The Ear and the Shunting Yard: Meaning Making as Resonance in Early Information Theory

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Our cultural institutions host large collections of audio recordings comprising important cultural artifacts. Some of these recordings date back to the nineteenth century and up to the present day. These recordings include music but also poetry readings, field recordings, and presidential speeches and phone calls, as well as the only recordings of languages, oral traditions, and voices that we no longer remember. We have dedicated significant resources to digitizing these collections, yet, even digitized, these artifacts are only marginally accessible for listening and almost completely inaccessible for new forms of access and scholarship. In order to discover convergences in seemingly divergent theories that may guide how we build information infrastructure around our sound heritage, this article considers how early information theory, much of which was crafted within the context of developing communication and sound technologies, can provide a framework for thinking through how to build an information infrastructure that facilitates inquiry with digital audio collections in the humanities.

Archives contain hundreds of thousands of hours of important audio files, dating back to the nineteenth century and up to the present day. Many of these files, which comprise poetry readings, interviews of folk musicians, and tales told by elders from tribal communities, contain the only recordings of significant cultural figures and bygone oral traditions. Yet, these artifacts are only marginally accessible for listening and almost completely inaccessible for new forms of analysis and instruction in the digital age. For example, an Ezra Pound scholar who visits the University of Pennsylvania PennSound online archive to analyze how Pound's cadence shifts across his 1939 Harvard Vocarium Readings, his wartime

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radio speeches, and his 1958 postwar Caedmon recordings must listen to each file, one by one, in order to determine how (or if) patterns change across the collection. Likewise, an Ojibwe *oshkabewis* (one empowered to translate between the spiritual and mundane worlds) might use recordings from the American Philosophical Society (APS) to teach students about the ways in which an English-speaking Ojibwe elder uses the Ojibwe language (Ojibwemowin) at culturally significant moments but has few means to map or show students when these transitions or "traditional cultural expressions" (TCE) typically occur. And a scholar doing research within the oral histories of the Texas Oil Industry Records at the Dolph Briscoe Center for American History cannot discover the hidden recording of Robert Frost poems within folklorist William A. Owens's recordings unless a diligent archivist has included that fact in the metadata.

That many such inquiries are essentially impossible in the digital age is more than the inconvenient result of bygone technologies or the limitations of new technologies. It is also a sociotechnical issue in which the tools being developed do not seem to match perceived user needs. In August 2010, the Council on Library and Information Resources (CLIR) and the Library of Congress (LC) issued a report titled *The State of Recorded Sound Preservation in the United States: A National Legacy at Risk in the Digital Age*.[1] This report explains that deterioration on legacy formats makes digitization of the utmost importance but also emphasizes that preservation and access problems cannot be solved through digitization alone. CLIR's *Survey of the State of Audio Collections in Academic Libraries* (2004) and CLIR's report with LC, *National Recording Preservation Plan* (2012), cite copyright legislation reform, organizational initiatives for shared preservation networks, and improvements in the processes of discovery and cataloging as the areas where research and development for increasing access and ensuring scholarship are most needed.[2] Specifically, the 2004 report calls for "new technologies for audio capture and automatic metadata extraction," since, according to the 2010 report, "the lack of sufficient cataloging or description of collections may result in the limited use of institutional audio collections and a consequent adverse impact on allocations of funding for the libraries and archives."[3] At this time, there is little provision for any uses that facilitate an archivist's ability to find genre information, such as the presence of speakers or music, or to identify the quality of a recording; there is no provision for a scholar to discover sonic patterns of interest within or across collections, such as how prosodic features change over time and space, how tones differ between groups of individuals and types of speech, or how one poet or storyteller's cadence might be influenced by or reflected in another's. Even though we have digitized hundreds of thousands of hours of culturally significant audio artifacts and have developed increasingly sophisticated systems for computational analysis of text and sound, there is no provision for these uses in the humanities.[4]

Fundamental questions remain: Can we build the information infrastructure needed to support how humanists want to interact with sound? More specifically for this discussion, can information studies provide a theoretical framework for this endeavor?

Technologies that record, transmit, reproduce, and broadcast the voice, such as the telegraph, radio, telephone, and phonograph, have been developed within the context of developing communication and sound technologies for commercial, military, scientific, or medical uses. As a result, much of the literature shaping the sociotechnical history of early information theory and sound reflects cultural critiques of existing technologies for accessing and disseminating sound that have developed from these interests (such as spectrographs, the MP3 and the iPod, and electroacoustics).[5] In contrast, this discussion considers early information theory in an attempt to imagine developing new information infrastructures that may facilitate productive inquiries with digital audio collections that reflect more humanistic concerns regarding hermeneutics or "making meaning." To this end, this discussion is divided into three parts: (1) the introduction of a use case research and development project in which humanists are asked to engage computational tools for discovery and analysis with sound collections; (2) a review of theoretical perspectives concerning hermeneutics of voice, as well as early information theory within sound studies literature; and (3) a rereading of current presentations of early information theories alongside a complementary history of philosophy and "resonance." In contrast to previous studies that have considered early information theorists, this discussion considers an alternative perspective on this rich history in order to suggest new models for developing productive information infrastructures for accessing and discovering sound in the humanities.

Background

The background for this discussion is a multiyear study funded by the National Endowment for the Humanities called High Performance Sound Technologies for Access and Scholarship (HiPSTAS).[6] The objectives of the study were to perform an assessment of user requirements and infrastructure needs for developing and supporting systems that facilitate large-scale computational analysis of spoken-word collections of keen interest to the humanities. Alongside limited software development support, a bulk of the funds supported participant use cases, travel for participants to an introductory meeting of expert panelists and workshops, and a final meeting to assess implementation needs. Both meetings took place at the School of Information at the University of Texas at Austin. The panelists included information scientists, librarians, researchers involved with indigenous communities, literary scholars, poets, and sound archivists. Participants included twenty humanities junior and senior faculty and advanced graduate students, as well as librarians and archivists from across the United States interested in creating access to and scholarship with large collections of spoken-word collections.

A significant part of the HiPSTAS project included introducing participants, all of whom had never used advanced machine-learning technologies and visualizations for accessing and analyzing audio, to the ARLO (Adaptive Recognition with Layered Optimization) software designed by HiPSTAS collaborator David Tcheng. Originally developed for acoustic studies in the fields of animal behavior and ecology to begin exploring the use of machine learning for data analysis, ARLO uses spectrograms to extract sonic features for matching, discovery (clustering), and automated classification (prediction or supervised learning).[7] A descendant of psychoacoustic and commercial technologies used to quantify speech, ARLO mimics the function of the hairs in the inner ear by modeling a bank of tuning forks that vibrate at different audio frequencies in response to sound waves.[8] Monitoring the instantaneous energy of these tuning forks by summing the potential energy (the deflection of the fork or hair) and kinetic energy (based on the speed of the movement), ARLO samples the instantaneous energy per second and creates a two-dimensional matrix of values (frequency vs. time) called a spectrogram. In the spectrogram, each pixel is a sample, and each row of pixels is a frequency band presented across an X-axis of time. Each pixel is colored according to a heat-based color scheme in which the color represents the numerical value of instantaneous energy of a particular frequency for that point in time, or how much the tuning fork, or hair, trembles. A white pixel represents the hottest or most intense energy; black represents the coolest or least amount of energy.

The ARLO infrastructure allows users to drive the creation of these spectrograms, since users can optimize the frequencies and damping factors in order to focus on an area of interest in the data—optimization that is crucial for machine learning and other analyses. For example, the spectrogram is computed using band pass filters linked with energy detectors, giving the user a number of parameters to control the way these are calculated, including sampling the entire audio spectrum or tuning the spectrum between a shorter range of frequencies to extract energy intensity profiles for that range. In order to prevent the tuning forks from accumulating too much energy or ringing forever, users can apply a tunable damping factor to each tuning fork in order to create a drag (much like air does). The effect of the damping factor is to make the tuning fork more or less sensitive to pitch and time information, thereby allowing the user to focus on aspects of sound specific to her interests.

The machine-learning algorithm ARLO uses to find events in audio is called "instance-based learning" (IBL). In IBL, the software "learns" a number of examples provided by the user and matches them against new examples to return results. Users determine a number of parameters for unsupervised and supervised learning, including the damping factor and the sampling rate, since to find a match in an audio stream is to find it in a certain number of positions per second. ARLO finds matches by taking each example provided by the user and "sliding" it across new audio files, looking for good matches. This means that users can shape each example for discovery by interacting with the spectrograms that ARLO produces (as described above), since changing these parameters means changing the sonic features ARLO uses for machine-learning tasks. In the case of the ornithologist who is examining thousands of hours of bird calls, this means marking examples of a particular call and asking the software to "go find more like these" based on the sonic features captured in the spectrogram.

The HiPSTAS workshop was developed to allow the participants to use the ARLO software to query large collections with which they were already familiar, including thirty thousand files of recordings from PennSound's poetry archive; six hundred thousand digital collections objects from the Library of Congress's American Folklife Center; thirty thousand hours of oral histories from StoryCorps; and three thousand hours in the American Philosophical Society's Native American Collection, which includes recordings from more than fifty tribes across Native America. Other collections of interest to the participants included collections of speeches from the Southern Christian Leadership Conference; readings and lectures in the Elliston Poetry Collection at the University of Cincinnati; and interviews in the Dust, Drought and Dreams Gone Dry: Oklahoma Women and the Dust Bowl (WDB) oral history project out of the Oklahoma State University Libraries.

While the applications and tools HiPSTAS participants had used previous to the workshop helped them align textual content to audio files in these collections and to visualize volume and tempo intensity for finding tracks or quality discrepancies, these applications provided them with very limited access to the collections' sonic features, which Charles Bernstein and others have identified as significant for linguistic and literary analysis.[9] Linguists argue that listeners make meaning with prosodic elements such as rhythm and tempo, pitch and intonation, which convey meaning through phrasing and prominence.[10] It is argued that these elements, used to study human behavior, culture, and society, reflect affect and emotional engagement, as well as age, cognitive process and development, ethnicity, gender, and region.[11] For poets and literary scholars, these sound traits ("the emphasis and character of the line, the pausing and halting of a voice among caesurae, the pattern of vowel music, the tone of delivery—and of course those points where the ear has failed and the line has gone flat") make meaning, since they indicate "the general trajectory of words, the large movements of syntactic play, the rhythms, which remain as much the meaning of the poem as does its semantic content."[12]

At the onset, however, very few of the HiPSTAS participants found the sonic features identified by ARLO useful for their explorations.[13] Instead, participants spoke of wanting to consider "media ecologies" by analyzing "sounded affinities between poets," for example, or "concepts of community poetics through sound" in order "to look at groups of poets who have a common locale in terms of their community formation"; they wanted to investigate "how ARLO may or may not track affinities across gender lines." Another participant wanted to discover what it meant to think through "how a digital archive can recover intangible and ephemeral yet deeply powerful social experiences of sound," including "what themes of identity, gendered relations, and intercultural relations, may be heard in the Native speakers' and singers' expressions and performances of the recorded stories and songs in the collections"; this participant wondered, "How might we thematize and index sounds to address issues of indigenous sonic embodiment in files from which we can hear but not necessarily see the speakers and singers? What are the [sonic] differences and similarities among performers of similar source material? How do these performative differences/similarities map or not map onto other factors (race, gender, region, class, age, etc.)?" Another participant wanted to analyze the APS holdings in order to classify Navajo speakers against a map of origin in order to illustrate the location of a speaker. With the ultimate goal of "develop[ing] a cultural map to show spheres of influence of those language-speaking approaches on the stories and motifs across time and in proximity to historical centers of tribal trauma," this participant wanted to use ARLO "to determine whether dialectical region or if proximity to historical centers of tribal trauma (e.g. boarding school experiences or Navajo Long Walk) influence that speaker's . . . Beauty Way and Protection Way approaches to speaking the Diné language."

Attempting to think through how software like ARLO affords access to and scholarship with sound frequencies rather than semantic content quickly evolved into questions concerning whether or not participants' inquiries could be facilitated by a machine. A typical question for participants who were dubious about how ARLO could enable access for the kinds of questions they were used to asking through access with transcripts was "What can spectrograph visualizations of oral history interviews tell us beyond the transcripts?" Could a computer be taught to identify a Beauty Way speaker versus a Protection Way speaker? Arguably, spectrograms make clusters of sonic features across time more accessible; users can see how loudness or amplification changes or corresponds to different frequencies across a timed sequence of audio events. Yet, mapping clusters with cultural concepts such as gender, race, and identity (which are tied to notions of "Protection Way" or "Beauty Way") seemed wholly inadequate to participants.

Defining the sonic features that map to specific cultural characteristics of the voice in spoken-word recordings caused much frustration. Better understanding of how humanists make meaning with the voice, which is such a profoundly personal and cultural phenomenon, is productive in helping to reframe how we develop computational systems for discovering or analyzing traces of voices through sonic traits.

Theories of the Voice in Cultural and Information Studies

Walter J. Ong once announced that recording technologies heralded a new age in the study of the voice, which was "muted by script and print."[14] Still, others argue that there is "something about speech that defies theory."[15] Along this spectrum, theories in sound studies use sound to consider a range of "big questions about the cultural moments and crises and problems of [the] time."[16] Within the *Sound Studies Reader* (2013), for example, Jonathan Sterne breaks the cultural study of sound into sections that represent what he sees as the main areas for new inquiries, including a range of theories and perspectives on the act of audition; a sound environment such as the city or the recording space;

the technological transduction, reproduction, and transmission of sound; communities of sound in radio and broadcasting; and sound aesthetics in literature and culture.[17] Notably, it is the last section, titled "Voices," upon which Sterne places special emphasis, claiming that these particular readings on the "most basic of human faculties" are debates over "what it means to be human," since people understand themselves and others through their voiced self-expressions.[18]

Some theories position the study of sonic vocal traits as meaningful only within the context of structural codes for meaning such as language. Roland Barthes identifies two aspects of the voice in vocal music, for instance, that contribute to meaning making: the pheno-song and the geno-song. The pheno-song refers to the structured elements of a piece such as "the language being sung, the rules of the genre, the coded form of the melisma, the composer's idiolect, the style of the interpretation: in short everything in the performance which is in the service of communication, representation, expression." The geno-song, on the other hand, is the material or corporeal aspect of the voice and maps to sonic features; it is the "volume of the singing and speaking voice, the space where significations germinate."[19] Privileging the pheno-song as more productive for communicating meaning, Barthes maintains that the geno-song is a system for transmitting that meaning. The geno-song has "nothing to do with communication, representation (of feelings), expression"; instead, the geno-song has "that apex (or that depth) of production where the melody really works at the language—not at what it says, but the voluptuousness of its sound-signifiers, of its letters—where melody explores how the language works and identifies with that work . . . the diction of the language."[20] For Barthes, the hermeneutics of "close listening" requires a concert of pheno-song with geno-song, since the pheno-song communicates, while the geno-song transmits that communication.[21]

While Barthes represents sonic features as noncommunicative or unexpressive, Michael Chion asserts that these features do have meaning, but our lack of a descriptive system precludes our ability to listen closely to them. In his essay "The Three Listening Modes," for example, Chion approaches sound study by considering a hermeneutics of listening in the form of causal, semantic, and reduced listening.[22] In *causal listening*, the listener seeks to find out more about the source of the sound, whether the source is a tuba, a man, or a female child. In *semantic listening*, one listens to "interpret a message"; thus, according to Chion, "causal listening to a voice is to listening to it semantically as perception of the handwriting of a written text is to reading it."[23] Chion describes listening to the sonic traits of a sound "independent of the sound's cause or comprehension of its meaning" as *reduced listening*.[24] Such listening precludes description and therefore meaning making, he argues, for two reasons: fixity and language. The "fixity" of sonic features through recording is necessary for close listening, since to perceive sonic traits, one must listen repeatedly. Chion, however, dismisses fixed sounds as "veritable objects" and as "physical data" that do not, he argues, represent what was actually spoken or what was actually heard within an authentic moment of uniqueness and real-time "presence." As a result, he considers reduced listening "an enterprise that is new, fruitful, and *hardly natural*."[25] Chion argues that our language for describing such sounds is ambiguous at best. He supports his assertion by describing a session of frustrated reduced listening:

> Participants quickly realize that in speaking about sounds they shuttle constantly between a sound's actual content, its source, and its meaning. They find it is not a mean task to talk about sounds in themselves, if the listener is forced to describe them independently of any cause, meaning, or effect. And language we employ as a matter of habit suddenly reveals all its ambiguity: "This is a squeaky sound," you say, but in what sense? Is "squeaking" an image only, or is it rather a word that refers to a source that squeaks, or to an unpleasant *effect*?[26]

Like Barthes, Chion privileges language codes for making meaning: "Sound," he writes, "is not defined solely by its pitch." Chion is arguing that the voice cannot be interpreted without reference to the semantic meanings carried by the words spoken, because our "present everyday language as well as specialized musical terminology are totally inadequate to describe the sonic traits."[27]

However, this argument that the voice is only meaningful in the context of speech that transmits a message is a logocentric theoretical stance that has been readily contested. Arguing that the voice as understood from this perspective privileges articulated speech and a disembodied "unique" voice, Adriana Cavarero, for example, asserts that "logocentrism radically denies to the voice a meaning of its own that is not always already destined to speech."[28] Cavarero wants to "pull speech itself from the deadly grip of logocentrism" in order to "understand speech from the perspective of the voice instead of from the perspective of language."[29] This critique counters the viewpoints of scholars such as Walter Ong and Marshall McLuhan who at once essentialize the voice as "presence" and disembody and mythicize orality. McLuhan argues that "neo-acoustic space gives us simultaneous access to all pasts. As for tribal man, for us there is no history. All is present, and the mundane becomes mythic."[30] It is because of these perspectives, Joshua Gunn argues, that privileging speech as "the stabilizer and achievement of voice, was killed" in theoretical discussions; "the voice it carries," he writes, "cannot be quieted or stilled; even in silence, the voice will not shut up."[31] In other words, if we treat language simply as code "whose semantic soul aspires to the universal," we render "imperceptible what is proper to the voice."[32]

Reflecting the stance of literary scholars who study experimental poetry to understand where the avant-garde pushes against and comments on culturally constructed language norms, Cavarero argues for understanding speech as "the point of tension between the uniqueness of the voice and the system of language."[33] Similarly, Mladen Dolar asserts that "it is not that our vocabulary is scanty and its deficiency should be remedied: faced with the voice, words structurally fail."[34] Entertaining the notion of a "linguistics of non-voices," including coughing, hiccuping, babbling, screaming, laughing, and singing, Dolar places these sounds outside of phonemic structures yet *not* outside of linguistic structure.[35] Seeking possibilities for studying aspects of the voice such as accent, intonation, and timbre, Dolar asks the question at the heart of all these queries: "How can we pursue this dimension of the voice?"[36]

In the next section, I look at early information theories on communication and meaning as a perspective in order to imagine systems that might afford and shape a hermeneutics in which the study of the voice and the computational analysis of sonic features are potentially reconciled.

Early Information Theories of Meaning

Early theories of information and meaning were developed within a context of new and emerging technologies for recording, transmitting, and receiving speech. These theories were cybernetic in nature: they imagined information systems that could be supposed to "think" because they could speak and listen like human beings. In Claude Shannon and Warren Weaver's book *The Mathematical Theory of Communication* (1949), for example, Weaver makes a connection between a theory of communication, a statistically based theory of meaning, and "the logical design of great computers" that "think," such as Shannon's widely publicized work on a chess-playing computer.[37] Fellow Bell Labs engineer John Pierce writes in *An Introduction to Information Theory: Symbols, Signals* *and Noise* (1961) that information theory "is useful in connection with written and spoken language, the electrical and mechanical transmission of messages, the behavior of machines, and, perhaps, the behavior of people."[38] Defining cybernetics as the study of "traffic between animal and machine," Jonathan Sterne argues that these theorists "tended to elide the difference between brains and media"; their imaginings were products of their time, "suffused in military thought and practice" while promoting "fundamentally economic and economistic logics."[39]

One point in common for many theorists is that they formed foundational information theories using Claude Shannon's original 1948 publication "A Mathematical Theory of Communication" as a starting point for considering the role meaning making has in information systems. Shannon set definitions of "meaning" outside of information theory because, he argued, meaning is apart from the mechanics of transmission. The revolutionary aspect of Shannon's work is that he statistically positions "noise" against "signal" to resolve "the fundamental problem of communication . . . reproducing at one point either exactly or approximately a message selected at another point."[40] Shannon's mathematical formulas and "schematic diagram of a general communication system" demonstrate this process. In this formula, the information source (e.g., the writer or the speaker) produces a message, which a transmitter encodes into a signal for transmission over the channel; the receiver then decodes the signals, thereby "reconstructing the message" for the "destination" or "the person (or thing) for whom the message was intended."[41] "Noise" in this schematic represents disturbances in the signal that create uncertainty as to whether or not the message that was received was the message sent. "Information" within Shannon's work becomes a function of the degree of uncertainty or the degree of entropy that is "produced when one message is chosen from the set" on the receiving end and that message is compared against the "intended" message from the information source.[42] Consequently, Weaver will subsequently argue that there is "more information" when "the received signal is selected out of a more varied set than is the transmitted signal."[43] Shannon is well known for dismissing the treatment of meaning within the transmission of a message: the "fundamental problem of communication," he writes, is that "frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities"; "these semantic aspects of communication," he continues, "are irrelevant to the engineering problem."[44]

While Shannon proclaims that meaning is irrelevant, Weaver and Pierce attempt to reconcile the role meanings must play in computing systems that are intended to "think" like humans. Weaver readily admits that a theory of communication that does not deal with meaning is "disappointing and bizarre."[45] To alleviate this concern, Weaver argues that Shannon's theory is merely discussing one level of a tripartite problem, the rest of which readily concerns meanings. That is, the overall triadic communication problem includes not only the "technical problem" or the "engineering problem" but also the "semantic problem" and the "effectiveness problem." For Weaver, the technical problem is concerned with the extent to which the received message symbols match the intended or sent message symbols (no matter if that message is made of a nonsensical language). His semantic problem, on the other hand, concerns whether the meaning *intended by* the sender is received by the recipient; meanwhile, the effectiveness problem is "concerned with the success with which the meaning conveyed to the receiver leads to the desired conduct on his part."[46] Admittedly, the effectiveness problem is a "very deep and involved situation," even in the case of "the relatively simpler problems of communicating through speech"; nevertheless, Weaver claims that a theory of communication can be as much an "engineering communication theory" (one that helps to determine whether a telegraphic system has delivered the right message) as it is a "real theory of meaning" or a framework for helping to think through what Weaver calls the semantic and effectiveness problems in communication in general.[47]

Weaver defines information as a measure of uncertainty based on the information source's "freedom of choice" in selecting a message to send. Measuring "what you *could* say" rather than "what you *do* say," Weaver measured information by the logarithm of the number of available choices that correlated to a statistically viable (on vs. off) representation of transmission success.[48] Consequently, when a communication system is "highly organized" and lacking "a large degree of randomness and choice" or entropy, information is low. On the other hand, when uncertainty that "arises by virtue of freedom of choice on the part of the sender" produces entropy, information is high.[49] While information is also high when undesirable uncertainty due to "errors" is introduced either by the channel or by the recipient, this information is considered noise or useless. "To get the *useful* information in the received signal," Weaver writes, "we must subtract out this spurious portion."[50] Ultimately, Weaver attempts to outline a "real theory of meaning" using Shannon's definitions of information as uncertainty. In this theory (which is an attempt to quantify meaning in order to measure a system's success or lack of success in communicating it), Weaver asserts that "desirable" and "undesirable" uncertainty (and therefore *information*) can be measured against the information source's intended meanings. Consequently, "the concept of information applies not to the individual messages (as the concept of meaning would)," Weaver writes, "but rather to the situation as a whole."[51]

Donald MacKay, a physicist at Kings College, London, and later at the University of Keele in Staffordshire who wrote widely on communication and neuroscience, also defined meaning in terms of the system of transmission, likewise using information theory to conceptualize computing machines that speak, listen, and think like humans. In an introduction dated 1968 to his collected talks on information science, MacKay looks back twenty years to the origins of his academic interests in information theory and technical computation. Citing the "lure of a new trail," MacKay identifies his own drive as an academic specifically as a quest for thinking through the following question: "What kind of a computing mechanism, one wondered, would be best adapted to handle the most general possible transformations of information? In particular, what sort of mechanism must the human brain be, in order to deal as it does with the sort of thing that information is?"[52] In particular, MacKay sought a theory or "conceptual bridge" by which he could talk about information "in relation either to human beings or to mechanical systems—or indeed to human beings as mechanical systems."[53] MacKay's work with computer technology considered the differences (rather than the similarities) between the human brain and computers.

Unlike Weaver, MacKay considered the perspective of the recipient rather than that of the information source, defining meaning as "a relationship between message and recipient."[54] Specifically, meaning is based on the source's understanding of "the listener's range of states of readiness" or the source's consideration for the range of possible meanings that might effect a listener's response.[55] Communication would begin with the information source for whom the intended meaning is the intended selective function the message should enact at its destination. Thus, MacKay defined *selectional information content* as a measurement of the extent to which this understanding of the recipient's readiness matched this enactment or effected response. This measurement, MacKay theorized, would necessarily have to take into account three different but interrelated types of meaning (intended, received, and conventional meaning) that effected responses. The message's intended meaning is what the information source intended (based on an understanding of readiness); the effective meaning is the selective function that the message actually enacts on the receiving end; and the conventional meaning is representative of a general or understood meaning.[56]

Because of MacKay's focus on the recipient, Katherine Hayles (1999) and Mark Hansen (2006) have attempted to situate MacKay's discussions of meaning within humanistic hermeneutics.[57] In particular, they argue that MacKay's emphasis on the role of the recipient presents a reconciliation of embodied contexts ("body" and "affect") and information theory. Contending that meaning in MacKay's work (as it is in the theories of Shannon and Weaver) is situated squarely in the context outside of the mechanical transmission of the message, however, Paul Kockelman critiques Hayles and Hansen for what he calls their misguided attempts to use MacKay's theories in order "to put the 'human' (as well as affect, meaning, and the body) back into a theory of Information."[58] In contrast to these ideas, Kockelman associates MacKay's theories with Shannon's and Weaver's, maintaining that MacKay's theory of meaning remains "relatively formal, quantitative, objective, and context-independent."[59] Instead, Kockelman asserts that MacKay's theories are offerings in which information is "the enclosure of meaning"; that is, information discloses or brings meaning to our attention, but information is not "of meaning" per se. Accordingly, Kockelman concludes that "if we think about meaning as disclosure—in the sense of bringing something to the attention of another—each of their [MacKay, Pierce, Shannon, and Weaver, among others] understandings of information may be understood as an attempt to enclose disclosure."[60]

In contrast to this perspective, I argue in the next section that MacKay's "theory of meaning" is a "theory of meaning making." This perspective positions information as a function of the meaning *making* rather than the meaning*ful* possibilities of a system; it discloses the processes of meaning *making* rather than meaning itself. Reframing MacKay's theory of information in this way—specifically by looking more closely at his use of the ear as a metaphor for the technological and philosophical contexts of his theory's development—repositions MacKay's theory of information as a productive perspective for considering how to design an information system that facilitates the kinds of expanded humanist inquiries with sound that scholars such as Cavarero, Dolar, and the HiPSTAS participants have imagined.

The Ear, Resonance, and Meaning Making in Information Studies

The history of our understandings of sound technologies in commercial, military, and science research-based practices has emerged alongside our understandings of how the ear works within deaf and deaf education, experimental phonetics, and psychoacoustic communities.

Scholars such as Mara Mills, Bernhard Siegert, and Jonathan Sterne (among others) have detailed the coemergent relationship between early information theorists and this history.[61] The relationship between early information theorists such as MacKay and the combined history of "reason and resonance" or *philosophy* and otology, however, has not been adequately examined.

Marshall McLuhan pronounced that "all Western 'scientific' models of communication are, like Claude E. Shannon and Warren Weaver's Model of Communication, linear, logical, and sequential in accordance with the pattern of efficient causality."[62] Claiming that this schematic "is a kind of model of a hardware container for software content," McLuhan asserted that this model "stresses the idea of 'inside' and 'outside' and assumes that communication is a kind of literal *matching* rather than resonant *making*."[63] A model for "resonant making" and a move toward the breakdown of the false distinctions that position meaning as "inside" or "outside" a system of communication are clearly implicated in the inquiries that Cavarero, Dolar, and others have imagined. In particular, they seek to better understand the voice as the resonance of linguistic and nonlinguistic sounds, and they desire a means to listen that is not geared toward separated modes of listening (or meaning making with sound) that rely on "reduced listening" to sonic parts or separated foci such as the geno-song or pheno-song.

Significantly, MacKay's model for a computing mechanism is based on the human system that reflects this kind of "close listening" environment. Defining his theory of information as a "theory of processes by which representations come into being," MacKay imagined "a computing mechanism" mirrored on the human brain that is "best adapted to handle the most general possible transformations of information" and "to deal with the sort of [complex] thing information is": the ear.[64] In a piece titled "Meaning and Mechanism," which was originally broadcast on the BBC Radio in January 1960, MacKay uses the human ear as an analogy for the complexities inherent to this system in which meaning-making processes occur:

> A human conversation depends on many processes which a scientist would call "mechanical," in the sense that only physical categories of cause and effect are needed to describe and explain them. Puffs of air produced by vibrations of the speaker's larynx, echo around the cavities of his mouth and result in a characteristic sequence of sound waves. These travel through space and vibrate the sensitive membrane of the listener's ear, giving rise to nerve

> impulses, and so on. Now, until the chain of explanation reaches the nervous system, nobody minds its mechanistic flavour. True, it has made no reference to the meaning of what is being said; but this, we might say, would obviously be premature.[65]

In this analogy, MacKay uses the example of the ear as a descriptive illustration to set up a false distinction between the mechanics of message transmission (the production of "vibrations") and the meanings created by the reasoning mind through the nervous system. Anticipating a question about meaning from an imaginary reader (or listener), MacKay implies in his straw man scenario that processing a communicated message (whereby sound waves become vibrations become nerve impulses become thoughts) is completely "mechanical": "Isn't the process by which the nerves convey these titillations to the brain a mechanical one?" he asks. "And what then? Isn't the next neurophysiological stage, though still puzzling in detail, plainly a mechanical one too?"[66] MacKay's ultimate goal in articulating the blurred boundary between the meaningful and the mechanical is to inquire "Where are we to draw the line?" and to suggest, in contrast, that we cannot: "I hope to show," MacKay decries, that "this opposition of 'meaningful' and 'mechanical' is false."[67]

Before looking more closely at MacKay's theory of information as a theory of resonant processes, it is useful to understand the relationship of reasoning to resonance as that relationship has been historically associated with the physiology of the ear—a physiology with which MacKay's community of scholars was also well acquainted. Veit Erlmann's *Reason and Resonance* (2010), for example, positions theories of reason from René Descartes's *De l'homme* (1664) to Martin Heidegger's *Sein und Zeit* (1927) within the context of developing understandings of the workings of the human ear:

> While reason implies the disjunction of subject and object, resonance involves their conjunction. Where reason requires separation and autonomy, resonance entails adjacency, sympathy, and the collapse of boundary between perceived and perceiver. Resonance is found in many areas, whether it is current within an electrical circuit that surges back and forth in step with the frequency of a signal coming from the outside or the representation of a normal state of a molecule by a combination of several alternative distinct structures among which the molecule moves. Most importantly, however, resonance is also taken to be at the base of how the human ear works.[68]

Erlmann tells an alternate history of modernity that includes a rich tradition of inquiry through the "Age of Reason" in which objectivity and subjectivity coexist. In this history, empiricism does not override subjective perspectives influenced by sensation, emotion, or situated and embodied meanings; these perspectives resonate. Describing a history of philosophy in which scientific reason commingles with a more subjective and situated notion of resonance, Erlmann describes how this historical trajectory mirrors a developing understanding of the physiognomy of the ear as a system that both *hears* as a physical organism and *listens* or interprets as a conduit to the mind.[69] It is a system that is both of mechanics and of meaning.

A further explanation of MacKay's theory of information will help illuminate the role resonance can play in an information system. When referring to *selective information content*, MacKay describes the kind of simple matching that McLuhan critiques as "a scenario in which information could be thought of as the answer to a question" or "one in which we are interested in choosing from a set of ready-made alternatives."[70] A problem that relies on *descriptive information content* for resolution, on the other hand, is more subjective: it is subject rather than object oriented; it is one in which we are "not to select but to build a picture . . . brick by brick."[71] MacKay called descriptive information content "information as construction" and broke it into metrical and structural units that he imagined related on a kind of two-dimensional plane in which metrical units reflect information about "atomic facts" and "provide one elementary building-block for an abstract representation of what occurred"; MacKay imagined that "the total of such building blocks [would be] distributed among the various categories or 'degrees of freedom' made available by the instrument, in much the same way as unit events are distributed among the columns of a histogram."[72] Giving agency to the "recipient" or user of the system, MacKay theorizes subjective "building blocks" ("abstract representations") as the base units of information provided by the user, while structural units imposed by the system provide information about the "degrees of freedom" or the dimensions of the representation.[73] It is MacKay's triangulation of these elements as information in process that brings us back to the resonating space for meaning making that was originally provided by his ear analogy.

Ultimately, MacKay imagines information in process as akin to building a three-dimensional field. "Selective, structural, and metrical information content are like volume, area, height," MacKay writes.[74] In triangulation, this process provides for a kind of cavity with volume, area, and height that shapes and allows for meaning making. Likening this process to what happens in the brain when one hears a message, MacKay offers another analogy—a railway shunting yard with a control box:

> At any given moment, the configuration of the levers in the box defines what the yard is ready to do to any wagon that happens to come along. . . . The selective job, of determining which levers shall move depends on the *form* of the message, and on the state of your brain before you hear it. This is where the meaning of the message comes in. . . . It isn't until we consider the range of other states of readiness, that *might have been selected but weren't*, that the notion of meaning comes into its own.[75]

In other words, MacKay realized that a state of readiness (the state of the brain), which precipitates the selection of the message, has been built by descriptive content information (the form of the message). We cannot build our hypotheses without the structures of information, a building or space that represents possible selections (by the availability of a certain range or depth of features) from a number of *plausible* (given the state of the "yard") selections. Triangulating these types of information makes the space in which meaning making happens—where resonance affords reasoning. Said differently, the mechanical system (the levers in the yard) affords the field of information (the shape of the yard) for the simultaneous process of selecting and constructing that is meaning making.

MacKay's theory of information attempts to resolve the tensions that Dolar locates in a similar physiognomic analogy. Like MacKay's journey through the ear, Dolar's perambulation to locate the embodied origin of the voice proves impossible. Traveling down the throat into the larynx, Dolar argues, "the source of the voice can never be seen, it stems from an undisclosed and structurally concealed interior, it cannot possibly match what we can see"—the source of the voice, in other words, cannot be defined by observation.[76] In Dolar's theory, the meanings we make—our understandings of the voice—are afforded by the resonant space our own systems for communication engender: "The voice stands at a paradoxical and ambiguous topological spot, at the intersection of language and the body. . . . What language and the body have in common is the voice, but the voice is neither of language nor of the body."[77] Consequently, it cannot be discerned by segregated, "reduced listening." Meaning *is not of* (does not match) the message, the transmission process, or the machine; what the message, the transmission process, and the transmission machine have in common is the space for resonant meaning making that

MacKay's theory of information attempts to imagine. Like MacKay, Dolar insists that there is no line between the mechanical and the meaningful. We cannot listen to or understand the voice either as a representative of or as a stand-in for the present body, the structured prose, or the machine that seems to listen or speak. Like MacKay, Dolar describes a framework for listening that reflects an interpretive field, "a paradoxical and ambiguous topological spot" where selective and descriptive information content about the body and language, about the information source, and about the information destination resonate.

Conclusion

Understanding a theory of information as a theory of processes by which representations (or understandings) come into being is crucial in this significant historical moment in which computational approaches and humanistic inquiry must also resonate to make "dark" sound archives more accessible for interpretation. Kockelman argues that MacKay's information triad maps *separately* into theories concerning construction, replication, and meaning: "Construction (of representation) maps onto structural and metrical information-content; replication maps onto selective information-content; and effect maps onto meaning, or change in conditional readiness (which itself . . . may be measured in terms of the selective information-content of a different ensemble)."[78] I have proposed a different mapping in which MacKay's selective, structural, and metrical information resonates and the "effect" of the information reflects meaning making rather than meaning itself. At the same time, MacKay reminds us that "what we really want in each case is to discover the method which will give us the maximum amount of information for a given outlay of time or space or other resources."[79] Using the ear as an analogy helps us reframe a theory like MacKay's and reconsider the nature of information that a system for accessing and analyzing the voice should afford.

For instance, understanding the ear as an analogous system makes it clear that developing an information system in which information reflects the perspectives of both the perceived and the perceiver is crucial for humanist inquiry. In the 1980s, at the onset of critiques geared toward analyzing taped recordings, Michael Davidson admonished criticism that focused on recordings as signposts for authorial intentions. "No simple correspondence exists between acoustic event and poetic meaning," Davidson writes. He further warns against the "pursuit of an independent or originary meaning" by reminding his readers of the complicated interactions that happen inside the poet's ear: "Since the poet 'hears' as much as 'thinks' (or to phrase it more accurately, since he hears his thinking), this sounded dimension is a source, rather than a reflection of poetic meaning."[80] Similarly, Richard Poirier insists that modernist literary texts such as Marcel Proust's *Remembrance of Things Past* and James Joyce's *Ulysses* (and I would add Gertrude Stein's *The Making of Americans*) are highly organized texts created precisely to inspire readers to let go of a desire for mastery over the message. He suggests that authors' intentions are unknowable and their freedom of choice is high, since "in reading what they are writing [modernist writers] find only the provocation to alternatives." As it does for the poet who hears his thinking aloud, meaning for the writer "resides in the performance of writing and reading, of reading in the act of writing."[81] So, too, meaning making may be prompted by a computational system that is built on the presupposition that supporting uncertain intentions and a variety of understandings produces productive results.

Understanding the ear as an analogous system also makes it clear that the success of the system can only be measured subjectively, by the extent to which it facilitates productive subjective interpolations within a discursive community. Kockelman writes that MacKay "offered a quantifiable model of meaning" and that "the problem with MacKay's account of meaning was not mathematical quantification; the problem was empirical measurement."[82] Put differently, MacKay offered a quantifiable model of information that offered an account of *meaning making*, the success of which could not be empirically measured. Testing whether a system has successfully provided information to facilitate interpretive work represents a measurement problem that is altogether different from quantifying whether a message has been transmitted successfully, however. If, for example, we consider Weaver's semantic problem a condition for making meanings rather than a problem to solve, there is no anticipated or "intended" resolution against which we can offer a statistical measure for success or failure. Weaver himself proves this point in his own "minor additions" to Shannon's schematic. When advising, for instance, of the necessity of the encoding and decoding semantic nodes, he warns that sending confusing messages is "overcrowd[ing] the capacity of the audience." Unable to quantify how much confusion could be considered "over capacity," he describes meaning as a substance with which the information source can, "so to speak, fill the audience up and then waste only the remainder by spilling."[83] This is an attempt at describing meaning and our ability to process meaning in terms of definitive limits.

To the contrary, as discussed, when uncertainty is increased, information is high. When information is high, meaning making happens in accordance with "a given outlay of time or space or other resources," including what has been defined as "noise" by the system (and the user). McLuhan proclaims that, "faced with information overload, we have no alternative but pattern-recognition."[84] According to MacKay, reframing information theory as a "theory of processes" means understanding that information shapes the patterns we can recognize; an "apparatus which gives us the most descriptive information . . . which yields the largest number of bricks" is one that helps us build or construct *productive* interpretations.[85] Measuring the amount of information that leads to productive interpretations becomes an issue of measuring the effect of that information or "the *precision* or *reliability*" of our resulting interpretations within a discursive community, an evaluative process that is more in line with the subjective practices of peer review than quantifiable statistics.[86]

The convergence in the humanities of these two points concerning intention and evaluation is best illuminated with an example that illustrates the ambiguity inherent in studies with sound and makes real the need to have information systems that make available the building blocks (both selective and constructive) for resonant meaning making. In a recording titled "Halimuhfack" from the WPA Collections recorded in Florida in June 1939 and now made accessible as part of the Library of Congress American Memory project, Zora Neale Hurston describes to Herbert Halpert, a fellow anthropologist, how she learns and collects songs. When asked how she learns a song, she says, "I just get in the crowd with the people if they're singing and I listen as best I can and I start to joining in with a phrase or two and then finally I get so I can sing a verse and then I keep on until I learn all the song, all the verses, and then I sing them back to the people until they tell me I can sing them just like them." Halpert asks if this is the same way she collected the songs she published in the journals and the book she published. Yes, she says, "I learned the song myself and I can take it with me wherever I go."[87] In this brief anecdote, we see resonance in action; we see the boundary between perceived and perceiver blurred; we see what sort of mechanism the human brain must be in order to deal as it does with the sort of thing that information about cultural sound artifacts entails; we see how the seemingly simple acts of recording, storing, sharing, and interpreting reflect a communication process that requires interpolation as well as peer and community evaluation and feedback.

The process of making meaning from recordings such as this one or any of those represented in the collections with which HiPSTAS participants have been working indicates that these are artifacts of culturally situated communicative processes, the study of which requires nuance, resonance, and more conversation. In light of this perspective on the complicated nature of critiquing the cultures in which we are embedded, the answer to MacKay's question "What kind of a computing mechanism . . . would be best adapted to handle the most general possible transformations of information?" is still the human brain. Likewise, the human ear is a productive model for developing a computing mechanism that facilitates access to the voice—it serves not only as a model for a situate mechanism but also as a testament to the fact that what continues to be meaningful is what resonates.

Notes

1. Council on Library and Information Resources and the Library of Congress, *The State of Recorded Sound Preservation in the United States: A National Legacy at Risk in the Digital Age* (Washington, DC: National Recording Preservation Board of the Library of Congress, 2010).

2. Abby Smith, David Randal Allen, and Karen Allen, *Survey of the State of Audio Collections in Academic Libraries* (Washington, DC: Council on Library and Information Resources, 2004); *The Library of Congress National Recording Preservation Plan* (Washington, DC: Council on Library and Information Resources and the Library of Congress, 2012).

3. Smith, Allen, and Allen, *Survey*, 11; Council on Library and Information Resources and the Library of Congress, *The State of Recorded Sound Preservation*, 42.

4. The Digging into Data challenge, which is funded by a variety of US and international agencies, is a testament to the wide array of perspectives and methodologies digital projects can encompass. In particular, the first (2009) and second (2011) rounds of awards included projects that use machine learning and visualization to provide new methods of discovery. Some analyze image files ("Digging into Image Data to Answer Authorship Related Questions") and the word ("Mapping the Republic of Letters" and "Using Zotero and TAPoR on the Old Bailey Proceedings: Data Mining with Criminal Intent"). Others provide new methods for discovery with audio files by analyzing large amounts of music information (the "Structural Analysis of Large Amounts of Music" and the "Electronic Locator of Vertical Interval Successions [ELVIS]" projects) and large-scale data analysis of audio, specifically the spoken word (the "Mining a Year of Speech" and the "Harvesting Speech Datasets for Linguistic Research on the Web" projects).

5. See Jonathan Sterne, *MP3: The Meaning of a Format* (Durham, NC: Duke University Press, 2012); M. Mills, "Deaf Jam: From Inscription to Reproduction to Information," *Social Text* 28, no. 1 (2010): 35–58; Roland Wittje, "The Electrical Imagination: Sound Analogies, Equivalent Circuits, and the Rise of Electroacoustics, 1863–1939," *Osiris* 28, no. 1 (2013): 40–63.

6. This project is the result of a collaboration between the School of Information (iSchool) at the University of Texas at Austin (UT) and the Illinois Informatics Institute (I3) at the University of Illinois at Urbana-Champaign

(UIUC). I am the primary investigator. Please see http://blogs.ischool.utexas.edu/hipstas/ for more information.

7. J. S. Downie, D. K. Tcheng, and X. Xiang, "Novel Interface Services for Bioacoustic Digital Libraries," in *Proceedings of the 8th ACM / IEEE-CS Joint Conference on Digital Libraries* (New York: ACM, 2008).

8. For discussions of psychoacoustic and commercial technologies used to quantify speech, see Mills, "Deaf Jam," 50; Sterne, *MP3*, 92–127; and Wittje, "The Electrical Imagination," 59.

9. Charles Bernstein explains that "there are four features or vocal gestures, that are available on tape but not page that are of special significance for poetry"; these include "the cluster of rhythm and tempo (including word duration), the cluster of pitch and intonation (including amplitude), timbre, and accent" (*Attack of the Difficult Poems: Essays and Inventions* [Chicago: University of Chicago Press, 2011], 126).

10. J. Cole, respondent to M. Rooth and M. Wagner, Harvesting Speech Datasets for Linguistic Research on the Web, Digging into Data Conference, National Endowment for the Humanities, Washington, DC, June 2011.

11. Ibid.

12. Michael Davidson, "'By ear, he sd': Audio-Tapes and Contemporary Criticism," *Credences* 1, no. 1 (1981), available online at http://www.audibleword.org/poetics/Davidson-By_Ear_He_Sd.htm.

13. These participant responses were gathered in three ways: (1) through the applications; (2) through pre-Institute interviews conducted by Clement; and (3) through post-Institute reporting.

14. Walter J. Ong, *The Presence of the Word: Some Prolegomena for Cultural and Religious History* (New Haven, CT: Yale University Press, 1967), 88.

15. Joshua Gunn, "Speech Is Dead; Long Live Speech," *Quarterly Journal of Speech* 94, no. 3 (2008): 343–64, 343.

16. Jonathan Sterne, "Sonic Imaginations," in *The Sound Studies Reader*, ed. Jonathan Sterne (New York: Routledge, 2012), 1–18, 3.

17. While an extensive list is not within the scope of this article, there are quite a few readings that comment on these perspectives for making meaning with sound in the humanities. Within the act of audition, see Mills, "Deaf Jam"; Gunn, "Speech Is Dead"; for sound environments such as the city or architecture, see Emily Ann Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900–1933* (Cambridge, MA: MIT Press, 2002); for technological transduction, reproduction, and transmission of sound, see Ana María Ochoa, "Sonic Transculturation, Epistemologies of Purification and the Aural Public Sphere in Latin America," *Social Identities* 12, no. 6 (2006): 803–25, and Tara Rodgers, *Pink Noises: Women on Electronic Music and Sound* (Durham, NC: Duke University Press, 2010); for communities of sound in radio, see Kristen Haring, *Ham Radio's Technical Culture* (Cambridge, MA: MIT Press, 2008); for aesthetics in literature and culture, see Marjorie Perloff and Craig Douglas Dworkin, *The Sound of Poetry, the Poetry of Sound* (Chicago: University of Chicago Press, 2009), and Adalaide Morris, ed., *Sound States: Innovative Poetics and Acoustical Technologies* (Chapel Hill: University of North Carolina Press, 1998).

18. Sterne, "Sonic Imaginations," 11.

19. Roland Barthes, "Grain," in *Image-Music-Text* (New York: Hill and Wang, 1978), 182.

20. Ibid., 183.

21. Poet and scholar Charles Bernstein, who calls interpreting sound "close listening," maintains that this kind of access should comprise a focus on "sound as material, where sound is neither arbitrary nor secondary but constitutive" of meaning (*Close Listening: Poetry and the Performed Word* [New York: Oxford University Press, 1998], 4).

22. Michael Chion, "The Three Listening Modes," in Sterne, *The Sound Studies Reader*, 48–53. This seems related to Roland Barthes's three distinct types of listening in his essay "Listening": the first represents a listener on "alert" as prey or predator, as mother or child, as lover on the lookout; the second represents "deciphering," or "what the ear tries to intercept are certain signs"; the third is the "intersubjective" listening of the psychoanalyst (*The Responsibility of Form*, trans. Richard Howard [New York: Hill and Wang, 1985], 245).

23. Chion, "Three Listening Modes," 50.

24. Ibid., 51.

25. Ibid., 50; emphasis added.

26. Ibid.

27. Ibid., 51.

28. Adriana Cavarero, "Multiple Voices," in Sterne, *The Sound Studies Reader*, 520–32, 529.

29. Ibid., 530, 531.

30. Marshall McLuhan, *Essential McLuhan*, ed. Eric McLuhan and Frank Zingrone (New York: Basic Books, 1995), 370.

31. Gunn, "Speech Is Dead," 360.

32. Cavarero, "Multiple Voices," 530.

33. Ibid.

34. Mladen Dolar, "The Linguistics of the Voice," in Sterne, *The Sound Studies Reader*, 539–54, 539.

35. Ibid., 552.

36. Ibid., 544.

37. Warren Weaver, "Recent Contributions to the Mathematical Theory of Communication," in The Mathematical Theory of Communication, by Claude Elwood Shannon and Warren Weaver (1949; Urbana: University of Illinois Press, 1971), 1–28, 25. And see Claude E. Shannon, "Programming a Computer for Playing Chess," Philosophical Magazine 41 (1950): 256–75.

38. John R. Pierce actually writes "communication theory" in this essay, but he notes in the foreword to his updated edition that "information theory" is the "term he would use today" (*An Introduction to Information Theory: Symbols, Signals and Noise* [1961; New York: Dover Publications, 1980], vii, 9).

39. Sterne, *MP3*, 77.

40. Shannon, "A Mathematical Theory of Communication," in The Mathematical Theory of Communication, by Claude Elwood Shannon and Warren Weaver (1949; Urbana: University of Illinois Press, 1971), 29–125, 31.

41. Ibid., 34.

42. Ibid., 31.

43. Weaver, "Recent Contributions," 19.

44. Shannon, "A Mathematical Theory," 31.

45. Weaver, "Recent Contributions," 27.

46. Ibid., 4, 5.

47. Ibid., 4.
48. Ibid., 8.
49. Ibid., 19.
50. Ibid., 19; emphasis added.
51. Ibid., 9.
52. Donald MacKay, *Information, Mechanism and Meaning* (Cambridge, MA: MIT Press, 1969), 6.
53. Ibid., 22.
54. Ibid., 85.
55. Ibid., 25.
56. Ibid., 24.
57. N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999); and Mark B. N. Hansen, *New Philosophy for New Media* (Cambridge, MA: MIT Press, 2006).
58. Paul Kockelman, "Information Is the Enclosure of Meaning: Cybernetics, Semiotics, and Alternative Theories of Information," *Language & Communication* 33 (2013): 115–27, 126.
59. Ibid.
60. Ibid.
61. Bernhard Siegert, "Mineral Sound or Missing Fundamental: Cultural History as Signal Analysis," *Osiris* 28, no. 1 (2013): 105–18.
62. Marshall McLuhan and Eric McLuhan, *Laws of Media: The New Science* (Toronto: University of Toronto Press, 1988), 90.
63. Ibid., 86.
64. MacKay, *Information*, 80, 6.
65. Ibid., 20.
66. Ibid., 21.
67. Ibid.
68. Veit Erlmann, *Reason and Resonance: A History of Modern Aurality* (New York: Zone Books; distributed by MIT Press, 2010), 10.
69. Roland Barthes differentiates between "hearing" as "a physiological phenomenon" and "listening" as "a psychological act" (*The Responsibility of Form*, 245).
70. MacKay, *Information*, 12, 13.
71. Ibid., 12.
72. Ibid., 3.
73. Ibid., 4.
74. Ibid., 14. Kockelman notes a similar metaphor related to "depth" in Pierce's writings ("Information," 123).
75. MacKay, *Information*, 22, 24.
76. Dolar, "Linguistics," 77.
77. Ibid., 73.
78. Kockelman, "Information," 119.
79. MacKay, *Information*, 10.
80. Davidson, "'By ear, he sd.'"
81. Richard Poirier, "The Difficulties of Modernism and the Modernism of Difficulty," in *Critical Essays on American Modernism*, ed. Michael Hoffman and Patrick D. Murphy (New York: G. K. Hall, 1992), 104–14, 113.
82. Kockelman, "Information," 119.
83. Weaver, "Recent Contributions," 27.

84. Marshall McLuhan, *Counter Blast* (New York: Harcourt, Brace and World, 1969), 132.

85. MacKay, *Information*, 13.

86. Ibid.

87. Zora Neale Hurston, “Halimuhfack,” 1939, Florida Folklife from the WPA Collections, 1937–42, Library of Congress.