ivens, *Queer Voices: Technologies, Vocalities, and the Musical Flaw* (New York: Palgrave Macmillan, 2011); Susan McClary, "This Is Not a Story My People Tell: Musical Time and Space According to Laurie Anderson," in *Feminine Endings: Music, Gender, and Sexuality* (Minneapolis: University of Minnesota Press, 1991), 132–147; Norie Neumark, Ross Gibson, and Theo van Leeuwen, eds., *Voice: Vocal Aesthetics in Digital Arts and Media* (Cambridge, MA: MIT Press, 2010); Osvaldo Oyola, "In Defense of Auto-Tune," September 12, 2011, accessed March 7, 2013, <http://soundstudiesblog.com/2011/09/12/in-defense-of-auto-tune/>; Rodgers, *Pink Noises*; Tompkins, *How to Wreck a Nice Beach: The Vocoder From World War II to Hip-Hop: The Machine Speaks*; Alexander G. Weheliye, "'Feenin': Posthuman Voices in Contemporary Black Popular Music," *Social Text* 20, no. 2 71 (2002): 21–47. *Voice: Vocal Aesthetics in Digital Arts and Media* is an edited collection in which the chapters deal with topics as varied as voice mail, vocal performativity in new media practices, sound poetry, the voice in videogames, humming,

awakened the history of the voice within media arts practices such as Fluxus, sound poetry, performance art, and new media art³. Below I consider some aspects of this recent scholarship in more detail, focusing on those components that enable me to trace how technology and the voice enable new forms of micropolitical engagements with the instrumentalization of the voice. Such an endeavor requires questioning the relationship of the voice to presence, asking how voices become singular, understanding the different sounds the voice can make outside of linguistic signification, and following the trajectories of the commodification of language in general.

“The Voice” and its lack of unity of presence

The contemporary consideration of “the voice” is haunted by the writings of Jacques Derrida. And it would be appropriate that this haunting has as its source his *writing*, given that Derrida’s interest in the voice comes from his project of critiquing the metaphysical privileging of speech over writing, that has thereby led to a phonocentrism and logocentrism within the trajectory of western philosophy. To address Derrida’s arguments in detail would take me too far afield, so I will only sketch his arguments schematically, primarily to note the challenge they make to a unified notion of “presence”. In his reading of Edmund Husserl’s phenomenology, Derrida notes that, “The ‘apparent transcendence’ of the voice thus results from the fact that

and the haunting of migratory voices. The book by Dave Tompkins was also discussed on page 31 in Chapter 1 in conjunction with the intersection of the development of the vocoder and the precedents of information theory. *Pink Noises* is one of the few books to focus on the intersection of women, technological, and experimental sonic practices.

³See a number of chapters in the edited collection *Voice: Vocal Aesthetics in Digital Arts and Media* as well as Labelle, *Background Noise: Perspectives on Sound Art* and Nina Sun Eidsheim, “Sensing Voice: Materiality and the Lived Body in Singing and Listening,” *The Senses and Society* 6, no. 2 (2011): 133–155.

the signified, which is always ideal by essence, the ‘expressed’ *Bedeutung*, is immediately present in the act of expression. [...] This effacement of the sensible body and its exteriority is *for consciousness* the very form of the immediate presence of the signified.”⁴ As such, this supposed “immediate presence” is due to the activity of “hearing oneself speak”:

As pure auto-affection, the operation of hearing oneself speak seems to reduce even the inward surface of one’s own body; in its phenomenal being it seems capable of dispensing with this exteriority within interiority, this interior space in which our experience or image of our own body is spread forth. This is why hearing oneself speak [*s’ entendre parler*] is experienced as an absolutely pure auto-affection, occurring in a self-proximity that would in fact be the absolute reduction of space in general.⁵

Yet, as is so often the case with Derrida, he shows that this is merely an *appearance*, for there can be no “pure auto-affection” without *différance*, or an extended chain of deferrals with no fixed origin or essence. In moving to one moment to the next there must be a “pure auto-affection in which the same is the same only in being affected by the other, only by becoming the other of the same”; that is, the continuity we experience when we hear ourselves speaking is only due to the differences that exist from one “primordial impression” to another as they are linked in time.⁶ Thus this difference “introduces into self-presence from the beginning all the impu-

⁴Derrida, *Speech and Phenomena and Other Essays on Husserl’s Theory of Signs*, 77.

⁵Ibid., 79.

⁶Ibid., 85.

rity putatively excluded from it".⁷ But this sequencing, these "intervals" from one moment into another, introduce spatiality into a temporal phenomenon through the technique of metaphor: "The externality of space, externality as space, does not overtake time; rather, it opens as pure 'outside' 'within' the movement of temporalization. [...] Hearing oneself speak is not the inwardness of an inside that is closed in upon itself; it is the irreducible openness in the inside; it is the eye and the world within speech".⁸ Thus speech is infused with the same impurities, the same traces, as writing with its movement across the page and in time. In the words of Adriana Cavarero, "Even the scenario of the voice thus belongs to the field of *différance*. The phonocentric matrix of the metaphysics of presence consists precisely in the effort of hiding this work of *différance*."⁹

Derrida's deconstruction of the philosophical privileging of the voice over writing of course extends beyond his consideration of Husserl's phenomenology.¹⁰ And given Derrida's wider project in the late 1960s and early 1970s of re-tracing the history of philosophy in order to understand the importance of writing at the expense of the voice, how could he be of use to a different project that attempts to foreground the micropolitics of computational manipulations of the voice? I will consider shortly the work of Cavarero and others who are influenced by Derrida's deconstruction of phonocentrism. However, I want to note here that his construction of the "pure-autoaffection" of the voice as a trace, and Cavarero's marking of this as *différance*, provides an intriguing way of understanding the simultaneous manipula-

⁷Derrida, *Speech and Phenomena and Other Essays on Husserl's Theory of Signs*, 85.

⁸Ibid., 86.

⁹Cavarero, *For More Than One Voice: Toward a Philosophy of Vocal Expression*, 225.

¹⁰Derrida, *Of Grammatology*.

tion of the voice through computational means. For added to the *différance* already there in hearing oneself speak is the transformation of the voice into an altogether-different form, one that highlights and heightens this play of signifiers¹¹. Thus if we accept Derrida's critique of phonocentrism as self-evident presence, replaced by the understanding of the voice as always already infused with *différance*, we are indeed a long way towards understanding the intersection of voice and computation as simply another link in the chain.

The irreducible specificity of voices

Even with Derrida's deconstruction of phonocentrism, there is still the problematic of "the voice" labeled with a definite article. Such theorizing tends to lump all voices into one undifferentiated sonic mass, the specificity of an individual voice removed in the service of philosophical unity. This is the starting point of Adriana Cavarero in *For More Than One Voice: Toward a Philosophy of Vocal Expression*:

Precisely because speech is sonorous, to speak to one another is to communicate oneself to others in the plurality of voices. In other words, the act of speaking is relational: what it communicates first and foremost, beyond the specific content that the words communicate, is the acoustic, empirical, material relationality of singular

¹¹This transformation is of course not entirely *simultaneous* with the production of vocal sounds, as computation takes some time to occur. However, in most situations this temporal delay—another deferral—is imperceptible. An important counter-example in the history of media art is Richard Serra's *Boomerang (with Nancy Holt)* (1974), in which Holt describes the experience of talking while hearing her own voice on a short delay. See http://www.ubu.com/film/serra_boomerang.html.

voices.¹²

The singular voice thus exists within a “plurality of voices”. This singularity comes because of the materiality of the voice, of an excess that is all-too-often silenced, removed, or ignored: “the sphere of the voice is constitutively broader than that of speech; it exceeds it. To reduce this excess to mere meaninglessness [...] is one of the chief vices of logocentrism.”¹³ Cavarero’s project is to rediscover this excess in the service of politics, to foreground the importance of the singularity of *a* voice within a philosophical milieu that would focus on abstract discursivity: “To thematize the primacy of the voice with respect to speech, in fact, also means opening new directions for a perspective that not only focuses on a primary and radical form of relation that is not yet captured in the order of language, but that is moreover able to specify this relation as a relation among uniqueness.”¹⁴

This attention to the uniqueness of a voice implies a parallel attention to the materiality of the unique body from which the voice sounds. Examples abound in Cavarero’s text: the ears listening to music and song are “acoustic chambers that enjoy the vibrations and resonances” of sound; Julia Kristeva’s *chora* shows how “speech is always a question of bodies, filled with drives, desires, and blood”; and Hélène Cixous’ *l’écriture féminine* participates in a “libidinal economy” with “an ear cocked to the rhythmic enchantment of the first voice” (the mother)¹⁵. A voice

¹²Cavarero, *For More Than One Voice: Toward a Philosophy of Vocal Expression*, 13.

¹³Ibid.

¹⁴Ibid., 16.

¹⁵ibid., 127, 134, 145. Cavarero is here referencing Kristeva’s discussion of the semiotic *chora* in Julia Kristeva, *Revolution in Poetic Language*, trans. Margaret Waller (New York: Columbia University Press, 1984 [1974]). For the text most associated with Cixous’ *l’écriture féminine* see Helene Cixous, “The Laugh of the Medusa,” trans. Keith Cohen and Paula Cohen, *Signs* 1, no. 4 (1976[1974]): 875–893.

comes from inside a body, resonates within the lungs and mouth of a body, enters into the ear of another body and causes the eardrum of this other body to vibrate. Voices always are connected to specific bodies, and our apperception of vocal sounds always exists within an embodied context. Noting this, Nina Eidsheim remarks on how the vocal sounds we hear travel through matter, including the matter of our own bodies, and are thus affected by the environment in which we hear them.¹⁶

Vocal excesses, redux

The excesses of the voice—those aspects that do not contribute to the intelligibility of an utterance, that interfere with sense-making—contribute to the difficulties we have in understanding the possibilities and the potentialities of the voice. For Mladen Dolar, “words fail us when we are faced with the infinite shades of the voice,

The *chora*, a term that Kristeva draws from Plato meaning “receptacle” or “space” and with connotations of “womb”, is an enveloping space-time for the infant prior to the mirror stage and the entry into the Lacanian Symbolic. Importantly it is associated with the “mother’s voice, face, and breast, and to the psychic and libidinal conditions of early infantile life” (Kaja Silverman, *The Acoustic Mirror: The Female Voice in Psychoanalysis and Cinema* (Bloomington and Indianapolis, IN, USA: Indiana University Press, 1988), 102). As such,

The *chora* is not yet a position that represents something for someone (i.e., it is not a sign); nor is it a *position* that represents someone for another position (i.e., it is not yet a signifier either); it is, however, generated in order to attain to this signifying position. Neither model nor copy, the *chora* precedes and underlies figuration and thus specularization, and is analogous only to vocal or kinetic rhythm (Kristeva, *Revolution in Poetic Language*, 26).

Kaja Silverman acknowledges this importance of the *chora*, but sees in it a “fantasy” in which the mother (and, by extension, the daughter) is excluded from language: “In order for the *choric* fantasy to function as an effective political implement, it must point forward as well as backward—accommodate transformation as well as return” (Silverman, *The Acoustic Mirror: The Female Voice in Psychoanalysis and Cinema*, 125).

I turn to Cixous’ *l’écriture féminine* in more detail below.

¹⁶Eidsheim, “Sensing Voice: Materiality and the Lived Body in Singing and Listening.”

which infinitely exceed meaning”.¹⁷ Thus the voice is

what does not contribute to making sense. It is the material element recalcitrant to meaning, and if we speak in order to say something, then the voice is precisely that which cannot be said. It is there, in the very act of saying, but it eludes any pinning down, to the point where we could maintain that it is the non-linguistic, the extralinguistic element which enables speech phenomena, but cannot itself be discerned by linguistics.¹⁸

Again, similar to Cavarero, the voice is this “material element” that has tended to be effaced in the philosophical abstractions of the voice. Yet the “extralinguistic” cannot be removed, cannot be ignored, for it is vital to the intelligibility of speech. We understand this intuitively: the specificity of an individual’s speech as a result of particular inflections, pauses, or intensities contributes as much to our understanding of what we hear in the voice as the signs themselves¹⁹.

In his essay on glossolalia, Michel De Certeau notes that when one ignores these elements of the voice a “fragility disappears from discourse. With the erasure of occasional stammers, hesitations, and vocal tics, or lapses and drifting sounds, the

¹⁷Dolar, *A Voice and Nothing More*, 13.

¹⁸*Ibid.*, 15, emphasis in original.

¹⁹This focus on the materiality of the voice, coupled with Cavarero’s attention to the singularity of individual voices, suggests a certain resonance with Roland Barthes’ notion of the “grain” of the voice: “The ‘grain’ is the body in the voice as it sings, the hand as it writes, the limb as it performs.” See Roland Barthes, *Image, Music, Text*, trans. Stephen Heath (New York: The Noonday Press, 1990), 188. In a convincing critique by Dolar, he suggests that the grain is ultimately unsatisfactory: “The problem is that the voice cannot be pinned to a body, or be seen as an emanation of the body, without a paradox” (Dolar, *A Voice and Nothing More*, 197, footnote 10). This is due to the fact that the voice, while being produced by a body, also enters into the world and is ultimately displaced from the body through the vibrations it creates into the air, creating a temporally modulating acoustic field.

interlocutor is removed to a distance, transformed into an audience”.²⁰ Like Dolar, De Certeau understands these aspects to be vital to the voice qua voice: “The secondary noises that populate ordinary conversations represent the tattoo of the vocal and the interlocutory on the body of discourse”.²¹

Vocal nonsense, or, sense in another register

There is more to glossolalia than these spaces and “extraneous” sounds that surround phonemes. For De Certeau, glossolalia “organizes a space where the possibility of speaking is deployed for itself” rather than in the service as a mode of communication: “Every glossolalia combines something prelinguistic, related to a silent origin or to the ‘attack’ of the spoken word, and something postlinguistic, made from the excesses, the overflows, and the wastes of language”²². While glossolalia can be heard within the excess of language, it can also be produced via the concatenation of sounds that masquerade as phonemes that cross “through the boundary of statements to test the potentialities of the vocal palette, to fill a space of enunciation with polyphonic chatter before falling off into silence”²³. This type of glossolalia can be heard throughout the long history of avant-garde poetry: the Italian Futurists’ attempts to evoke the sounds of war and industry; the Russian Futurists’ invention

²⁰Michel De Certeau, “Vocal Utopias: Glossolalias,” *Representations*, no. 56 (1996): 30.

²¹*Ibid.*, 30.

²²*ibid.*, 30, 33. According to the translator, “attack” is meant to refer to its musical sense, i.e., the “attack” of a bow on a string. See *ibid.*, 44, footnote 22.

²³*ibid.*, 32. In De Certeau’s typology, this is the second form of glossolalia and is typified by an absence of an obligation that would compel these sounds. The first form, often found within sacred contexts, is due to some form of obligation that is compelled by a Spirit or an Other. In this chapter I draw from De Certeau’s second typology exclusively, although it would be interesting to consider the intersection of the two in the incantations of someone like Hugo Ball. See *ibid.*, 31–33.

of zaum; the Dadaist experiments in non-sense, simultaneity, and sacred incantation; the Lettrists' formalist experiments; and the "ugly" lyrics and voices of punk, especially post-punk feminist groups such as Hole, L7, and Babes in Toyland²⁴.

As Brandon LaBelle has remarked, in sound poetry, "one does not leave behind signification simply by speaking nonsense, or by turning the mouth into a noise machine": "Rather than dissipate into meaningless, much sound poetry then occupies phonological territories by performing on the level of the phonemic, and further to the oral energy of the glottal, multiplying and pluralizing meaning by disintegrating words into sonic gesturing, into a prolongation and amplification of the ruptured sign."²⁵ Consider a portion of "Klink—Hratzvenga (Deathwail)" a poem from the Baroness Elsa von Freytag-Loringhoven (1874–1927), a poet and artist associated with New York Dada, and written shortly after her husband's suicide after his return from a World War I prisoner of war camp: "Ildrich mitzdonja—astatootch / Ninj—iffe kniek — / Ninj—iffe kniek!"²⁶ Said aloud, the three lines, through the dynamics of how the sounds are produced by one's larynx and throat and the corporal proprioception of pushing the sounds out through one's mouth, foreground the guttural and the phonemic. Signs remain on the margins, always elusively out of understanding. The production and the hearing of the sounds puts one in a dif-

²⁴Karina Eileraas hears the "ugly" voice and lyrics of these girl-bands as a form of resistance: "Girl bands often use the ugly voice as a tool of cathartic expression; a means to articulate the 'self' while acknowledging it as a site of fiction, contest, incoherence, social inspection, and performativity. Girl bands use their voices as weapons." See Karina Eileraas, "Witches, Bitches & Fluids: Girl Bands Performing Ugliness as Resistance," *The Drama Review* 41, no. 3 (1997): 125.

²⁵Brandon LaBelle, "Raw Orality: Sound Poetry and Live Bodies," in Neumark, Gibson, and Leeuwen, *Voice: Vocal Aesthetics in Digital Arts and Media*, 152.

²⁶Irene Gammel and Suzanne Zelazo, "'Harpsichords Metallic Howl—': The Baroness Elsa von Freytag-Loringhoven's Sound Poetry," *Modernism/modernity* 18, no. 2 (2011): 255.

ferent register that is contrary to our regular experiences of hearing vocal sounds²⁷. Irene Gammel and Suzanne Zelazo hear “a spatio-temporal resounding of her [the Baroness’s] own embodiment” and argue for a “gendered and corporeal aesthetic in the Baroness’s sound poetry”²⁸.

The unfortunate reality, however, is that the sounding of vocal excesses from a woman’s body all-too-often lead to accusations of witchcraft, sorcery, or a diagnosis of hysteria. Indeed, the Baroness herself spent time in a psychiatric asylum²⁹. In a poetic history of the sorceress and the hysteric, published alongside another text and a conversation with Cixous, Catherine Clément traces how such “spasmodic speech disorder[s]” (in the words of Freud), combined with other types of seemingly excessive behaviors at the margins of the socially acceptable, have impacted women negatively. Yet this is a conundrum for Clément: “The heart of the story linking the figures of sorceress and hysteric lies in the subversive weight attributed to the return of the repressed, in the evaluation of the power of the archaic, and in the Imaginary’s power or lack of it over the Symbolic and the Real. Still, it must be understood that this question is pertinent only to the extent that these two women [the sorceress and hysteric] serve as reference, models, and allegory”³⁰. In her ode to the power and problematics of opera’s representation of women, Clément additionally traces

²⁷An interesting question here is the role of sounding and hearing *accent* in sound poetry. When the sounds are merely *phonemic*, belonging to no language in particular, how does one hear one’s own “accent”? The “accent” of another?

²⁸Gammel and Zelazo, “‘Harpsichords Metallic Howl—’: The Baroness Elsa von Freytag-Loringhoven’s Sound Poetry,” 259, 258. For more on the Baroness, see Irene Gammel, *Baroness Elsa: Gender, Dada, and Everyday Modernity* (Cambridge, MA: MIT Press, 2002).

²⁹Gammel, *Baroness Elsa: Gender, Dada, and Everyday Modernity*, 352–354.

³⁰Hélène Cixous and Catherine Clément, *The Newly Born Woman*, trans. Betsy Wing (University Of Minnesota Press, 1986), 9. For her complete archaeology and argument, see *ibid.*, 3–59.

the trope of the hysterical woman on-stage.³¹ Like in the later work with Cixous, Clément encourages the recuperation of hysteria: “Hysteria is woman’s principal resource”.³² Similarly, in an elaboration of *l’écriture féminine*, Cixous exclaims:

Voice! That, too, is launching forth and effusion without return. Exclamation, cry, breathlessness, yell, cough, vomit, music. Voice leaves. Voice loses. She leaves. She loses. And that is how she writes, as one throws a voice—forward, into the void.

[...]

Voice-cry. Agony—the spoken “word” exploded, blown to bits by suffering and anger, demolishing discourse: this is how she has always been heard before, ever since the time when masculine society began to push her offstage, expulsing her, plundering her. Ever since Medea, ever since Electra.³³

Cixous has, at times and especially within Anglo-American contexts, been accused of an essentialism in her equation of certain forms of writing with women³⁴. And

³¹Catherine Clément, *Opera, or the Undoing of Women*, trans. Betsy Wing (University of Minnesota Press, 1999), 32–38.

³²Ibid., 176.

³³Cixous and Clément, *The Newly Born Woman*, 94.

³⁴However, we have to note that just a few pages before the quoted passage Cixous writes of the potential creativity of men who recognize a certain *bisexuality*, that of recognizing the presence of the other sex within them: “Bisexuality—that is to say the location within oneself of the presence of both sexes, evident and insistent in different ways according to the individual, the nonexclusion of difference or of a sex, and starting with this ‘permission’ one gives oneself, the multiplication of the effects of desire’s inscription on every part of the body and the other body” (ibid., 85). Similarly, Clément, in her “Finale” where she calls upon the power of hysteria, notes that men too must re-learn language: “They must unlearn how to be men; they must undo their language and their sniggering; and like a baby who crawls around on the ground so his legs someday can hold him up, they must learn tenderness and forbidden caresses. They have to discover weakness in themselves—or at least what their good

the recuperation of the hysterical by women is not an entirely innocent endeavor either, as it could imply an acceptance of the *lack* of language and thus the removal of women from the domain of discourse³⁵. Nevertheless, as we will hear in the works below, the sounds produced by Ratkje and Herndon playfully engage with this history, at times working within the conventional parameters of the female hysteric in a satirical way, at other times rejecting it forcefully in order to disrupt such a narrative³⁶. In their interviews they reference these debates in the history of feminism and their performances map their own trajectories for moving forward.

In connection with some of the sound poets, Ratkje and Herndon add an additional complexity: the computational modification of their voices. This transformation further moves their project away from an essential linkage of the non-discursive with the hysterical gendered body³⁷. Such noisy practices, combined with their own

education has always called weakness" (Clément, *Opera, or the Undoing of Women*, 178). Finally, Kaja Silverman, in acknowledging the cultural-specificity of experience while simultaneously accepting some commonality of experience amongst the categories of "man" and "woman", suggests that women have no reason to reject "feminization": "On the contrary, what is needed here is not so much a 'masculinization' of the female subject as a 'feminization' of the male subject—a much more generalized acknowledgment, in other words, of the necessary terms of cultural identity" (Silverman, *The Acoustic Mirror: The Female Voice in Psychoanalysis and Cinema*, 148).

³⁵In parallel with the challenges brought on by recuperation of hysteria as a political project is the need to trace the histories of male hysteria. Such an endeavor would connect to question surrounding war trauma and artistic production. A beginning can be found in Mark S. Micale, *Hysterical Men: The Hidden History of Male Nervous Illness* (Cambridge, MA and London: Harvard University Press, 2008).

³⁶Ratkje and Herndon are of course not the only contemporary women musicians to rework these histories of hysteria. In her discussion of the underwater operas of the performance artist and composer Juliana Snapper, Nina Eidsheim writes: "Snapper attempts to rearrange these beliefs through what she calls 'hystericism'—alluding not to an illness, like the hysteria historically assigned to women who did not align with prescribed gender roles, but to a technical approach to technique that deliberately harnesses physical responses to terror in a musico-dramatic operation" (Eidsheim, "Sensing Voice: Materiality and the Lived Body in Singing and Listening," 144).

³⁷Further, *pace* Sadie Plant, neither Ratkje nor Herndon evince an essential connection between their work with technology and their identification as women. Additionally, María Fernández has noted how Plant's identification of women with technology tends to efface other forms of labor—that which is not today marked as technological—by women of color. See María Fernández, Faith Wilding,

interferences in the histories of feminism, performs new micropolitical reconfigurations of the voice.

The commodification of language and the voice

My interest in the practices of Ratkje and Herndon comes from my hearing of novel techniques that respond to the commodification of language and the voice. By this I mean the ways in which language especially plays an increasingly key role in processes of commodification line: we only have to look at the advertisements that appear next to our e-mail messages or social networking posts to see this at work³⁸. And while we could understand the commodification of the voice as simply the materialization of these sounds within various recording media, I hear it as something different. While the political economy of recording technologies is important, I consider the commodification of the voice to be the ways in which we define the socially-acceptable boundaries of vocal production. While we may allow the metallic sounds of an auto-tuned voice, a radically-cutup one remains on the fringes, relegated to the extremities of society. A similar case can be made for vocal outbursts in public, as screaming, vocal tics, or glossolalia in a public space are liable to lead to one's arrest—or institutionalization. Yet within a society suffused with algorithmic attempts to calculate exchange value for vocal and textural utterances we urgently need tactics for escaping this commodification—for women as for men³⁹.

and Michelle M. Wright, eds., *Domain Errors! Cyberfeminist Practices* (New York: Autonomedia, 2002), 33.

³⁸For a linguistic anthropological take on this see Monica Heller, "The Commodification of Language," *Annual Review of Anthropology* 39, no. 1 (2010): 101–114.

³⁹In the vocal "assistant" software provided on modern smartphones, the audio is sent to centralized servers provided by the phone manufacturers for processing and offline analysis. While the services

As with the sound poets, there is a long history of attempts by the avant-garde to interfere with language commodification: witness the irreverent vocal performances of the Fluxists; the chance procedures that directed the lectures of John Cage; and the attention to the materiality of language in the L=A=N=G=U=A=G=E poets⁴⁰. The response of the poet Kenneth Goldsmith is to transcribe the effluent of always-on voices: his *Weather* (2005) is a set of a year's worth of weather reports, while *Traffic* (2007) is a compilation of twenty-four hours of traffic updates⁴¹.

While such techniques certainly provide one response to the commodification of language—by disarming the commodity through highlighting its existence as a commodity—I will show below that Ratkje and Herndon perform a different form, one that is a micropolitical gesture in line with the comments of Berardi discussed at the end of the previous chapter. Recall his words: “We have to start a process of deautomating the word, and a process of reactivating sensuousness (singularity of enunciation, the voice) in the sphere of social communication.”⁴² I will add that in light of the theoretical issues just raised, we also have to move beyond the word into the materiality of the voice as it is produced by a singular-yet-differentiated subject, as it flows out of the mouth and becomes a separate object within the world, and as it is transformed by computational systems. In the words of LaBelle, “In following the voice on this course of rupture and rapture, of flayed subjectivity and raw

provide a convenience to some, they also provide data for the refinement of these algorithms.

⁴⁰For the L=A=N=G=U=A=G=E poets, see Bruce Andrews and Charles Bernstein, eds., *The L=A=N=G=U=A=G=E Book* (Carbondale, IL: Southern Illinois University Press, 1984).

⁴¹Goldsmith has recently catalogued some of these techniques of what he calls “uncreative writing”, along with other practitioners of such writing; see Kenneth Goldsmith, *Uncreative Writing* (New York: Columbia University Press, 2011).

⁴²Berardi, *The Uprising: On Poetry and Finance*, 21.

orality, I'm interested in lending an ear to not only the granularity of a broken voice, in all its aesthetic intensity, but to take notice of the specificity of a body seeking a renewed and reinvigorated language".⁴³ This is certainly a political project, but one that works in a *micropolitical* register, one that relies less on the molar aggregation of masses of people, of movements, or of technologies, but rather on the molecular trajectories that can also reconfigure—and interfere—with a social field⁴⁴. This micropolitics accepts its lack of pure originality, revelling in its reconfiguration of long histories of avant-garde attempts to perform new constellations of subjectivity, of disciplinary regimes that regulated acceptable vocal excesses. These works function as *experiments* that overflow with affectual and potentiality, never guaranteed to work, but rather offered as provisional constructions subject to change.

Maja Ratkje's Noisy Practices

Born in 1973, Maja Solveig Kjelstrup Ratkje (Figure 28) has established herself as a composer, sound artist, free improviser, and vocalist⁴⁵. Ratkje's musical training include time both at the Norwegian State Academy of Music, where she learned traditional forms of academic composition, and simultaneous experiences in jazz and improvisation that eventually lead to the formation of one of her long-standing

⁴³LaBelle, "Raw Orality: Sound Poetry and Live Bodies," 162.

⁴⁴Deleuze and Guattari, *A Thousand Plateaus*, 208–231. For a more detailed exposition on micropolitics and the philosophical orientations of Deleuze and Guattari, see Ralf Krause and Marc Rölli, "Micropolitical Associations," in *Deleuze and Politics*, ed. Ian Buchanan and Nicholas Thoburn, trans. Millay Hyatt (Edinburgh: Edinburgh University Press, 2008), 240–254. In his *Sonic Warfare: Sound, Affect, and the Ecology of Fear*, Steve Goodman has investigated the "micropolitics of frequency" in its full equivocality, as both a component of a logic of control as well as a tactic of resistance. See, for example, Goodman, *Sonic Warfare: Sound, Affect, and the Ecology of Fear*, 105–107, 187–188, 189–194.

⁴⁵For Ratkje's website, see <http://ratkje.no/>.



Figure 28: Maja Ratkje; photo by svennevenn, <https://secure.flickr.com/photos/78042051@N00/8564610054>

collaborative projects entitled SPUNK.⁴⁶ Ratkje's projects span individual manipulations of her voice through extended technique and computational technologies; composition for dance, choir, chamber ensembles, and orchestras; extreme noise; and improvisation. Ratkje's works, then, offer a microcosm of the various ways through which noise interferes with its surrounding contexts. By following how these interferences occur we can trace the micropolitical potentials of the voice.

⁴⁶Jean-Claude Gevrey and Maja Ratkje, "The Voice That Came In From the Cold: An Interview with Maja S.K. Ratkje," 2005, accessed July 3, 2013, <http://www.dustedmagazine.com/features/746>.

Voice

Maja Ratkje has become best-known for her vocal manipulations that involve extended technique, electronic manipulation, and extreme noise. Such varied capabilities are showcased on her solo debut album *Voice*⁴⁷ from 2003 and which won an award of distinction at Prix Ars Electronic the same year. Via a series of vocal experiments Ratkje breaks through any one-sided approach to the voice: it does not immediately signify presence, yet it comes through clear; it conjures animal-like vocalizations yet recites poetry; it is rhythmic yet sustains single notes. “Intro” begins atmospherically, drenched in reverb as if in a cathedral. Recordings played backwards at differing speeds add to the otherworldly ambience. Bits of speech are cut up, sped-up, and re-arranged as in standard *musique concrète* techniques; yet out of these fragments come requests: “I want to hear more.” “I want to hear all about....” “Dada” is heard as a result of this manipulation⁴⁸. With “Joy” Ratkje’s voice is heard in a controlled scream, falling into a rolling sequence of phonemic vocalizations. Yet simultaneously Ratkje sings the word “Joy” in a clear, sustained tone in the style of a pop diva. This juxtaposition prevents any unambiguous assigning of meaning to the voice. “Trio” is a trio with herself. The left channel presents heavy processing of fragments of the voice, while the right continues the non-sense sounds of the prior track. Both channels tend towards the rhythmic, but never settle into something regular, always off by a bit, the noise of the sound entering into the noise of

⁴⁷Maja Ratkje, *Voice*, Rune Grammofon RCD2028, 2003.

⁴⁸There is an obvious historical resonance with Kurt Schwitters’ *Ursonate* (1922–1932), as well as other Dada sound poems, throughout Ratkje’s vocal work. For the *ursonate* see Kurt Schwitters, *Poems Performance Pieces Proses Plays Poetics* (Philadelphia: Temple University Press, 1993), 52–80, 233–237.

the tempo. Yet on “Octo” the voice is subsumed to its materiality on tape; it rather recalls the frenetic aural manipulations of cartoons or films, where pre-recorded segments are played at varied of speeds in a variety of combinations.

The pivot is “Vacuum”, the longest track on the album. Starting out with a plaintively sung “You” that recalls the sustained words heard in “Joy”, it is quickly obliterated with electronic pulses. Sustained synthesized notes in the background are never able to hold their pitch, decaying as if their machinery is slowly grinding to a halt. Randomness takes over, muffled, distorted. Suddenly everything stops. Heavy breathing, attempts to catch her breath. Is this an astronaut who has left the airlock without her protective spacesuit? Air is scarce, barely coming out of her throat. A minuscule, strained stream of air begins to come out, high frequency, like when one lets air out of a balloon. It’s caught in the electronic loops, growing in intensity and moving about the stereo field. Rhythmic exhales transitions into a looped Hammond organ phrase.

Ratkje is well-known for her use of microcassette recorders and dictaphones, and the latter is the subject of “Dictaphone Jam”. Immediately it recalls the streams of voice from the previous track, but quickly moves into Ratkje becoming-duck interspersed with the beeps of the recorder. The device is used to create fragments that move at a frenetic pace always coupled with a more prosaic sung phrase that is full of the characteristic tape hiss. The peeps of the dictaphone become more repetitive as if it got stuck in an endless loop.

The title track returns to the fragments played in reverse that were heard at the beginning of the album. Settling in on a single sung note, Ratkje then punctuates the reverb-heavy space with a set of randomly pitched tones. Front and cen-

ter she sings a simple phrase, with isolated words bouncing harmoniously in the left and right channel. Occasionally blips and beeps evocative of 1960s computers are faintly heard. From the haunting serenity of a beneficent computer, Ratkje becomes-chipmunk in “Chipmunk Party”. Referencing the experience of “sounding like a chipmunk” through the speeding-up of an audio tape, Ratkje uses fragments of a single recording of a sung tone to create sounds of a variety of frequencies. Simultaneously she moves into a set of clicks and cuts that are an auditory miming of the imagined sounds of a chipmunk gnawing on a nut. As a prelude to the final two tracks, “Interlude” is a series of rhythmic loops of accentuated breathing. “Acid” never is able to move forward; ever starting and stopping, it is like traveling on square wheels.

None of the previous tracks, however, prepares oneself for the onslaught of “Insomnia”. It begins as a rather standard—within the genre at least—noise piece, grains of Ratkje’s voice combined and multiplied to enormous levels. Ending abruptly we move to an obvious recording of Ratkje’s voice, a sinister chuckle launching into an extreme scream. This scream ends in another laugh before it is immediately distorted and multiplied beyond recognition. Continuing like this for three minutes with minute variations it is only endurance that carries one forward. A brief pause, and then we end with a reprise of the looped Hammond organ slowly fading out.

Ratkje acknowledges the influence of spoken poetics on her work: “I draw on experience from sound poetry, however not being a performer in this specific genre myself, but drawn to the idea that vocal music can be so much more than just singing

melodic lines with poetic words"⁴⁹. Additionally, Ratkje's vocal manipulations call forth obvious historical resonances with performers such as Meredith Monk, Joan LaBarbara, Jaap Blonk (with whom Ratkje has collaborated) and Diamonda Galas. Yet Ratkje is careful to distance herself from Galas, claiming that she is not telling autobiographical stories about herself through her work⁵⁰. For Ratkje it is about creating new spaces for the audience and for their own interpretations. As she says in an interview, "I do not wish to push my own private emotion upon the listener as that is also very limiting for their experience of the music which can certainly include totally different emotional connotations than the one's I think I include, and as I want the music to be as full of ambiguity as possible, opening up for more than one solution of perception..."⁵¹

While Ratkje tends to abstract her own emotional investment in her voice during performance, the audience is unable to do so upon listening. The sounds heard on *Voice* foregrounds the multiplicity of the voice-as-noise. Combined with the effacement of the voice as the simple carrier of an intelligent signal, this produces alternative forms of being with one's own voice. The flow of air that is shaped by our larynx, coupled with electronic manipulations and its amplification by intensely moving speaker membranes, opens up other options of communication that exist

⁴⁹Rui Eduardo Paes and Maja Ratkje, "Looking forward (interview with Maja Ratkje)," accessed July 3, 2013, http://rep.no.sapo.pt/entrevistas_ratkje.htm.

⁵⁰Anne Hilde Neset and Maja Ratkje, "Maja Ratkje: Woman behaving madly," *Wire* 229 (2003): 12. In her listening of Galas' work, Freya Jarman-Ivens hears a "queer monstrous cyborg" at work: "The monstrous, the cyborg, and queer slip freely alongside each other in Galas's work, each of them committed to disrupting borders and rethinking connections and oppositions—the monster between human and nonhuman; the cyborg between human and machine; queer between sexual desire, chromosomal sex, and gender identity." See Jarman-Ivens, *Queer Voices: Technologies, Vocalities, and the Musical Flaw*, 140.

⁵¹Paes and Ratkje, "Looking forward (interview with Maja Ratkje)."

at the limit of being. This is not an entirely serious endeavor, as the cackling of Ratkje attests. But it cannot be reduced to a joke, either; it is a poetic-serious statement that is its own form of micropolitics. Beyond the pitch of a sung note, or the meaning of individual poetic words, the recombined fragments suggest an excess of affect that always overflows the boundaries of the signified. Such an excess exists indeed in the non-manipulated voice, but is amplified with computational machines, upsetting their informational theoretic programming. Neither entirely human nor electronic, the noises performed on *Voice* portend an alternative form of subjectivity that exists at the intersection of humans and machines. Sound does not reside solely between the two ears, but rather extends outward via new configurations of the sonic field.

Adventura Automatica

*Adventura Anatomica*⁵² is a recording of Ratkje's live improvisations as incidental music for a dance performance. Little about the performance is mentioned, but the images that appear in the liner notes show a set made of strips of paper suspended in the air, and tight-fitting costumes of irregular blocks of black and white, not altogether dissimilar to those created by Oskar Schlemmer for his dance performances at the Bauhaus⁵³. The titles suggest fairy tales, ones that retains malevolent characteristics, as in an overabundance of craggy trees, or the hidden spirit that is always listening in the *wald*.

⁵²Maja Ratkje, *Adventura Anatomica*, Semishigure SEMI 009, 2006.

⁵³For more on how Bauhaus constructions, such as garments for dance, masks, dolls, and puppets functioned to connect child's play with serious adult activity, see Juliet Koss, "Bauhaus Theater of Human Dolls," *The Art Bulletin* 85, no. 4 (2003): 724–745.

The opening track, “Bark Up a Tree and Get Leaves in Your Mouth”, begins impossibly sparse, collections of static bits popping into and out of existence at irregular intervals. As the silences between these collections decreases, Ratkje’s characteristic vocal machinations are heard, punctuated by sudden silences where the sounds are left nailed to the acoustics of the space. The space becomes ever more filled. In contrast, “Ground Creatures” involves muffled shuffling, distant, barely perceptible.

“The Red Hooded Lady of the Woods” starts with the phrase “Once upon a time upon a lake upon a line...”, the precise words being lost in the doubling and tripling of fragments. There is an abrupt stop, a silence, and then it restarts across the stereo field layered upon itself, the phrase occasionally becoming perceptible. The overlapping fragments begin to sound like whispers, or perhaps birds in the trees next to the lake. Words start to become held, transforming from units of intelligibility into pitched notes. Simultaneously there are loops of manipulated fragments of “nonsense” words, coupled with sustained notes that move throughout the stereo field. While the progression of these events implies that every sound is related to the initial phrase, it is also obvious that it has been mutated beyond cognitive recognition. The track ends with ascending squeaks from electronic birds, and the final sentence, “Too many trees, between the trees...”

The titular next track, “Too many trees”, opens with a sparse set of words and sounds: “You”, an airy grunt, “Fi”, and “Yeah”. These events begin to happen more often, but fail to do so within a regular rhythm. The combination of these sounds suggests something both flighty and earthy, filled with air and dirt. Wails begin to be overlaid, electronic zaps zipping throughout the sonic space. A dissonant beeping

sets out a stabilising rhythm, and the phrase from the previous track returns, ended by an abrupt click. “Once Upon a Time” continues with reedy sustained tones overlaid in conventional harmony, but also vibrating in and out of consonance. The phrase “Too many trees” is heard again, coupled with wind whipping at a piece of metal.

Ratkje foregrounds the voice in “Floating, Hiding, Posing”, heard tongued and flittering. It descends in a conventional G Major scale from G to an F sharp to an E, each note layered on top of each other and heard simultaneously. Following this are reversed fragments of sound, distorted and warped into a growing electronic nothingness. Guttural clucks and fragments of hoarse air multiply and recombine. Throughout are faint remnants of the beginning notes of the track. Suddenly silence, and sparse resonances of what has come previously. “The Wolf” follows directly: again the guttural, yet duck-like, low in pitch. This is combined with bits of non-vocal sounds of a different quality, grainy and variegated. This becomes combined without number into an intense soundscape that covers the entire stereo field, noisier and noisier—menacing—until there is no space (or time) left open. Yet bits of high-pitched sounds are able to make it through the mass of lower-frequency noise. It is as if the sound is scraping and multiplying, crawling on wooden walls. It is suffocating, there is no way to escape. But it ends suddenly, the bits being sucked into a void. Silence returns. The final track, “Woods have ears”, releases the sounds of tinny bells; they are all slightly off in pitch, creating a sense of dissonance. A harmonica enters, taking part in the makeup of traditionally-sounding chords. Doubling of these instruments sounds a calming end.

For this performance Ratkje used a piece of software called *ImproSculpt* written

by Øyvind Brandtsegg, a member of the software engineering group at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. A recent research report about the software describes it thusly: “ImproSculpt is software for live sampling and manipulation, algorithmic composition and improvised audio manipulation in real time. ImproSculpt might be considered also a live performance instrument”.⁵⁴ The software itself is built on existing computer music systems such as *csound*, one of the oldest sound synthesis platforms,⁵⁵ and is itself available as open source software for download.⁵⁶ Much as in *Voice*, Ratkje uses digital technology to mutate and multiply the voice beyond intelligible recognition. By involving a software system for live improvisation, Ratkje is able to augment the sounds based on minute changes in the configurations of people and objects on the stage. Finally, connecting the singularity of the performance to the wider networks of artistic free software hackers extends the reach of the work into new territories.

SPUNK and Fe-Mail

While both of the previous albums I discussed involved collaborations of some sort (the Norwegian duo Jazzkammer as producers on *Voice* and the dancers, choreographers, and software developers on *Adventura Anatomica*) I want to turn in this final section to two projects that involve Ratkje’s work with other live performers,

⁵⁴Anna Trifonova, Øyvind Brandtsegg, and Letizia Jaccheri, *Software Engineering in an Artistic Project: ImproSculpt Case Study*, technical report (Norwegian University of Science and Technology, 2007).

⁵⁵Richard Boulanger, ed., *The Csound Book: Perspectives in Software Synthesis, Sound Design, Signal Processing, and Programming* (Cambridge, MA: MIT Press, 2000).

⁵⁶Øyvind Brandtsegg, “Wiki ImproSculpt,” accessed July 3, 2013, <http://improsculpt.sourceforge.net/pmwiki/pmwiki.php>.

SPUNK and Fe-Mail. Both cases involve exclusively women and we will see that this is Ratkje's own brand of feminism within the noise sphere.

As mentioned previously, SPUNK began while Ratkje was a student at the Norwegian State Academy of Music in the mid-1990s. Involving Kristin Andersen, Hild Sofie Tafjord and Lene Grenager, the name of the group comes from Astrid Lindgren's series of Pippi Longstocking novels. SPUNK is a word that is "discovered" by Pippi and she attempts to find out what it means; thus, in the context of the musical collaboration, it means, in the words of Ratkje, "Nothing, -or anything! It's free music".⁵⁷ The reference to Pippi connotes an anarchistic spirit, a childlike curiosity with the world, an "undogmatic role model for young girls".⁵⁸

SPUNK have released four full-length albums to-date. Their album from 2007, entitled *en aldeles forferdelig sykdom*, translates roughly as "An Absolutely Terrible Disease".⁵⁹ Involving Andersen on trumpet, violin, and flute, Tafjord on french horn, flute, and electronics, Grenager on cello, and Ratkje on voice, theremin, and electronics, the album opens with "Marbles", an evocation of a childlike wonderland with warbling and whistling theremin, interrupted by squeaks from the brass instruments. Throughout the album, haunting ethereal women's voices singing in harmony alternative with more aggressive electronic blips and bursts of sharp static, as on "Mårenhår". "Dead Man Walking" features a plaintive off-kilter march with a wailing muted trumpet. "Hvis En Kantklipper Fikk Lov Til Å Synge" squeezes sounds out of the brass instruments and places them in an alternating set

⁵⁷Neset and Ratkje, "Maja Ratkje: Woman behaving madly."

⁵⁸Ibid.

⁵⁹Boomkat, "En Aldeles Forferdelig Sykdom," 2010, accessed July 3, 2013, <http://boomkat.com/cds/20060-spunk-en-aldeles-forferdelig-sykdom>.

of crescendo and release of voices—people, machines, and instruments. This give and take collapses upon itself, however, in an all-out noise-fest of growls, shouts, sawing at the cello and screams from the trumpet, all unintelligible.

With Hild Sofie Tafjord, Ratkje formed the noise duo Fe-Mail. Involving more electronic manipulations than in SPUNK, Fe-Mail offers their own take on the genre within an already crowded set of other noise musicians. Rarely do Fe-Mail bombard the listener's ears with the onslaught of direct, punishing sound that might be found in someone like Merzbow. In Fe-Mail we hear the noisy sonic field in all its complexity and nuance. In talking about Fe-Mail in particular, Ratkje says, "Noise is a positive energy even if it has dark forces. It's directness goes straight to my heart. Playing or listening to noise is like covering all dull colours with white paint, a powerful white wall fencing off all personal frustrations and hang-ups".⁶⁰ This is heard especially on their 2006 2CD album *Blixter Toad*.⁶¹ On the opening track, "Belonging", conventionally sung phrases are molded to extreme static, interspersed with field recordings of safety demonstrations on airplanes. "Navrattan Korma" begins with a looped non-sense vocal phrase over a repetitive minimal techno beat. This quickly becomes increasingly broken into component frequencies, yet the arhythmic rhythm never entirely fades away. "In Den Schonen Gruen Wald" recalls early 1980s New Wave electronics before turning into an auditory cacophony of twisted voices, electronic bits without order, and extremely dense clouds of sonic particles.

Perhaps their most provocative track, in terms of recalling the wall of noise that is the characteristic of the genre, is "They Look As Innocent As Newborn Lambs.

⁶⁰Neset and Ratkje, "Maja Ratkje: Woman behaving madly."

⁶¹Fe-Mail, *Blixter Toad*, Asphodel ASP 2033, 2006.

The Sick Fucks.” on the 3CD compilation entitled *Women Take Back the Noise* (WTBTN).⁶² Feedback upon feedback, relentless static, wails of electronic and human variety, the track forces you to pay attention to it. On the WTBTN compilation are forty-seven other women musicians who, like Fe-Mail, work with sonic noise in various ways; the CDs are presented in a custom package with a specially-built circuit-bent flower, assembled by some artists on the compilation themselves. This aspect of Fe-Mail’s practice is important for Ratkje:

I am a feminist of course, and damned serious about that, even though it is not an outspoken topic of my work. My work is much too ambivalent and self-contradicting or abstract. I certainly can speak about feminism, but I don’t want my work to be about it alone. I believe it is liberating and important to question stereotypical representations through provocation and contradiction.⁶³

In this context, then, feminism is about moving beyond simple binaries: “I’m sick and tired of the only two true possibilities of female behaviour; the whore/madonna dualism is limiting the possibilities of expression for women who are ‘different’”.⁶⁴ Ratkje’s oeuvre is an attempt to foreground a certain “surrealistic” approach that involves a “child’s curious view”, irrespective of its historical negative connection to women⁶⁵. This aspect opens onto another type of politics, one that is not confined

⁶²Various Artists, *Women Take Back the Noise*, WTBTN, 2006.

⁶³Gevrey and Ratkje, “The Voice That Came In From the Cold: An Interview with Maja S.K. Ratkje.”

⁶⁴Ibid.

⁶⁵ibid. In this same interview, Ratkje mentions that she has improvised to *Häxan*, a 1922 silent film about early witch hunts that is strikingly balanced, in comparison to other films about the topic.

to rationality or discursivity: “So it’s political, but very abstract-political. To encourage people to think for themselves, to think that there are other possibilities—that’s at the heart of my philosophy of what music can be in society. To encourage thinking about how you can change it”⁶⁶. This capacity for change extends to the political economy of the music “business” and “scene”. Like the do-it-yourself attitude found in WTBTN, Ratkje connects this to her own projects, saying, “I believe in non-commercial and experimental music being a political statement in itself: one chooses to omit the prevailing, the conformist and the commercial aspects of artistic expression, giving people another alternative, something new to explore, to hopefully function as an eye-opener for other possibilities, in the end to make a difference!”⁶⁷ Noise, disruption, and surreality are put forth as viable alternatives to present configurations of the social order, attempts to create other islands of “order” within the sonic field.

Nevertheless, these possibilities are too often arrested by conventional and regressive understandings of women and noise, women and improvisation. Ratkje has noted on a number of occasions the ways in which women are excluded from festivals in these genres.⁶⁸ Even so, she finds that many other noise musicians (if, perhaps, not festival producers themselves) are welcoming to her and her colleagues in Fe-Mail and SPUNK: “There’s more prejudice towards the things I do in other musical fields. At least in the noise world you can be whoever you are, you get respect

⁶⁶Ratkje, quoted in Keith Moliné, “Hear me roar,” *Wire* 278 (2007): 27.

⁶⁷Gevrey and Ratkje, “The Voice That Came In From the Cold: An Interview with Maja S.K. Ratkje.”

⁶⁸Neset and Ratkje, “Maja Ratkje: Woman behaving madly”; Gevrey and Ratkje, “The Voice That Came In From the Cold: An Interview with Maja S.K. Ratkje.”



Figure 29: Holly Herndon; photo by fabonthemoon, <https://secure.flickr.com/photos/fabonthemoon/8418791667/>

and you feel encouraged to do it and develop”⁶⁹. This foregrounds the continual need to prevent blockages within the flow of the sonic field, to counteract tendencies that would solidify it into concrete forms that would not be open to alternative configurations.

Holly Herndon and the Manipulation of Genres

Holly Herndon (Figure 29) was born in the early 1980s in rural eastern Tennessee⁷⁰. Herndon was a musician at an early age on instruments such as guitar,

⁶⁹Ratkje, quoted in Moliné, “Hear me roar,” 27.

⁷⁰For her website, see <http://hollyherndon.com>.

piano, and her voice through extensive participation in choirs. An exchange trip to Germany eventually led to her moving to Berlin and becoming a self-professed “club kid” and spending five years immersed in Berlin’s well-known electronic music scene, an experience with influences that we will hear in her tracks.⁷¹ Herndon returned to the states to complete a MFA in Electronic Music and Recording Media at Mills College in Oakland, CA. Her thesis, entitled “Embodiment in Electronic Music Performance,” situated her work within post-human and cyborgian thought and involved the composition of a piece called *195* for six female vocalists and computer.⁷² Now a PhD student in composition at Stanford, Herndon additionally is affiliated with Center for Computer Research in Music and Acoustics (CCRMA), their well-known center for research at the intersection of sound and technology⁷³.

Herndon came to modern composition through improvisation, specifically the vocal improvisations of Lauren Newton⁷⁴. These improvisations center on software constructed on the laptop, an instrument Herndon vehemently defends. While there has been a lot of debate in the past decade within electronic music circles on the role of the so-called “laptop performer”, Herndon notes the affectual importance of laptops in our everyday lives⁷⁵. For example, laptops contain records of intimate conversations, audio-visual documentation of important events, and can

⁷¹David Wagner, “Holly Herndon straddles 2 worlds,” December 2, 2012, accessed July 3, 2013, <http://www.sfgate.com/music/article/Holly-Herndon-straddles-2-worlds-4085441.php>.

⁷²Holly Herndon, “Embodiment in Electronic Music Performance” (master’s thesis, Mills College, 2010).

⁷³For more on CCRMA, see <https://ccrma.stanford.edu/>.

⁷⁴TheFaderTeam, “Interview with Holly Herndon,” December 4, 2012, accessed July 3, 2013, <https://www.youtube.com/watch?v=6XwUXZKu26k>. For more on Newton’s work see <http://www.laurennewton.com/>.

⁷⁵For an early account of these debates see Kim Cascone, ed., *Contemporary Music Review* 22, no. 4 (2003).

be simultaneously the conveyor of wonderful and horrendous news. In her own words, Herndon says that laptops contain an “incredible amount of personal and emotional data, and I think that’s something that could be explored a lot further” within composition.⁷⁶ Thus for Herndon laptops are not generic screens or surfaces but rather intensive objects that play a deeply personal role in our embodied experience. And it is this connection to embodiment that Herndon makes clear in the references to the post-human theories of Katherine Hayles and Haraway’s cyborg⁷⁷. In Herndon’s understanding, gestures on a laptop are just as an embodied action as gestures on a musical instrument; to not accept this would be to construe performance with a laptop as disembodied. Coupled with the manipulative potential of digital technologies, the combination of laptop and performer(s) enables one to question core assumptions of musical performance, thereby suggesting “alternate configurations” of experience.⁷⁸

The *Movement* of Granular Voices

Herndon’s debut album, entitled *Movement* (2012), was recently released to much critical acclaim.⁷⁹ Each track of the album involves not only some manipulation of the voice, but also new takes on standard genres of electronic and experimental mu-

⁷⁶pitchforktv, “Holly Herndon defends Laptop Musicians - Pitchfork Weekly,” December 5, 2012, accessed July 3, 2013, <https://www.youtube.com/watch?v=SVK57x3UzrQ>.

⁷⁷Hayles, *How We Became Posthuman : Virtual Bodies in Cybernetics, Literature, and Informatics*; Donna J. Haraway, “A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century,” in *Simians, Cyborgs, and Women: The Reinvention of Nature* (Routledge, 1991), 149–181. For Herndon’s take on these authors see Herndon, “Embodiment in Electronic Music Performance,” 2–17.

⁷⁸Ibid., 17.

⁷⁹Holly Herndon, *Movement*, RVNG Intl. RVNGNL15, 2012.

sic. “Terminal”, the opening, is also the longest track on the album. Beginning with bursts of filtered white noise that move across the stereo field, the movement speeds up dramatically until no space can be heard between the bursts. Rhythmic pulses enter, accompanied by ominous bass notes followed by frightening high-pitched sounds. Two-thirds of the way in we hear the voice for the first time, obviously manipulated and filtered in a way that suggests aliasing. At a certain point the bottom drops out and the voice, accompanied by the white noise and the squeaks of digital manipulation, are heard over a building train of bass.

“Fade” is the most club-like track on the album. From the beginning it builds within the genred parameters of a typical minimal track. “Reach” and “without” are heard with rapid amplitude modulation creating an uncanny vibrato. Fragments of phonemes move across the stereo field. “Reach out your hand” sounds above the relentless beat, one that is nevertheless kinder than those heard in more punishing forms of dance music such as gabber. Within electronic dance music, the voice is more often heard in genres such as vocal trance or Eurodance and not minimal. In this sense, then, Herndon is already upsetting the formulas of genred dance music by incorporating the voice within a genre not accustomed to it⁸⁰. Additionally, even in genres such as vocal trance or Eurodance, the female voice “floats” above the underlying synths, drums, and samples; such a voice is heard as pleasant, angelic, and often without extensive modification. Thus Herndon’s processing of her voice marks it as a material equal in status to the drums and the synths, rather than simple adornment. Indeed, Herndon comments on this directly, noting that within

⁸⁰For more on these dance music genres, see Simon Reynolds, *Energy Flash: A Journey Through Rave Music and Dance Culture* (Berkeley, CA: Soft Skull Press, 2012 [1998]).

the confines of a genred song, there is an amazing variability in what can be embedded within it that might sound strange on its own; in sum, the song becomes a conveyance for the experimental.⁸¹

With “Breathe” we move from the most conventional track to the most experimental. A sudden, deep inhale begins the track, the aspiration augmented by granular synthesis⁸². There’s silence for nearly thirty seconds: no sounds whatsoever, only the aural void of the inhale. A sudden exhale, and then another inhale: less time now between the inhale and its exhale. Inhales and exhales begin to alternate between the left and right channels: an inhale in the left is paired with an exhale in the right, and vice versa. Inhales become more frightened, more sudden, more processed. The breath becomes less directly produced by a human larynx and more by a digital synthesizer. Throat sounds, gurgling, strained releases of breath excite the activity of the granular synthesis. A weary pair of exhales and inhales ends the track.

“Control and” and “Movement” are a pair of interrelated tracks. Synthesized phonemic sounds—no actual phoneme can be identified—rhythmically begin “Control and” low in pitch. Higher diva-like voices come in, punctuated by a driving bass line as if it is pushing the track somewhere. That somewhere is “Movement”, which begins as if in a standard four-on-the-floor rhythm, but a mid-range arpeg-

⁸¹pitchforktv, “Holly Herndon defends Laptop Musicians - Pitchfork Weekly.”

⁸²In granular synthesis, short fragments of a sound sample, with lengths on the order of tens or hundreds of milliseconds, are combined together. By choosing the ways in which these grains are filtered, how long they are, how many grains are combined together, and where they are sampled from the sound source, one can create a great variety of effects. Granular synthesis was developed from the research on hearing and communication of Dennis Gabor discussed in Chapter 1, although Iannis Xenakis also claimed that he was the first inventor. For much more on the technological and compositional aspects of the technique see Roads, *Microsound*.

giated figure, and the occasional drop-out of down beats, defeats that expectation. Heavily processed vocal sounds enter in line with the underlying beat. The tempo is slightly slower than in “Fade”; coupled with the slightly off-kilter rhythm, this makes the track a difficult one to dance to. The low phonemic sounds of “Control and” sound occasionally, ultimately ending the track.

On “Interlude” the voice and its grains are processed through a resonant filter, producing a metallic-sounding quality. Random bits of filtered noise, resonant shouts, and sharp high shots of synthesizers sound one after another. This moves directly into “Dilato”, a word that means to spread out, extend, or dilate. While Herndon’s voice has been exclusively heard elsewhere on the album, on this track she processes the voice of Bruce Rameker, a baritone and countertenor who has performed with classical groups as well as the Meredith Monk & Vocal Ensemble. Rameker sings low vocal notes in processed duets or trios with himself. Individual phonemes become temporally extended beyond the length possible in normal singing. Rameker purposely loses pitch control at points, a precise pitch descending into a mass of vocal noise. Herndon’s processing also pitch shifts his voice up into a range usually unreachable by a man. Throughout, the transformations of Rameker’s singing reconstruct his voice into something that sounds right at the boundary of “natural” and “artificial”.

Herndon’s production processes mirrors her ecumenical approach to genres. Using commercial mass-market software such as Ableton Live, alongside specialist tools such as Max/MSP and free and open-source software such as Chuck, Herndon eschews the presets in order to consider the sound as a material in order to

“whittle away at it”⁸³. This attention to the software used to produce the work is not merely a “gear fetish”; rather it illustrates Herndon’s attention to new forms of embodiment enabled by the intersection of humans and computers. In another interview Herndon remarks: “[The laptop] can do things that no other instrument has ever been able to do, and I also think that it’s the most personal instrument that the world has ever seen.”⁸⁴

While those who critique “laptop music” concerts might question Herndon’s reasoning, she finds that the intersection of the voice and laptop performance provides a way of highlighting this connection: “...I started thinking about how to really kind of hammer home the embodied experience of laptop performance, and probably the most obvious way to show that was through the human voice.”⁸⁵ Given Herndon’s citation of Hayles and Haraway as important to her work, we can understand a new take on the cyborg and the post-human: no longer the sci-fi fantasy of technology physically merged with the body, but rather the augmentation via sonic technologies of the mundane, daily experience of humans and their computer: “By having an instrument that almost everyone can relate to, that helps bring the human into it. Even though my voice sometimes comes out so mangled it doesn’t

⁸³Sean Higgins, “BOMBlog: Holly Herndon by Sean Higgins,” January 23, 2013, accessed July 3, 2013, <http://bombsite.com/articles/7023>. For more information on the software mentioned, see <https://www.ableton.com/>, <http://cycling74.com/products/max/>, and <http://chuck.cs.princeton.edu/>. A free and open-source alternative to Max/MSP that is popular amongst many sound artists is called Pure Data; see <http://puredata.info/>.

⁸⁴Mark Baynham, “Speaking in code: Holly Herndon explains why the laptop is the most personal instrument the world has ever known—FACT Magazine: Music News, New Music,” November 15, 2012, accessed July 3, 2013, <http://www.factmag.com/2012/11/15/speaking-in-code-holly-herndon-explains-why-the-laptop-is-the-most-personal-instrument-the-world-has-ever-known/>.

⁸⁵Ibid.

even sound human, I think the audience still realises that I'm doing that"⁸⁶. Herndon is an avowed techno-optimist, but one who is firmly rooted within the material experience of an embodied performer, eschewing pronouncements regarding the obsolescence of the body.⁸⁷

It is this attention to embodiment that also drives her understanding of the politics of being a female producer and composer: "I think my approach to gender politics is an embodied one—imagine that! [...] I usually let people know that I agree with Donna Haraway in that I don't buy into a sisterhood or an idea of 'female' music. We are all individuals and groups—I have just as much in common with someone from my same socio-economic background as someone of the same gender"⁸⁸. This is complicated by the role of the female *voice* in many of the electronic genres Herndon deconstructs: "Most vocal processing of the female voice happens through male producers—there's a lot of pitchshifting and reverb and angelic choral effects. That's fine, but it's really liberating to process my own voice,

⁸⁶Herndon quoted in Jennifer Lucy Allan, "Future Human," *Wire* (November 2012): 10.

⁸⁷Higgins, "BOMBlog: Holly Herndon by Sean Higgins"; Herndon, "Embodiment in Electronic Music Performance," 11.

⁸⁸Higgins, "BOMBlog: Holly Herndon by Sean Higgins." In connection with Haraway, then, Herndon's projects are attempts to harness the potential of the machine to move beyond simple identity politics. Herndon's weariness with the notion of a "female" music is of a piece with many other third-wave feminists; see, for example, Maria-Elena Buszek, "'Oh! Dogma (Up Yours!): Surfing the Third Wave," *thirdspace: a journal of feminist theory & culture* 1, no. 1 (July 2001). In the case of Cixous, and *pace* the critiques of her essentialism, she notes that there will not be a singular feminist discourse:

There will not be *one* feminine discourse, there will be thousands of different kinds of feminine words, and then there will be the code for a general communication, philosophical discourse, rhetoric like now but with a great number of subversive discourses in addition that are somewhere else entirely. That is what is going to happen. Until now women were not speaking out loud, were not writing, not creating their tongues—plural, but they will create them, which doesn't mean that the others (either men or tongues) are going to die off (Cixous and Clément, *The Newly Born Woman*, 137).

to make it ugly if I want to make it ugly”⁸⁹. This “making ugly” is accomplished through many of the same technologies used to make it “angelic”: “To me it is more interesting to find new forms, and this is happening more and more. This of course does not mean that we have to discard all of the old forms at the same time. I see it as a continuum.”⁹⁰ Thus this is a compositional practice—a politics—that does not admit of a newly-created *tabla rasa*; rather, problematic components are mixed, re-mixed, re-worked, and re-constituted.

Whither Vocal Micropolitics?

In light of the theoretical discussion that began this chapter, we can hear Ratkje and Herndon further complicating the dynamic *différance* of the voice, creating ever more links in the chain via computational modification. These transformations constructively interfere with the so-called un-mediated voice, providing new combinations that performatively question assumed gender roles within electronic music. Working on the level of the phonemic, the sounds do not *argue* for a different configurations of language, but rather *enact* such constellations through the embodied interplay of humans and technology.

The works of Ratkje and Herndon exist within a relatively circumscribed domain of contemporary experimental music practices. While both are well-known within their various fields (with press attention on specialized blogs and spreads within enthusiast magazines such as *Wire*), it has to be stated that their music is

⁸⁹Herndon quoted in Allan, “Future Human,” 10.

⁹⁰Higgins, “BOMBlog: Holly Herndon by Sean Higgins.”

not of the mainstream. As such, one can wonder about the micropolitical efficacy given their relatively limited reach. Yet I want to argue that the practices of Ratkje and Herndon cannot be evaluated on the basis of “number of listeners” or other standard forms of either artistic or political success. Measuring things in such a way adheres to the logic of traditional revolutionary *movements* based on the orientation and organization of masses of people. The practices of Ratkje and Herndon function on a smaller, more humble register of the affectual, producing experimental situations that may or may not be effective. However, the point is in the attempt: when working within the domain of a micropolitics of the voice there are bound to be false starts, aural configurations that adhere too closely to commodified logics, or pure ugliness without merit. Producing new constellations and configurations of the voice is bound to be a challenge and requires training in new forms of listening and being through the (re-)activation of what has come before. Such activities are by their very nature tactical rather than strategic; these are noisy affectual irruptions whose limitedness in time and space prevents recuperation—for now.

Conclusion

In this dissertation I have explored the different ways in which noise causes interferences within various disciplinary fields. I have done this through a conjoint sonic and informatic investigation; that is, I have not considered noise solely from the perspective of sound nor of information, but rather the complicated interrelationships that have formed between the two. This first contribution was done to provide a gentle corrective to recent trends in scholarship on noise that primarily consider it as a sonic phenomenon with the informatic remaining at the margins⁹¹. The examples in this dissertation have shown that the two are fundamentally intertwined throughout their twentieth- and twenty-first century histories. A second contribution has been to consider noise as a form of *interference* in the constitution of various disciplinary *fields*. By focusing on interference rather than positive or negative valences we can move away from value judgments regarding the impact of noise, and consider instead the dynamics of how noise causes changes within various disciplines or fields of study.

In the first part of the dissertation I examine the connections between the sonic and informatic aspects of noise. The intersections become clear when we consider

⁹¹The exceptions to this have come recently in Goddard, Halligan, and Hegarty, *Reverberations: The Philosophy, Aesthetics and Politics of Noise* and Hainge, *Noise Matters: Towards an Ontology of Noise*.

the telephonic context of Claude Shannon's version of information theory. Twenty years prior to Shannon, Harvey Fletcher considered the potential need to transmit forms of "room noises" over telephone lines in order to improve intelligibility. Yet Shannon was not the only one developing theories of information mid-century; competing versions by people such as Norbert Wiener, Dennis Gabor, Donald MacKay and D. K. C. MacDonald considered noise and information to be inter-related in different ways, with MacDonald's version suggesting that noise could be the generator of new scientific knowledge.

While recent scholarly attention has been paid to the uptake of cybernetics in diverse disciplines in the 1950s and 1960s, there has been a corresponding lack of attention to the percolation of information theory during the same period. I make the distinction between information theory and cybernetics because one does not necessarily require the other; cybernetics does need a theory of information, but information theory does not imply nor require a theory of cybernetics. Because of some of the over-hyped claims being made for cybernetics at the time, those working on information theory often tried to distance themselves from cybernetics.

My evidence for this distinction came from a rather interesting case, that of the uptake of information theory in electronic and experimental musics of the 1950s. Numerous different types of actors—composers, musicologists, performers, engineers, and information theorists—applied different forms of information theory to the analysis and/or production of new forms of music. For example, Lejaren Hiller and Leonard Isaacson used information theory to produce novel compositions; Leonard Meyer took concepts from information theory as evidence for his theories of musical anticipation; and Abraham Moles drew from information the-

ory for his expansive theories of aesthetic perception. In all of these cases the feedback connections of cybernetics were not present. Thus, even though the discourse of transmitters and receivers of information theory seems to reduce humans to mere functional agents, the lack of a corrective, normalizing negative feedback actually enables novel forms of music to be produced through an expansion of possibilities beyond Western tonalities.

Moving to the present day I transitioned to a domain seemingly far removed from sound and music, that of finance. However, there is an interesting nexus between sound, information, and finance. I drew from studies that investigated how the shouts from open-outcry pits could suggest future movements in the market. Prior to these studies, there had been a long series of debates within financial economics regarding the importance of noise—as an informatic phenomenon—to the behavior of markets, with someone as well-known as Fischer Black (one of the developers of the pricing model for derivatives) hypothesizing the necessity of noise (and “noise traders”) to the smooth functioning of markets. These two aspects of noise were brought together with a focus on HFT, a new form of trading in the market where algorithms rule and speed is of the essence. In HFT, algorithms prey on the “microstructure noise” of the market to capture minuscule profits many times over. The French artists collective *rybn* produced a sonification from a particularly important event during the rise of HFT, the Flash Crash of 2010, to highlight the informatic dangers of trading at the timescale of microseconds.

The second part of the dissertation undertook a close listening of two forms of interferences of noise and the voice. In both cases, nevertheless, the informatic was never far from my attention, as computational devices provided some of the en-

abling conditions for the vocal manipulations we heard. As such, these two cases showed how the embedding of information theory within contemporary electronic software and hardware does not necessarily determine what can be produced. Additionally, the examples highlighted more politically-charged situations than those considered in the first part; however, progressive political outcomes were never a foregone conclusion, illustrating the need to be attuned to the equivocalities of noise.

The first chapter in this part considered the intersection of *parrhesia* (or “fearless” speech) and computational performing objects, or devices that help to guide or manipulate the voice. Michel Foucault’s excavation of Greek and Roman *parrhesia* foregrounded the guidelines and situations where sanctioned interferences in political systems could take place. I considered three contemporary forms of *parrhesia* that each engaged with different manipulations of the voice. The first, involving the projects of Krzysztof Wodiczko, highlighted “prostheses” that enabled those who have little ability to speak in public—the immigrant, the foreigner—to do so through the actions of the prosthetic intermediary. The second considered projects by the collective IAA and their distancing of the *parrhesiastes* from the physical location of the speech event. The third listened to the devices of Kelly Dobson and her activation of non-speech vocal sounds as a form of interference within public spaces.

The second chapter in this part, and the final one of the dissertation, returned to the field of music proper to listen to works by Maja Ratkje and Holly Herndon. Both use custom electronic and software interfaces to manipulate their voices beyond the domain of the purely signifying. As such, this necessitated the examina-

tion of recent theoretical work surrounding the voice, as well as an attention to the long histories of vocal repression of the female voice through the tropes of the hysteric. I hear in Ratkje and Herndon's work a micropolitics, an attempt to produce new forms of being through a more humble affectual politics that is aware of its own provisional status.

Over these five chapters the dissertation has contributed to the discourses of critical theory, science and technology studies, and media studies. Through a close reading of the technical literature of information theory, I brought to critical theory an understanding of varying approaches to noise. Some of these approaches resonate with later works of critical theory, such as those by Michel Serres, Félix Guattari, or Nick Land. This usage of technical journals as archives in their own right additionally highlights the need to reacquaint ourselves with this material. While some in science and technology studies have focused recently on the histories of cybernetics, histories of information theory remain to be written. I showed information theory should be understood as conceptually separate, yet related, to cybernetics. Additionally, by paying attention to the uptake of information theory in electronic and experimental music of the 1950s, we saw how an attention to artistic practices expanded our understanding of a scientific and technological construct. Finally, while media studies scholars have recently explored concepts of noise in some depth, few have engaged with noise as a joint sonic and informatic phenomenon. I showed how an attention to both sides of noise enables us to follow its complicated dynamics. By bringing media studies approaches into conversation with different, yet related, approaches in critical theory and science and technology studies, we can see areas of productive tension.

The breadth of the examples in the dissertation illustrates the need for a transdisciplinary account of noise. I draw here again from the work of Félix Guattari when I refer to transdisciplinary: that is, something that is more than multi- (more than one) or inter- (between) disciplines. Rather, transdisciplinarity reaches across different disciplinary fields to create new connections between assumed separate domains.⁹² Gary Genosko, in his elaboration of Guattari's term, coins the phrase "transdisciplinary metamethodology" to denote research that engages in the construction and elaboration of these assemblages and linkages across different disciplines; this research must remain open to these new connections. As Genosko writes,

This openness means that researchers will have to familiarize themselves with concepts from other disciplines and learn how to work with them. In this way certain common fundamental traits of such complex objects may come to be known relative to cultural elements (and their subcultural utilizations); social elements (gender and race interests from micro- and macro-perspectives crossed by diverse universes of value; economic factors in local, regional, national and global contexts; technico-scientific developments; and ecological implications. The principal characteristics of complex objects, relative to the areas just listed, are crossed by processes that reveal: dynamic instabilities; contingencies and vulnerabilities; entropic irreversibility; and creative possibilities of negative entropy. The metamethod

⁹²Guattari, *Chaosmosis*.

would map the transitions, transformations and effects of complex objects theoretically and empirically—because they constantly undergo changes based on imbalances between their elements, they must be capable of modification in their turn.⁹³

As we have seen throughout this dissertation, the types of complex objects Genosko writes about are precisely the interferences noise causes within the systems under study. While transdisciplinarity is a process that we must consciously undertake in the era of hyper-specialization, we saw that in the early days of information theory and electronic music many of these disciplinary boundaries were more porous—if they existed at all. Indeed, noise makes a mess of disciplinary fields: a mess that does not have a positive or negative connotation, but rather one that highlights the importance of a transdisciplinary approach that can be attuned to the equivocality of noisy interferences.

⁹³Gary Genosko, “Félix Guattari: towards a transdisciplinary metamethodology,” *Angelaki: Journal of the Theoretical Humanities* 8, no. 1 (2003): 137.

Appendix A

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Glossary

algorithmic trading The use of computer algorithms, rather than the immediate decisions of a human trader, to execute a trade.

arbitrage In short, arbitrage is the identification of a discrepancy between the price of a security and what it “should” be, according to fundamental analysis or technical analysis, and then the exploitation of this discrepancy for the capture of profit. Arbitrage can be conducted in a number of ways depending on the market or the security; see, for example statistical arbitrage.

ask Lowest price a seller is willing to accept for a security.

automated trading system A computational system for the automated submission of securities trades to an electronic exchange, enabling the development of algorithmic trading and its subset, high-frequency trading.

bid Highest price a buyer is willing to pay for a security.

book depth The number of entries in the order book; can be artificially limited or unlimited.

Capital Asset Pricing Model Defines the expected rate of return on a risky asset dependent on its risk profile (β), the expected rate of return of the market as a whole, and the risk-free rate of return. See also the Efficient-Market Hypothesis.

derivative Any security whose price depends on the price of another security, such as stock, stock index, bond, or mortgage. Derivatives include futures, options, and swaps.

Direct Market Access Exchange technologies that enable so-called “buy-side” firms direct access to the order book of an exchange, by-passing sell-side firms or their own in-house brokers.

Efficient-Market Hypothesis The Efficient-Market hypothesis is that capital markets immediately reflect available information, thereby preventing arbitrage situations. The hypothesis has been roundly criticized, most notably by behavioral economists and those who suggest that belief in it was strongly responsible for the most recent credit crisis. See also the Capital Asset Pricing Model.

Electronic Communication Network Purely electronic systems for the trading of securities.

E-Mini S&P Index futures product linked to the S&P 500 index, the contract trades at \$50 times the value of the index. Recent volumes of the contract were upwards of 1,800,000, meaning the value of the daily trades is over \$120 billion.

fundamental analysis Form of financial analysis based on so-called “fundamental” properties of a security, such as a firm’s profit, its performance in relationship to other firms in its market segment, and broader changes in the economy (e.g., interest rates). See also technical analysis.

high-frequency data The necessary counterpart to high-frequency trading, high-frequency data is the rapid distribution of market data from exchanges, on the timescale of a minute. So-called “tick-by-tick” data—that is, data from each transaction as it occurs—is occasionally termed ultra-high-frequency data; such transactions can occur on the millisecond timescale.

high-frequency trading A form of algorithmic trading that operates on extremely small time scales, on the order of tens of milliseconds, in order to capture potential profits as a result of its speed.

limit order book The list of open limit orders consisting of the set of bids and asks. The limit order book has often been only available to specialists and/or market makers, and therefore not visible to the public. With the move to Direct Market Access so-called “buy-side” investors are now able to interact with the limit order book without the need for an intervening broker.

Markets in Finance Instruments Directive European Union law to harmonize the regulation of financial instruments across the EU.

Natural Language Processing Algorithms constructed for computers to be able to “understand” so-called “natural language” enabling, for example, a

decision to be made based on the content of a released news article.

noise trader One who is assumed to be unable to distinguish between valid and invalid information within a market. It was often assumed that noise traders would not be able to survive within a market due to the quick exhaustion of their capital, but recent models and empirical evidence has shown otherwise.

open-outcry trading Material and bodily form of trading whereby offers to buy or sell a security are settled through specific hand motions and vocal shouts. In the CBOT such activity is done in the “pits”, a series of raised steps that also determines position within the social hierarchy of traders. Such trading has diminished greatly in importance with the rise of ECNs. For an ethnography of this practice see Zaloom, *Out of the Pits: Traders And Technology from Chicago to London*.

order book See limit order book.

over-the-counter Transactions that do not take place on open exchanges, but rather between individual entities, such as two investment banks.

proprietary trading Trading conducted with the firm’s own capital, rather than with the capital contributed by its clients.

Regulation National Market System SEC regulations “designed to modernize and strengthen the national market system for equity securities” that additionally lead to the proliferation of Electronic Communication Networks.

serialism A compositional technique where fundamental aspects of sound—pitch, rhythm, register, dynamics, timbre—are ordered into a “row” and permuted in an algorithmic fashion. For example, in twelve-tone (dodeca-phonic) composition, the twelve tones of the Western scale are arranged in a particular order and then used in that order—and that order only—within a given composition. Various permutations are allowed, such as inverting the row melodically or reading it out backwards. Twelve-tone composition was meant to break down the last remaining harmonic relationships and produce situations where there would be no given harmonic tendency to a piece.

Smart Order Routing The routing of market orders to the exchange with the most favorable terms for bid, ask, and/or volume.

spread The difference in price between the bid and the ask.

statistical arbitrage See technical analysis.

Straight-Through Processing The attempt to enable all aspects of a securities transaction—from the initial trade, to its clearing, to its ultimate settlement—to be conducted electronically, thereby reducing the amount of time for completion from days to ideally minutes or seconds.

technical analysis Form of financial analysis based on observable properties of market data, such as the temporal sequence of the price and volume of a security, that aims to understand how such data fits into previously defined patterns that suggest particular future changes in the security. In its most advanced form, technical analysis develops a statistical model based on

prior data in order to predict future movements. When a deviation from this model is found it is a potential arbitrage opportunity, leading to the term “statistical arbitrage”, a key technique in HFT. See also fundamental analysis.

Time-Weighted Average Price Algorithm for splitting up a large order into smaller pieces to be distributed over a given period of time.

Volume-Weighted Average Price Algorithm for splitting up a large order into smaller pieces to be distributed over a given period of time, dependent on the historical volume profile for the given security. The goal is to not have any given trade take up an appreciable amount of the volume in order to not affect the desired price by the trading activity.

Acronyms

ANT Actor-Network Theory.

AT Algorithmic Trading.

ATS Automated Trading System.

CAE Critical Art Ensemble.

CAPM Capital Asset Pricing Model.

CBOT Chicago Board of Trade.

CCRMA Center for Computer Research in Music and Acoustics.

Ccru Cybernetic Culture Research Unit.

CFTC Commodity Futures Trading Commission.

DMA Direct Market Access.

ECN Electronic Communication Network.

EMH Efficient-Market Hypothesis.

HFD High-Frequency Data.

HFT High-Frequency Trading.

IAA Institute for Applied Autonomy.

JJPS Journal of Journal Performance Studies.

MiFID Markets in Financial Instruments Directive.

NLP Natural Language Processing.

NSA National Security Agency.

NYSE New York Stock Exchange.

OTC over-the-counter.

RAC Rockefeller Archive Center.

regNMS Regulation National Market System.

RF Rockefeller Foundation.

SEC Securities and Exchange Commission.

SOR Smart Order Routing.

STP Straight-Through Processing.

TWAP Time-Weighted Average Price.

VWAP Volume-Weighted Average Price.

WBO Wearable Body Organ.

Bibliography

Allan, Jennifer Lucy. "Future Human." *Wire* (November 2012): 10.

Alloway, Tracy. "More bad news from Merrill, squawkbox edition." March 11, 2009.

Accessed July 3, 2012. <http://ftalphaville.ft.com/blog/2009/03/11/53471/more-bad-news-from-merrill-squawkbox-edition/>.

Andrews, Bruce, and Charles Bernstein, eds. *The L=A=N=G=U=A=G=E Book*. Carbondale, IL: Southern Illinois University Press, 1984.

Angel, James J. "Impact of special relativity on securities regulation." *The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 15*, 2011.

Anonymous. "1Q 2010 NJ Office, Industrial Markets Mixed." April 14, 2010. Accessed July 3, 2012. <http://newyork.citybizlist.com/article/1q-2010-nj-office-industrial-markets-mixed-0>.

Anonymous Hedge Fund Manager and Keith Gessen. *Diary of a Very Bad Year: Confessions of an Anonymous Hedge Fund Manager*. New York: Harper Perennial, 2010.

- Arnheim, Rudolf. "Information Theory: An Introductory Note." *The Journal of Aesthetics and Art Criticism* 17, no. 4 (1959): 501–503.
- Aspray, William F. "The Scientific Conceptualization of Information: A Survey." *Annals of the History of Computing* 7, no. 2 (April 1985): 117–140.
- Attali, Jacques. *Noise: The Political Economy of Music*. Minneapolis, MN: University of Minnesota Press, 1985.
- Autogena, Lise. "Lise Autogena." n.d. Accessed July 3, 2013. <http://research.ncl.ac.uk/sacs/projects/Autogena4.html>.
- Babbitt, Milton. *A Life of Learning*. ACLS Occasional Paper, No. 17. Charles Homer Haskins Lecture, 1991.
- . "Who Cares if You Listen?" *High Fidelity Magazine* VIII, no. 2 (February 1958): 38–40, 126–127.
- Bailey, Stephanie, Lisa Mazza, Juliane Peiser, and Laura Windhager, eds. *Masquerades of Truth (PARRHESIA: Technologies of Truth)*. London, 2012.
- Bamford, James. "The NSA Is Building the Country's Biggest Spy Center (Watch What You Say)." March 15, 2012. Accessed July 3, 2013. http://www.wired.com/threatlevel/2012/03/ff_nsadatacenter/all/1.
- Barber, Brad M., Terrance Odean, and Ning Zhu. "Systematic noise." *Journal of Financial Markets* 12, no. 4 (2009): 547–569.

- Barry, Andrew, and Don Slater, eds. *The Technological Economy*. New York: Routledge, 2005.
- Barthes, Roland. *Image, Music, Text*. Translated by Stephen Heath. New York: The Noonday Press, 1990.
- Baynham, Mark. "Speaking in code: Holly Herndon explains why the laptop is the most personal instrument the world has ever known—FACT Magazine: Music News, New Music." November 15, 2012. Accessed July 3, 2013. <http://www.factmag.com/2012/11/15/speaking-in-code-holly-herndon-explains-why-the-laptop-is-the-most-personal-instrument-the-world-has-ever-known/>.
- Bell, John. "Puppets and Performing Objects in the Twentieth Century." *Performing Arts Journal* 19, no. 2 (1997): 29–46.
- Berardi, Franco "Bifo." *The Uprising: On Poetry and Finance*. Intervention Series 14. Los Angeles: Semiotext(e), 2012.
- Biais, Bruno, and Paul Woolley. "High Frequency Trading." Preliminary Paper, 2011.
- Bijsterveld, Karin. *Mechanical Sound: Technology, Culture, and Public Problems of Noise in the Twentieth Century*. Cambridge, MA: MIT Press, 2008.
- Black, Fischer. "A Deductive Question-Answering System." In Minsky, *Semantic Information Processing*, 354–402.

Black, Fischer. "Noise." *The Journal of Finance* 41, no. 3 (1986): 529–543.

Black, Fischer, and Myron Scholes. "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy* 81, no. 3 (1973): 637–654.

Boehner, Kirsten, Rogério DePaula, Paul Dourish, and Phoebe Sengers. "How emotion is made and measured." *International Journal of Human-Computer Studies* 65, no. 4 (2007): 275–291.

Boomkat. "En Aldeles Forferdelig Sykdom." 2010. Accessed July 3, 2013. <http://boomkat.com/cds/20060-spunk-en-aldeles-forferdelig-sykdom>.

Both, Christoph. "The influence of concepts of information theory on the birth of electronic music composition: Lejaren A. Hiller and Karlheinz Stockhausen, 1953–1960." PhD diss., University of Victoria, 1995.

Boulangier, Richard, ed. *The Csound Book: Perspectives in Software Synthesis, Sound Design, Signal Processing, and Programming*. Cambridge, MA: MIT Press, 2000.

Brandtsegg, Øyvind. "Wiki ImproSculpt." Accessed July 3, 2013. <http://improsculpt.sourceforge.net/pmwiki/pmwiki.php>.

Brassier, Ray. "Accelerationism." Presentation at Accelerationism conference at Goldsmiths. September 14, 2010. Accessed July 3, 2013. <https://moskvax.wordpress.com/2010/09/30/accelerationism-ray-brassier/>.

Brillouin, Léon. "Thermodynamics and Information Theory." *American Scientist* 38 (1950): 594–599.

Brody, Martin. "Music For the Masses': Milton Babbitt's Cold War Music Theory." *Musical Quarterly* 77, no. 2 (1993): 161–192.

Brooks, F. P., A. L. Hopkins, P. G. Neumann, and W. V. Wright. "An experiment in musical composition." *Electronic Computers, IRE Transactions on EC-6*, no. 3 (September 1957): 175–182.

Brush, Silla, and Asjylyn Loder. "CFTC Told Disruptive Trading Rules Threaten Market Liquidity." December 2, 2010. Accessed July 3, 2013. <http://www.bloomberg.com/news/2010-12-02/commodities-regulators-told-disruptive-trading-rules-threaten-liquidity.html>.

Buszek, Maria-Elena. "Oh! Dogma (Up Yours!): Surfing the Third Wave." *thirdspace: a journal of feminist theory & culture* 1, no. 1 (July 2001).

Callon, Michel, ed. *The Laws of Markets*. Oxford and Malden, MA: Blackwell Publishers/The Sociological Review, 1998.

- Cardew, Cornelius. *Stockhausen Serves Imperialism*. ubuclassics. London, UK: Latimer New Dimensions Limited, 2004 [1974].
- Carlson, Mark. "A Brief History of the 1987 Stock Market Crash with a Discussion of the Federal Reserve Response." Federal Reserve Board Finance and Economics Discussion Series 2007-13, 2007.
- Carroll, Mark. *Music and Ideology in Cold War Europe*. Cambridge, UK: Cambridge University Press, 2003.
- Cascone, Kim, ed. *Contemporary Music Review* 22, no. 4 (2003).
- Cavarero, Adriana. *For More Than One Voice: Toward a Philosophy of Vocal Expression*. Translated by Paul A. Kottman. Stanford University Press, 2005 [2003].
- Ccru. "Swarmachines." n.d. Accessed July 3, 2013. http://www.ccru.net/swarm1/1_swarm.htm.
- Certeau, Michel De. "Vocal Utopias: Glossolalias." *Representations*, no. 56 (1996): 29–47.
- Chan, Palace. "statistics - What exactly is meant by 'microstructure noise'?" November 11, 2011. Accessed July 3, 2013. <http://quant.stackexchange.com/questions/2360/what-exactly-is-meant-by-microstructure-noise>.

Cherlin, Michael. *Schoenberg's Musical Imagination*. Cambridge, UK: Cambridge University Press, 2007.

Cherry, Colin, ed. *Information Theory*. Papers read at a Symposium on "Information Theory" held at the Royal Institution, London, September 12th to 16th 1955. London, UK: Butterworths Scientific Publications, 1956.

Cherry, E. Colin. "A History of the Theory of Information." *Transactions of the I.R.E. Professional Group on Information Theory* 1 (1953): 22–43.

Cixous, Helene. "The Laugh of the Medusa." Translated by Keith Cohen and Paula Cohen. *Signs* 1, no. 4 (1976[1974]): 875–893.

Cixous, Hélène, and Catherine Clément. *The Newly Born Woman*. Translated by Betsy Wing. University Of Minnesota Press, 1986.

Clément, Catherine. *Opera, or the Undoing of Women*. Translated by Betsy Wing. University of Minnesota Press, 1999.

Cliff, Dave, Dan Brown, and Philip Treleaven. "Technology trends in the financial markets: A 2020 vision." *The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 3*, 2010.

Cliff, Dave, and Linda Northrop. "The global financial markets: an ultra-large-scale systems perspective." *The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 4*, 2010.

Cohen, Joel E. "Information theory and music." *Behavioral Science* 7, no. 2 (1962): 137–163.

Commodity Futures Trading Commission and Securities and Exchange Commission. "Findings Regarding the Market Events of May 6th, 2010." Report of the Staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues, September 30, 2010.

———. "Preliminary Findings Regarding the Market Events of May 6, 2010." Report of the Staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues, May 18, 2010.

Connor, Steven. *Dumbstruck: A Cultural History of Ventriloquism*. Oxford and New York: Oxford University Press, 2001.

Coons, Edgar, and David Kraehenbuehl. "Information as a Measure of Structure in Music." *Journal of Music Theory* 2, no. 2 (1958): 127–161.

Coupling, J. J. "Chance Remarks." *Astounding Science Fiction* (October 1949): 104–111.

———. "Science for Art's Sake." *Astounding Science Fiction* (November 1950): 83–92.

Coval, Joshua D., and Tyler Shumway. "Is Sound Just Noise?" *The Journal of Finance* 56, no. 5 (2001): 1887–1910.

- Critical Art Ensemble and Institute for Applied Autonomy. "Contestational Robotics." 1998. Accessed July 3, 2013. <http://www.appliedautonomy.com/objectors.html>.
- Cross, Lowell. "Electronic Music, 1948-1953." *Perspectives of New Music* 7, no. 1 (1968): 32–65.
- Crosthwaite, Paul. "Blood on the Trading Floor." *Angelaki* 15, no. 2 (2010): 3–18.
- Cvetkovich, Ann. *Depression: A Public Feeling*. Durham, NC: Duke University Press, 2012.
- De Long, J. Bradford, Andrei Shleifer, Lawrence H. Summers, and Robert J. Waldmann. "Noise Trader Risk in Financial Markets." *Journal of Political Economy* 98, no. 4 (1990): 703–738.
- . "The Survival of Noise Traders in Financial Markets." *The Journal of Business* 64, no. 1 (1991): 1–19.
- Debrouillard Group. "Trading Pit History." n.d. Accessed July 3, 2013. <http://tradingpithistory.com/>.
- Deleuze, Gilles, and Félix Guattari. *A Thousand Plateaus: Capitalism and Schizophrenia*. Translated by Brian Massumi. University of Minnesota Press, 1987 [1980].

Deleuze, Gilles, and Félix Guattari. *Anti-Oedipus: Capitalism and Schizophrenia*.

Translated by Robert Hurley, Mark Seem, and Helen R. Lane. Minneapolis, MN: University of Minnesota Press, 1983 [1972].

Demers, Joanna. *Listening through the Noise: The Aesthetics of Experimental Electronic Music*. Oxford and New York: Oxford University Press, 2010.

Derrida, Jacques. *Of Grammatology*. Translated by Gayatri Chakravorty Spivak.

Baltimore, Maryland, USA: Johns Hopkins University Press, 1997 [1976].

———. *Speech and Phenomena and Other Essays on Husserl's Theory of Signs*.

Translated by David B. Allison. Evanston, IL: Northwestern University Press, 1973.

Deutsche, Rosalyn. "Sharing Strangeness: Krzysztof Wodiczko's *Ægis* and the Question of Hospitality." *Grey Room*, no. 6 (2002): 26–43.

Dickinson, Kay. "'Believe'? Vocoder, Digitalised Female Identity and Camp" [in English]. *Popular Music* 20, no. 3 (2001): 333–347.

DiSalvo, Carl. *Adversarial Design*. Cambridge, MA: MIT Press, 2012.

Dobson, Kelly. "BOOM." Master's thesis, Massachusetts Institute of Technology, 2000.

———. "Machine Therapy." PhD diss., Massachusetts Institute of Technology, 2007.

- Dobson, Kelly. "Wearable Body Organs: Critical Cognition Becomes (Again) Somatic." In *Proceedings of Creativity & Cognition 2005*, 259–262. 2005.
- Dolar, Mladen. *A Voice and Nothing More*. Cambridge, MA, USA: MIT Press, 2006.
- Dudley, Homer. "Remaking Speech." *Journal of the Acoustical Society of America* 11, no. 2 (1939): 169–177.
- Dunbar-Hester, Christina. "Listening to Cybernetics." *Science, Technology & Human Values* 35, no. 1 (2010): 113–139.
- Durden, Tyler. "MUST HEAR: Panic And Loathing From The S&P 500 Pits." May 7, 2010. Accessed July 3, 2013. <http://www.zerohedge.com/article/panic-and-loathing-sp-500-pits>.
- Easley, David, Marcos M. Lópezde Prado, and Maureen O'Hara. "The Microstructure of the 'Flash Crash': Flow Toxicity, Liquidity Crashes and the Probability of Informed Trading." Working paper, 2010.
- Edwards, Paul N. *The Closed World: Computers and the Politics of Discourse in Cold War America*. Cambridge, MA: The MIT Press, 1997.
- Eidsheim, Nina Sun. "Sensing Voice: Materiality and the Lived Body in Singing and Listening." *The Senses and Society* 6, no. 2 (2011): 133–155.
- Eileraas, Karina. "Witches, Bitches & Fluids: Girl Bands Performing Ugliness as Resistance." *The Drama Review* 41, no. 3 (1997): 122–139.

- Eimert, Herbert, and Karlheinz Stockhausen, eds. *die Reihe VIII* (1968 [1962]).
- Elite Trader Forums. "Forum - floor squawk box?" August 23, 2006. Accessed July 3, 2013. <http://www.elitetrader.com/vb/showthread.php?threadid=75425>.
- Evens, Aden. *Sound Ideas: Music, Machines, and Experience*. Theory Out of Bounds. Minneapolis: University of Minnesota Press, 2005.
- Faas, Ekbart. "Interview with Karlheinz Stockhausen Held August 11, 1976." *Interface: Journal of New Music Research* 6 (1977): 187–204.
- Fabozzi, Frank J., Sergio M. Focardi, and Caroline Jonas. "High-frequency trading: methodologies and market impact." *Review of Futures Markets* 19 (2011): 7–38.
- Fagen, M. D., ed. *A History of Engineering and Science in the Bell System: National Service in War and Peace (1925–1975)*. Murray Hill, NJ: Bell Telephone Laboratories, Incorporated, 1978.
- Fama, Eugene F. "Efficient Capital Markets: A Review of Theory and Empirical Work." *The Journal of Finance* 25, no. 2 (1970): 383–417.
- Farmer, J. Doyne, and Spyros Skouras. "An ecological perspective on the future of computer trading." *The Future of Computer Trading in Financial Markets - Foresight Driver Review – DR 6*, 2010.

Fernández, María, Faith Wilding, and Michelle M. Wright, eds. *Domain Errors! Cyberfeminist Practices*. New York: Autonomedia, 2002.

Fletcher, Harvey. *Physical Properties of Speech, Music, and Noise: A Lecture Outlining the Physical Properties of Speech, Music, and Noise and Their Relation to Transmission Problems*. New York: Western Electric Company Engineering Department, 1924.

Foresight Project. "The Future of Computer Trading in Financial Markets." Working Paper, UK Government Office for Science, 2011.

Foucault, Michel. *Fearless Speech*. Edited by Joseph Pearson. Foreign Agents. Los Angeles: Semiotext(e), 2001.

———. *The Courage of the Truth (The Government of Self and Others II): Lectures at the Collège de France 1983-1984*. Translated by Graham Burchell. New York: Palgrave Macmillan, 2011 [2008].

Frankfurter, George M., and Elton G. McGoun. "Ideology and the theory of financial economics." *Journal of Economic Behavior & Organization* 39, no. 2 (1999): 159–177.

Freud, Sigmund. "Mourning and Melancholia." In *The Standard Edition of the Complete Psychological Works of Sigmund Freud*, edited by James Strachey, 239–258. London, UK: The Hogarth Press, 1953-1974 [1917] [1915].

Friedman, Milton. "The Methodology of Positive Economics." In *Essays in Positive Economics*, 3–43. Chicago: University of Chicago Press, 1953.

Gabor, Dennis. "Theory of communication. Part 1: The analysis of information." *Journal of the Institution of Electrical Engineers - Part III: Radio and Communication Engineering* 93, no. 26 (November 1946): 429–441.

———. "Theory of communication. Part 2: The analysis of hearing." *Journal of the Institution of Electrical Engineers - Part III: Radio and Communication Engineering* 93, no. 26 (November 1946): 442–445.

Gamba, A. "Information Theory and Knowledge: Remarks on a Paper by D. K. C. MacDonald." *Journal of Applied Physics* 25, no. 12 (December 1954): 1549.

Gammel, Irene. *Baroness Elsa: Gender, Dada, and Everyday Modernity*. Cambridge, MA: MIT Press, 2002.

Gammel, Irene, and Suzanne Zelazo. "Harpsichords Metallic Howl—': The Baroness Elsa von Freytag-Loringhoven's Sound Poetry." *Modernism/modernity* 18, no. 2 (2011): 255–271.

Genosko, Gary. "Félix Guattari: towards a transdisciplinary metamethodology." *Angelaki: Journal of the Theoretical Humanities* 8, no. 1 (2003): 129–136.

Geoghegan, Bernard Dionysius. "From Information Theory to French Theory: Jakobson, Lévi-Strauss, and the Cybernetic Apparatus." *Critical Inquiry* 38, no. 1 (2011): 96–126.

- Geoghegan, Bernard Dionysius. "Historiographic Conceptualization of Information: A Critical Survey." *Annals of the History of Computing, IEEE* 30, no. 1 (January 2008): 66–81.
- . "The Cybernetic Apparatus: Media, Liberalism, and the Reform of the Human Sciences." PhD diss., Northwestern University, 2012.
- Gessen, Keith. "HFM Redux, Part Two." December 16, 2010. Accessed July 3, 2013. <http://nplusonemag.com/hfm-redux-part-two>.
- Gevrey, Jean-Claude, and Maja Ratkje. "The Voice That Came In From the Cold: An Interview with Maja S.K. Ratkje." 2005. Accessed July 3, 2013. <http://www.dustedmagazine.com/features/746>.
- Gleick, James. *The Information: A History, A Theory, A Flood*. New York: Pantheon Books, 2012.
- Goddard, Michael, Benjamin Halligan, and Paul Hegarty, eds. *Reverberations: The Philosophy, Aesthetics and Politics of Noise*. London and New York: Continuum, 2012.
- Goldsmith, Kenneth. *Uncreative Writing*. New York: Columbia University Press, 2011.
- Gomber, Peter, Björn Arndt, Marco Lutat, and Tim Uhle. "High-Frequency Trading." Working paper commissioned by the Deutsche Börse Group, 2011.

- Goodman, Steve. *Sonic Warfare: Sound, Affect, and the Ecology of Fear*. Cambridge, MA: MIT Press, 2009.
- Grant, Iain Hamilton. "Introduction." In Lyotard, *Libidinal Economy*, xvii–xxxiv.
- Grant, M. J. *Serial music, serial aesthetics: Compositional theory in post-war Europe*. Cambridge, UK: Cambridge University Press, 2001.
- Guattari, Félix. *Chaosmosis*. Translated by Paul Bains and Julian Perfanis. Bloomington: Indiana University Press, 1995.
- . "Ritornellos and Existential Affects." *Discourse* 12, no. 2 (1990): 66–81.
- Hainge, Greg. *Noise Matters: Towards an Ontology of Noise*. New York: Bloomsbury Academic, 2013.
- Haldane, Andrew G. "The race to zero." Speech given to the International Economic Association Sixteenth World Congress, Beijing, China. July 8, 2011. Accessed July 3, 2013. <http://www.bankofengland.co.uk/publications/Pages/news/2011/068.aspx>.
- Hansen, Mark. B. N. "Cinema Beyond Cybernetics, or How to Frame the Digital Image." *Configurations* 10, no. 1 (2002): 51–90.
- Haraway, Donna J. "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century." In *Simians, Cyborgs, and Women: The Reinvention of Nature*, 149–181. Routledge, 1991.

Harris, Robert. *The Fear Index*. New York: Alfred A. Knopf, 2012.

Hartley, Ralph Vinton Lyon. "Transmission of Information." *Bell Systems Technical Journal* 7 (1928): 535–563.

Hasbrouck, Joel, and Gideon Saar. "Low-Latency Trading." Johnson School Research Paper Series No. 35-2010, 2011.

Hayek, F. A. *Law, Legislation and Liberty*. London: Routledge, 1993 [1982].

———. "The Use of Knowledge in Society." *The American Economic Review* 35, no. 4 (1945): 519–530.

Hayles, N. Katherine. *Chaos Bound: Orderly Disorder in Contemporary Literature and Science*. Ithaca, NY: Cornell University Press, 1990.

———. *How We Became Posthuman : Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago: University Of Chicago Press, 1999.

Hegarty, Paul. *Noise/Music: A History*. New York and London: Continuum International Publishing Group, August 15, 2007.

Heims, Steve Joshua. *The Cybernetics Group*. Cambridge, MA, USA: MIT Press, 1991.

Heller, Monica. "The Commodification of Language." *Annual Review of Anthropology* 39, no. 1 (2010): 101–114.

Hemmings, Clare. "Invoking Affect: Cultural Theory and the Ontological Turn." *Cultural Studies* 19, no. 5 (2005): 548–567.

Hendershott, Terrence, Charles M. Jones A., and Albert J. Menkveld. "Does Algorithmic Trading Improve Liquidity?" *The Journal of Finance* 66, no. 1 (2011): 1–33.

Hendershott, Terrence, and Ryan Riodan. "Algorithmic Trading and Information." NET Institute Working Paper No. 09-08, 2011.

Hermann, Thomas, Andy Hunt, and John G. Neuhoﬀ, eds. *The Sonification Handbook*. Berlin: Logos Verlag, 2011.

Herndon, Holly. "Embodiment in Electronic Music Performance." Master's thesis, Mills College, 2010.

———. *Movement*. RVNG Intl. RVNGNL15, 2012.

Higgins, Sean. "BOMBlog: Holly Herndon by Sean Higgins." January 23, 2013. Accessed July 3, 2013. <http://bombsite.com/articles/7023>.

Hiller, Lejaren A., Jr., and Leonard M. Isaacson. *Experimental Music: Composition with an Electronic Computer*. New York: McGraw-Hill Book Company, Inc., 1959.

Hoile, Cefn. *Black Shoals: Evolving Organisms in a World of Financial Data*, n.d.

Holmes, Brian. "Is it written in the stars? Global finance, precarious destinies." *ephemera: theory & politics in organization* 10, nos. 3/4 (2010): 222–233.

Hutchison, Dennis C. "Performance, Technology, and Politics: Hermann Scherchen's Aesthetics of Modern Music." PhD diss., Florida State University, 2003.

Ihde, Don. *Listening and Voice: Phenomenologies of Sound*. State University of New York Press, 2007.

Institute for Applied Autonomy. "Mission." n.d. Accessed July 3, 2013. <http://www.appliedautonomy.com/mission.html>.

———. "Nike Chalkbot Rips-off Streetwriter." July 7, 2009. Accessed July 3, 2013. <http://www.appliedautonomy.com/chalkbot.html>.

———. "Pamphleteer: A Propaganda Robot for Cultural Resistance." n.d. Accessed July 3, 2013. <http://appliedautonomy.com/pamphleteer.html>.

———. "Robotic Insurrection in Philadelphia Streets." August 20, 1999. Accessed July 3, 2013. <http://www.appliedautonomy.com/phillypr.html>.

- Jackson, Willis, ed. *Communication Theory*. Papers read at a Symposium on “Applications of Communication Theory” held at the Institution of Electrical Engineers, London, September 22nd–26th 1952. New York, NY, USA: Academic Press, Inc., 1953.
- Jacobson, Homer. “Information and the Human Ear.” 23, no. 4 (1951): 463–471.
- Janata, Petr, and Edward Childs. “Marketbuzz: Sonification of Real-Time Financial Data.” In *Proceedings of ICAD 04—Tenth Meeting of the International Conference on Auditory Display*. 2004.
- Jarman-Ivens, Freya. *Queer Voices: Technologies, Vocalities, and the Musical Flaw*. New York: Palgrave Macmillan, 2011.
- JCL’s Forex. “Floored: Into The Pit - Epic Trader Movie!” May 11, 2012. Accessed July 3, 2013. <https://www.youtube.com/watch?v=tCcxr-fyF4Q>.
- Jensen, Michael C. “Some anomalous evidence regarding market efficiency.” *Journal of Financial Economics* 6, no. 2–3 (1978): 95–101.
- Kahn, Douglas. *Noise, Water, Meat: A History of Sound in the Arts*. The MIT Press, 2001.
- Kahneman, Daniel, and Amos Tversky. “On the psychology of prediction.” *Psychological Review* 80, no. 4 (1973): 237–251.
- . “Prospect Theory: An Analysis of Decision under Risk.” *Econometrica* 47, no. 2 (1979): 263–292.

Kelly, Caleb. *Cracked Media: The Sound of Malfunction*. Cambridge, MA: MIT Press, 2009.

Kim-Cohen, Seth. *In the Blink of an Ear: Toward a Non-Cochlear Sonic Art*. New York and London: Continuum, 2009.

Kirilenko, Andrei, Albert S. Kyle, Mehrdad Samadi, and Tugkan Tuzun. "The Flash Crash: The Impact of High Frequency Trading on an Electronic Market." Working paper, 2011.

Kline, Ronald. "Cybernetics, Automata Studies, and the Dartmouth Conference on Artificial Intelligence." *Annals of the History of Computing*, IEEE 33, no. 4 (2011): 5–16.

Kline, Ronald R. "What Is Information Theory a Theory of? Boundary Work among Information Theorists and Information Scientists in the United States and Britain during the Early Cold War." In *Second Conference on the History and Heritage of Scientific and Technical Information Systems*, November 16–17, 2002. Chemical Heritage Foundation, 2002.

Knorr-Cetina, Karin, and Alex Preda, eds. *The Sociology of Financial Markets*. London: Oxford University Press, 2005.

Knouf, Nicholas A. "Encouraging the Expression of the Unspeakable: Influence and Agency in a Robotic Creature." Master's thesis, Massachusetts Institute of Technology, 2007.

Knouf, Nicholas A. "The Patterning Table." In *The Inner History of Devices*, edited by Sherry Turkle, 49–54. Cambridge, MA: MIT Press, 2008.

———. "Transnetworks and the Fluid Nexus Project." In *Dis Connecting Media*, edited by Ulla Autenrieth, Andreas Blättler, Regine Buschauer, and Doris Gassert, 199–206. Christoph Merian Verlag, 2011.

Koss, Juliet. "Bauhaus Theater of Human Dolls." *The Art Bulletin* 85, no. 4 (2003): 724–745.

Kraehenbuehl, David, and Edgar Coons. "Information as a Measure of the Experience of Music." *The Journal of Aesthetics and Art Criticism* 17, no. 4 (1959): 510–522.

Krapp, Peter. *Noise Channels: Glitch and Error in Digital Culture*. Minneapolis: University of Minnesota Press, 2011.

Krause, Ralf, and Marc Röllli. "Micropolitical Associations." In *Deleuze and Politics*, edited by Ian Buchanan and Nicholas Thoburn, translated by Millay Hyatt, 240–254. Edinburgh: Edinburgh University Press, 2008.

Kristeva, Julia. *Revolution in Poetic Language*. Translated by Margaret Waller. New York: Columbia University Press, 1984 [1974].

Labelle, Brandon. *Background Noise: Perspectives on Sound Art*. New York: Continuum International Publishing Group, April 1, 2006.

LaBelle, Brandon. "Raw Orality: Sound Poetry and Live Bodies." In Neumark, Gibson, and Leeuwen, *Voice: Vocal Aesthetics in Digital Arts and Media*, 147–171.

Lajer-Burcharth, Ewa. "The Global Wanderer." In McCorquodale, *Krzysztof Wodiczko*, 210–219.

Land, Nick. *Fanged Noumena: Collected Writings 1987–2007*. Falmouth, UK: Urbanomic, 2011.

———. "Machinic desire." *Textural Practice* 7, no. 3 (1993): 471–482.

———. "Machinic Desire." In *Fanged Noumena: Collected Writings 1987–2007*, 319–344.

———. "Meltdown." In *Fanged Noumena: Collected Writings 1987–2007*, 441–459. 2011 [1994].

———. "No Future." In *Fanged Noumena: Collected Writings 1987–2007*, 391–399.

Lasch, Christopher. "The Cultural Cold War: A Short History of the Congress for Cultural Freedom." In *The Agony of the American Left*, 61–114. Alfred A. Knopf, 1969.

Lefebvre, Henri. *Rhythmanalysis: Space, Time and Everyday Life*. Translated by Stuart Elden and Gerald Moore. New York: Continuum, 2004 [1992].

Lenglet, Marc. "Conflicting Codes and Codings." *Theory, Culture & Society* 28, no. 6 (2011): 44–66.

Licklider, J. C. R. "Man-Computer Symbiosis." *IRE Transactions on Human Factors in Electronics* 1, no. 1 (March 1960): 4–11.

Liu, Lydia H. *The Freudian Robot: Digital Media and the Future of the Unconscious*. Chicago: University of Chicago Press, 2011.

Lo, Andrew W. "Introduction." In *Market Efficiency: Stock Market Behaviour in Theory and Practice*, edited by Andrew W. Lo, I:xi–xix. Cheltenham, UK and Lyme, NH: Edward Elgar Publishing, 1997.

Luening, Otto. "An Unfinished History of Electronic Music." *Music Educators Journal* 55, no. 3 (1968): 42–49, 135–142, 145.

———. "Some Random Remarks about Electronic Music." *Journal of Music Theory* 8, no. 1 (1964): 89–98.

Lyotard, Jean-François. *Libidinal Economy*. Translated by Iain Hamilton Grant. Bloomington, IN: Indiana University Press, 1993 [1974].

MacDonald, D. K. C. "Fluctuations and theory of noise." *Transactions of the I.R.E. Professional Group on Information Theory* 1, no. 1 (February 1953): 114–119.

———. "Information Theory and Knowledge." *Journal of Applied Physics* 25, no. 5 (May 1954): 619–622.

MacKay, Donald. "Quantal aspects of scientific information." *Transactions of the I.R.E. Professional Group on Information Theory* 1, no. 1 (1953): 60–80.

———. "The nomenclature of information theory." *Transactions of the I.R.E. Professional Group on Information Theory* 1, no. 1 (1953): 9–21.

MacKenzie, Donald. *An Engine, Not a Camera: How Financial Models Shape Markets*. Cambridge, MA: MIT Press, 2006.

———. "How to Make Money in Microseconds." *London Review of Books* 33, no. 10 (2011): 16–18.

———. *Material Markets: How Economic Agents are Constructed*. Oxford: Oxford University Press, 2009.

MacKenzie, Donald, Fabian Muniesa, and Lucia Siu, eds. *Do Economists Make Markets? On the Performativity of Economics*. Princeton and Oxford: Princeton University Press, 2007.

———. "Introduction." In *Do Economists Make Markets? On the Performativity of Economics*.

Mackenzie, Michael, and Aline van Duyn. "Regulators may silence derivative squawk boxes." July 21, 2010. Accessed July 3, 2013. <http://www.ft.com/intl/cms/s/0/cce3f6e4-94f8-11df-af3b-00144feab49a.html>.

Maconie, Robin. "Care to Listen: Milton Babbitt and Information Science in the 1950s." *Tempo* 65, no. 258 (2011): 20–36.

Madhavan, Ananth, and Venkatesh Panchapagesan. "Price Discovery in Auction Markets: A Look Inside the Black Box." *The Review of Financial Studies* 13, no. 3 (2000): 627–658.

Fe-Mail. *Blixter Toad*. Asphodel ASP 2033, 2006.

Manning, Peter. *Electronic and Computer Music*. New York: Oxford University Press, 2004.

Mason, Luke Robert. "Nick Land's Academic Meltdown." May 3, 2011. Accessed July 3, 2013. <http://virtualfutures.co.uk/2011/05/23/lands-academic-meltdown/>.

Massumi, Brian. *Parables for the Virtual: Movement, Affect, Sensation*. Durham, NC: Duke University Press, 2002.

McClary, Susan. "This Is Not a Story My People Tell: Musical Time and Space According to Laurie Anderson." In *Feminine Endings: Music, Gender, and Sexuality*, 132–147. Minneapolis: University of Minnesota Press, 1991.

McCool, Thomas J., and Cecile O. Trop. "Commodity Exchange Act: Issues Related to the Regulation of Electronic Trading Systems." General Accounting Office report GGD-00-99, 2000.

McCorquodale, Duncan, ed. *Krzysztof Wodiczko*. London, UK: Black Dog Publishing Limited, 2011.

Merton, Robert C. "Theory of Rational Option Pricing." *The Bell Journal of Economics and Management Science* 4, no. 1 (1973): 141–183.

Meyer, Leonard B. *Emotion and Meaning in Music*. Chicago: University of Chicago Press, 1956.

———. "Meaning in Music and Information Theory." *The Journal of Aesthetics and Art Criticism* 15, no. 4 (1957): 412–424.

Meyer-Eppler, Werner. "Exhaustion Methods of Selecting Signals from Noisy Backgrounds." In Jackson, *Communication Theory*, 183–194.

———. "Musical communication as a problem of information theory." *Gravesaner Blätter*, no. 26 (1965): 98–102.

———. "Musical communication as a problem of information theory." *die Reihe* VIII (1968 [1962]): 7–10.

———. "Sichtbargemachte Musik." *Gravesaner Blätter* 1 (1955): 27–31.

———. "Statistic and Psychological Problems of Sound." *die Reihe* 1 (1958 [1955]): 55–61.

———. *The Terminology of Electronic Music*. Technical Translation TT-602. Translated From Tech. Hausmitt. NWDR, 6: 5–7, 1954. National Research Council of Canada, 1956 [1954].

Meyer-Eppler, Werner, and G. Darius. "Two-Dimensional Photographic Auto-Correlation of Pictures and Alphabet Letters." In Cherry, *Information Theory*, 34–36.

Micale, Mark S. *Hysterical Men: The Hidden History of Male Nervous Illness*. Cambridge, MA and London: Harvard University Press, 2008.

Mills, Mara. "Deaf Jam." *Social Text* 28, no. 1 (2010): 35–58.

———. "Deafening: Noise and the Engineering of Communication in the Telephone System." *Grey Room* 43 (2011): 118–143.

Mindell, David A. *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*. Baltimore: Johns Hopkins University Press, 2002.

Minsky, Marvin. "Introduction." In *Semantic Information Processing*, 1–32.

———, ed. *Semantic Information Processing*. Cambridge, MA: MIT Press, 1968.

Mirowski, Philip. "Inherent Vice: Minsky, Markomata, and the tendency of markets to undermine themselves." *Journal of Institutional Economics* 6, no. 04 (2010): 415–443.

———. *Machine Dreams: Economics Becomes a Cyborg Science*. Cambridge, UK: Cambridge University Press, 2002.

- Mirowski, Philip. "Markets come to bits: Evolution, computation and markomata in economic science." *Journal of Economic Behavior & Organization* 63, no. 2 (2007): 209–242.
- . "Minding the Cybernetic Gap." *Technology and Culture* 53, no. 1 (2012): 192–195.
- . *More heat than light: Economics as social physics: Physics as nature's economics*. Cambridge, UK: Cambridge University Press, 1989.
- Mirowski, Philip, and Edward Nik-Khah. "Markets Made Flesh: Performativity, and a Problem in Science Studies, Augmented with Consideration of the FCC Auctions." In MacKenzie, Muniesa, and Siu, *Do Economists Make Markets? On the Performativity of Economics*, 190–224.
- Mol, Annemarie. *The Body Multiple: Ontology in Medical Practice*. Durham: Duke University Press, 2003.
- Moles, Abraham. *Information Theory and Esthetic Perception*. Translated by Joel E. Cohen. Urbana, IL: University of Illinois Press, 1968 [1958].
- . "Some Basic Aspects of an Information Theory of Music." *Journal of the Audio Engineering Society* 6, no. 3 (1958): 184–186.
- . "The Prospects of Electronic Instrumentation." *Gravesaner Blätter* 4, nos. XV/XVI (1960): 36–44.

- Moles, Abraham, and Vladimir Ussachevsky. "L'emploi du spectrographe acoustique et le problème de la partition en musique expérimentale." *Annals of Telecommunications* 12, no. 9 (1, 1957): 299–304.
- Moliné, Keith. "Hear me roar." *Wire* 278 (2007): 24–28.
- Moore, Rebecca. "SEC Takes Another Step in Regulating OTC Derivatives." July 9, 2012. Accessed July 3, 2013. http://www.planadviser.com/SEC_Takes_Another_Step_in_Regulating_OTC_Derivatives.aspx.
- Morris, Catherine, Jane Farver, Clarisse Bardiot, and Michelle Kuo. *9 Evenings Reconsidered*. Cambridge, MA: MIT List Visual Arts Center, 2006.
- Mouffe, Chantal. *The Democratic Paradox*. New York: Verso, 2000.
- Muniesa, Fabian. "Trading-Room Telephones and the Identification of Counterparts." In Pinch and Swedberg, *Living in a Material World: Economic Sociology Meets Science and Technology Studies*, 291–313.
- Muniesa, Fabian, Yuval Millo, and Michel Callon, eds. *Market Devices*. Oxford: Blackwell Publishing, 2007.
- Munster, Anna. "Data Undermining: The Work of Networked Art in an Age of Imperceptibility." In *networked: a (networked_book) about (networked_art)*. turbulence.org, 2009.
- Nechvatal, Joseph. *Immersion Into Noise*. Ann Arbor: Open Humanities Press, 2011.

- Nesbitt, Keith V., and Stephen Barrass. "Evaluation of a Multimodal Sonification and Visualisation of Depth of Market Stock Data." In *Proceedings of the 2002 International Conference on Auditory Display*. 2002.
- Neset, Anne Hilde, and Maja Ratkje. "Maja Ratkje: Woman behaving madly." *Wire* 229 (2003): 12.
- Neumark, Norie, Ross Gibson, and Theo van Leeuwen, eds. *Voice: Vocal Aesthetics in Digital Arts and Media*. Cambridge, MA: MIT Press, 2010.
- Noys, Benjamin. "Accelerationism." October 20, 2008. Accessed July 3, 2013. <http://leniency.blogspot.com/2008/10/accelerationism.html>.
- . *The Persistence of the Negative: A Critique of Contemporary Continental Theory*. Edinburgh: Edinburgh University Press, 2010.
- Nunes, Mark, ed. *Error: Glitch, Noise, and Jam in New Media Cultures*. London, UK: Continuum, 2011.
- Nyquist, Harry. "Certain Factors Affecting Telegraph Speed." *Transactions of the American Institute of Electrical Engineers* XLIII (January 1924): 412–422.
- Oliver, B.M., J.R. Pierce, and C.E. Shannon. "The Philosophy of PCM." *Proceedings of the IRE* 36, no. 11 (1948): 1324–1331.
- Olson, H. F., H. Belar, and J. Timmens. "Electronic Music Synthesis." *Journal of the Acoustical Society of America* 32, no. 3 (1960): 311–319.

- Olson, Harry F. Oral history conducted in 1975 by Mark Heyer, IEEE History Center, New Brunswick, NJ, USA. 1975.
- Olson, Harry F., and Herbert Belar. "Aid to Music Composition Employing a Random Probability System." 33, no. 9 (1961): 1163–1170.
- . "Electronic Music Synthesizer." *Journal of the Acoustical Society of America* 27, no. 3 (1955): 595–612.
- Oppenheim, Allan V., Alan S. Willsky, and S. Hamid Nawab. *Signals and Systems*. 2nd ed. New York: Prentice Hall, 1996.
- Oyola, Osvaldo. "In Defense of Auto-Tune." September 12, 2011. Accessed March 7, 2013. <http://soundstudiesblog.com/2011/09/12/in-defense-of-auto-tune/>.
- Paes, Rui Eduardo, and Maja Ratkje. "Looking forward (interview with Maja Ratkje)." Accessed July 3, 2013. http://rep.no.sapo.pt/entrevistas_ratkje.htm.
- Palombini, Carlos. "Machine Songs V: Pierre Schaeffer: From Research into Noises to Experimental Music." *Computer Music Journal* 17, no. 3 (1993): 14–19.
- Papanek, Victor. *Design for the Real World: Human Ecology and Social Change*. New York, NY, USA: Pantheon Books, 1971 [1970].
- Papoulias, Constantina, and Felicity Callard. "Biology's Gift: Interrogating the Turn to Affect." *Body & Society* 16, no. 1 (2010): 29–56.

- Patterson, Nick. "The Archives of the Columbia-Princeton Electronic Music Center." *Notes* 67, no. 3 (2011): 483–502.
- Paulson, William R. *The Noise of Culture: Literary Texts in a World of Information*. Ithaca, NY: Cornell University Press, 1988.
- Phillips, Patricia C. "Creating Democracy: A Dialogue with Krzysztof Wodiczko." *Art Journal* 62, no. 4 (2003): 32–47.
- Pickering, Andrew. *The Cybernetic Brain: Sketches of Another Future*. Chicago: University Of Chicago Press, 2010.
- Piekut, Benjamin. *Experimentalism Otherwise: The New York Avant-Garde and Its Limits*. Berkeley and Los Angeles: University of California Press, 2011.
- Pierce, John R. Interview by Harriett Lyle. Pasadena, California, April 16, 23, and 27, 1979. Oral History Project, California Institute of Technology Archives. 1979.
- Pinch, Trevor, and Richard Swedberg, eds. *Living in a Material World: Economic Sociology Meets Science and Technology Studies*. Cambridge, MA: MIT Press, 2008.
- Pinkerton, Richard C. "Information Theory and Melody." *Scientific American* 194 (1956): 77–87.

pitchforktv. "Holly Herndon defends Laptop Musicians - Pitchfork Weekly." December 5, 2012. Accessed July 3, 2013. <https://www.youtube.com/watch?v=SVK57x3UzrQ>.

Plant, Sadie, and Nick Land. "Cyberpositive." In *Unnatural: Techno-Theory for a Contaminated Culture*, edited by Matthew Fuller, n.p. London: Underground, 1994.

———. "Cyberpositive." 1994. Accessed July 3, 2013. <http://www.sterneck.net/cyber/plant-land-cyber/index.php>.

Popper, Nathaniel. "On Wall Street, the Rising Cost of Faster Trades." August 13, 2012. Accessed July 3, 2013. <https://www.nytimes.com/2012/08/14/business/on-wall-street-the-rising-cost-of-high-speed-trading.html>.

Potter, Ralph K. "New Scientific Tools for the Arts." *The Journal of Aesthetics and Art Criticism* 10, no. 2 (1951): 126–134.

———. "Visible Patterns of Sound." *Science* 102, no. 2654 (1945): 463–470.

Proschan, Frank. "The semiotic study of puppets, masks, and performing objects." *Semiotica* 47, nos. 1/4 (1983): 3–44.

Raley, Rita. *Tactical Media*. Minneapolis: University of Minnesota Press, 2009.

Ratkje, Maja. *Adventura Anatomica*. Semishigure SEMI 009, 2006.

Ratkje, Maja. *Voice*. Rune Grammofon RCD2028, 2003.

Reynolds, Simon. *Energy Flash: A Journey Through Rave Music and Dance Culture*. Berkeley, CA: Soft Skull Press, 2012 [1998].

———. “Renegade Academia: The Cybernetic Culture Research Unit.” Originally published in 1999. November 3, 2009. Accessed April 18, 2012. <http://energyflashbysimonreynolds.blogspot.com/2009/11/renegade-academia-cybernetic-culture.html>.

Roads, Curtis. *Microsound*. Cambridge, MA, USA: MIT, 2001.

Rockefeller Foundation. *Rockefeller Foundation Annual Report*, 1953.

———. *Rockefeller Foundation Annual Report*, 1955.

———. *Rockefeller Foundation Annual Report*, 1956.

———. *Rockefeller Foundation Annual Report*, 1963.

———. *Rockefeller Foundation Annual Report*, 1965.

Rodgers, Tara. *Pink Noises: Women on Electronic Music and Sound*. Durham: Duke University Press, 2010.

Rosen, Margit, ed. *A Little-Known Story about a Movement, a Magazine, and the Computer's Arrival in Art: New Tendencies and Bit International, 1961–1973*. Cambridge, MA: MIT, 2011.

Russolo, Luigi. *The Art of Noises*. Pendragon Press, 2005.

rybn. "ANTIDATAMINING." n.d. Accessed July 3, 2013. [http : / / www . antidatamining.net/](http://www.antidatamining.net/).

———. "ANTIDATAMINING VIII." April 19, 2012. Accessed July 3, 2013. <http://rybn.org/ANTI/ADM8/>.

———. *E-mail interview with the author*, April 27, 2012.

———. "FLASHCRASH SONIFICATION." n.d. Accessed July 3, 2013. <http://rybn.free.fr/ANTI/FLASHCRASH.html>.

Schaeffer, Pierre. "An interview with Pierre Schaeffer—pioneer of Musique Concrète." Interviewed by Tim Hodgkinson, 2 May 1986 for *ReR Quarterly* magazine, volume 2, number 1. 1987. Accessed July 3, 2013. [http : / / www . timhodgkinson.co.uk/schaeffer.pdf](http://www.timhodgkinson.co.uk/schaeffer.pdf).

Schafer, R. Murray. "The Music of the Environment." In *Audio Culture: Readings in Modern Music*, edited by Christoph Cox and Daniel Warner, 29–39. New York: Continuum, 2005 [1973].

Schwartz, Hillel. *Making Noise: From Babel to the Big Bang & Beyond*. Brooklyn: Zone Books, 2011.

Schwitters, Kurt. *Poems Performance Pieces Proses Plays Poetics*. Philadelphia: Temple University Press, 1993.

Securities and Exchange Commission. "Administrative Proceeding Release No. 34-59555." March 11, 2007.

Sedgwick, Eve K. *Touching Feeling: Affect, Pedagogy, Performativity*. Durham: Duke University Press, 2003.

Seigworth, Gregory J., and Melissa Gregg. "An Inventory of Shimmers." In *The Affect Theory Reader*, edited by Melissa Gregg and Gregory J. Seigworth. Durham: Duke University Press, 2010.

Serres, Michel. *Genesis*. Translated by Genevieve James and James Nielson. Ann Arbor: University of Michigan Press, 1997 [1982].

Shannon, Claude. "The bandwagon." *Information Theory, IRE Transactions on* 2, no. 1 (March 1956): 3.

Shannon, Claude E. "A Mathematical Theory of Communication." *Bell System Technical Journal* 27 (1948): 379–423, 623–656.

Shannon, Claude E., and Warren Weaver. *The Mathematical Theory of Communication*. Urbana, IL: The University of Illinois Press, 1949.

Shleifer, Andrei, and Lawrence H. Summers. "The Noise Trader Approach to Finance." *The Journal of Economic Perspectives* 4, no. 2 (1990): 19–33.

Silverman, Kaja. *The Acoustic Mirror: The Female Voice in Psychoanalysis and Cinema*. Bloomington and Indianapolis, IN, USA: Indiana University Press, 1988.

Situationist International. "Our Goals and Methods in the Strasbourg Scandal."

In *The Situationist International Anthology*, edited and translated by Ken Knabb, 263–273. Originally published in *Internationale Situationiste* #11 (1967). Berkeley: Bureau Of Public Secrets, 2006.

Solon, Olivia. "GPS 'spoofers' could be used for high-frequency financial trading fraud." February 22, 2012. Accessed July 3, 2013. <http://www.wired.co.uk/news/archive/2012-02/22/gps-spoofing>.

splintering bone ashes. "Xenoeconomics and Capital Unbound." October 19, 2008. Accessed July 3, 2013. <http://splinteringboneashes.blogspot.com/2008/10/xenoeconomics-and-capital-unbound.html>.

Spread Networks. "Spread Networks® Collocation Centers." Specifications Sheet, 2011.

SPUNK. *en aldeles forferdelig sykdom*. Rune Grammofon RCD 2048, 2007.

Star, Susan Leigh. "Power technologies, and the phenomenology of conventions: on being allergic to onions." In *A Sociology of Monsters: Essays on Power, Technology, and Domination*, edited by John Law, 26–56. London, UK: Routledge, 1991.

Steiner, Christopher. "Wall Street's Speed War." September 9, 2010. Accessed July 3, 2013. <http://www.forbes.com/forbes/2010/0927/outfront-netscape-jim-barksdale-daniel-spivey-wall-street-speed-war.html>.

Sterling, Bruce. "Contestational Robotics." September 5, 1998. Accessed July 3, 2013. <http://www.nettime.org/Lists-Archives/nettime-1-9809/msg00015.html>.

Sterne, Jonathan. *MP3: The Meaning of a Format*. Durham, NC: Duke University Press, 2012.

———. *The Audible Past: Cultural Origins of Sound Reproduction*. Durham: Duke University Press, 2003.

Supper, Alexandra. "The Search for the 'Killer Application': Drawing the Boundaries Around the Sonification of Scientific Data." In *Oxford Handbook of Science Studies*, edited by Trevor Pinch and Karen Bijsterveld, 249–270. Oxford: Oxford University Press, 2011.

Taubman, Howard. "Synthesized Piano Music Found To Have Tone Matching a Grand's." *New York Times* (1955): 35.

TheFaderTeam. "Interview with Holly Herndon." December 4, 2012. Accessed July 3, 2013. <https://www.youtube.com/watch?v=6XwUXZKu26k>.

Thompson, Emily. *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933*. Cambridge, MA: MIT Press, 2004.

Tomkins, Calvin. "Profiles: Woomera Has It!" *New Yorker* 39 (September 1963): 49–110.

Tompkins, Dave. *How to Wreck a Nice Beach: The Vocoder From World War II to Hip-Hop: The Machine Speaks*. Brooklyn: Melville House Publishing, 2010.

Trader Film LLC. "About - FLOORED." 2009. Accessed July 3, 2013. <http://flooredthemovie.com/community/>.

Traders Audio. "|| Traders Audio ||." 2009. Accessed July 3, 2013. <https://www.tradersaudio.com/amember4/signup.php>.

TradeTheNews.com. "Live Stock Market Forex News Expert Market Analysis - TradeTheNews.com." July 17, 2012. Accessed July 3, 2013. <http://www.tradethenews.com/>.

Transactions of the I. R. E. Professional Group on Information Theory 1 (1953).

Trifonova, Anna, Øyvind Brandtsegg, and Letizia Jaccheri. *Software Engineering in an Artistic Project: ImproSculpt Case Study*. Technical report. Norwegian University of Science and Technology, 2007.

Turkle, Sherry. *Alone Together: Why We Expect More from Technology and Less from Each Other*. New York: Basic Books, 2011.

———. *Life on the Screen: Identity in the Age of the Internet*. New York: Touchstone, 1995.

Various Artists. *Women Take Back the Noise*. WTBTN, 2006.

Voegelin, Salomé. *Listening to Noise and Silence: Towards a Philosophy of Sound Art*. New York and London: Continuum, 2010.

Vogl, Joseph. "Taming Time: Media of Financialization." Translated by Christopher Reid. *Grey Room* 46 (2012): 72–83.

Wagner, David. "Holly Herndon straddles 2 worlds." December 2, 2012. Accessed July 3, 2013. <http://www.sfgate.com/music/article/Holly-Herndon-straddles-2-worlds-4085441.php>.

Wamser, Christian A., and Carl C. Wamser. "Lejaren A. Hiller, Jr.: A Memorial Tribute to a Chemist-Composer." *Journal of Chemical Education* 73, no. 7 (1996): 601.

Weheliye, Alexander G. "'Feenin': Posthuman Voices in Contemporary Black Popular Music." *Social Text* 20, no. 2 71 (2002): 21–47.

Wiener, Norbert. *Cybernetics: or Control and Communication in the Animal and the Machine*. Cambridge, MA: MIT Press, 1961 [1948].

Winnicott, D. W. *Playing and Reality*. New York: Routledge, 1971.

Wissner-Gross, A. D., and C. E. Freer. "Relativistic statistical arbitrage." *Phys. Rev. E* 82 (5 2010): 056104.

Wodiczko, Krzysztof. "Ægis: Equipment for a City of Strangers." In McCorquodale, *Krzysztof Wodiczko*, 254–257.

Wodiczko, Krzysztof. "Identity and Community: Alien Staff." In McCorquodale, *Krzysztof Wodiczko*, 220–221.

———. "Interrogative Design." In *Critical Vehicles: Writings, Projects, Interviews*, 16–17. Cambridge, MA: MIT Press, 1994.

———. "Mouthpiece (Porte-Parole)." In McCorquodale, *Krzysztof Wodiczko*.

Wood, Patte, and John Robinson Pierce. "Recollections with John Robinson Pierce." *Computer Music Journal* 15, no. 4 (1991): 17–28.

Worrall, David. "Sonification and Information: Concepts, Instruments and Techniques." PhD diss., University of Canberra, 2009.

———. "The Use of Sonic Articulation in Identifying Correlation in Capital Market Trading Data." In *Proceedings of the 15th International Conference on Auditory Display*. 2009.

———. "Using Sound to Identify Correlations in Market Data." In *Auditory Display*, edited by Sølvi Ystad, Mitsuko Aramaki, Richard Kronland-Martinet, and Kristoffer Jensen, 5954:202–218. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, 2010.

Youngblood, Joseph E. "Style as Information." *Journal of Music Theory* 2, no. 1 (1958): 24–35.

Zaloom, Caitlin. *Out of the Pits: Traders And Technology from Chicago to London*. Chicago: University of Chicago Press, 2006.

Zhang, Frank. "High-Frequency Trading, Stock Volatility, and Price Discovery."
2010. Accessed July 18, 2012. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1691679.