Cybernetics, listening, and sound-studio phenomenotechnique in Abraham Moles’s *Théorie de l’information et perception esthétique* (1958)

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Abstract

In his *Théorie de l’information et perception esthétique* (1958), the sociologist of culture Abraham Moles (1920–1992) set out to demonstrate the applicability of information theory—a mathematical linchpin of cybernetics—to the arts more generally. Moles drew on classical psychophysics, Gestalt psychology, more modern behavioral psychology, and contemporary psychoacoustic research to advocate a cybernetic model of the perception and creation of art. Moles repeatedly returned to musical examples therein to make his case, leveraging his dual expertise in philosophy and electroacoustics, drawing on formative experiences with Pierre Schaeffer in Paris and Hermann Scherchen at his Gravesano studio. Moles’s interdisciplinary text found many attentive readers across Europe and, following an English translation by the precocious Joel E. Cohen (1966), the Anglophone academic world, but was valued more as an inspiration for the burgeoning area of “information aesthetics” than as a source of hard scientific evidence.

Drawing lightly on positions in the history and philosophy of science articulated by Gaston Bachelard (who supervised Moles’s second PhD, in philosophy) and Hans-Jörg Rheinberger suggests a change of emphasis away from its apparent scientific infelicities and toward Moles’s use of sound-studio technique, which is described with reference to the technologies available to Moles in the years leading up to the publication of the *Théorie*. Moles manipulated and processed sound recordings—filtering, clipping, and reversing them—in his attempts to empirically estimate the relative proportions of semantic and aesthetic information in speech and music. Moles’s text, when understood in tandem with the traces of his practical experiments in the sound studio, appears as an influential and occasionally prescient exposition of the many possible applications of the principles of information theory to the production, perception, and consumption of sound culture, that makes ready use of the latest technical innovations in the media environment of its time.

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Introduction

Abraham André Moles (1920–1992) is perhaps best known as the one-time director of the electronic music studios at Gravesano, Switzerland (1954–1960) and the author of a treatise that appeared in English under the title *Information Theory and Esthetic Perception* (1966 [1958]). Moles features in both Morag Grant's important monograph on the music journal *Die Reihe* and as one of the "hidden collaborators" in Jennifer Iverson's recent work, a link in a network that fostered the mutual exchange of new musical ideas in continental Europe during the 1950s and 1960s.[1] His connection with Pierre Schaeffer is also well-known: Moles is credited as the co-author of Schaeffer's "*Esquisse d'un solfège concret*" [Sketch of a "concrete" music theory] (1952), in which they described a controlled vocabulary to classify and describe sounds as dynamic, temporal processes.[2] Patrick Valiquet has convincingly argued that Schaeffer's later repudiation of his collaborator's cybernetic approach was not total, suggesting that certain of Schaeffer's own later writings be read anew in the light shed by Moles's more techno-optimistic approach to sound.[3] In this article, I set out neither to recover nor rehabilitate Moles's cybernetic music theory but instead to perform what Hasok Chang in closely related contexts has called the history of science in its "complementary" mode: history that is open to alterity, failure, non-standard paradigms and to the pursuit of apparent dead ends, that takes lost or understudied experimental techniques seriously since they may potentially generate ideas for novel scientific research.[4]

Moles's contributions to the *Gravesaner Blätter* (the Gravesano studios' house journal that he co-edited with founder Hermann Scherchen) only hint at the breadth of his technical knowledge: a trilingual illustrated glossary of sound-technical terms (1955), a discussion of

[1] M. J. Grant, *Serial Music, Serial Aesthetics: Compositional Theory in Post-War Europe*, Music in the Twentieth Century (Cambridge: Cambridge University Press, 2001); Jennifer Iverson, *Electronic Inspirations: Technologies of the Cold War Musical Avant-Garde* (New York, NY: Oxford University Press, 2019); See also, Christoph Both, "The Influence of Concepts of Information Theory on the Birth of Electronic Music Composition: Lejaren A. Hiller and Karlheinz Stockhausen, 1953–1960" (University of Victoria, 1995), https://hdl.handle.net/1828/6399.

[2] Pierre Schaeffer, Christine North, and John Dack, *In Search of a Concrete Music*, California Studies in 20th-Century Music 15 (Berkeley: University of California Press, 2012), 189–221. In French, see Pierre Schaeffer, *À la Recherche d'une Musique Concrète* (Paris: Éditions du Seuil, 1952).

[3] Patrick Valiquet, "Hearing the Music of Others: Pierre Schaeffer's Humanist Interdiscipline," *Music and Letters* 98, no. 2 (May 2017): 255–80, https://doi.org/10.1093/ml/gcx052, 270–272.

[4] Hasok Chang, *Inventing Temperature: Measurement and Scientific Progress*, Oxford Studies in Philosophy of Science (Oxford: Oxford University Press, 2004).

the information-theoretic basis for musical pleasure in relation to "light" music (1956), a German-language summary of his work on information theory and music (1956), a prospectus on the electronic instrumentarium (1960), a case for the objective certification of the build quality of violins (1960), and a position piece on the "new relationship" between music and mathematics (1961).[5] His output comprises hundreds of single-author articles and over a dozen monographs touching on sound engineering, music, and the sociology of mass culture.[6] Moles's most widely read and translated works include his *Sociodynamique de la culture* (1967) [Sociodynamics of Culture], *Art et ordinateur* (1971) [Art and the Computer], his book on the psychology of kitsch (1971 onward), and his 500-page introduction to communication studies, *La communication* (1973).[7]

Before Gravesano, however, Moles had studied both physics and philosophy, leading ultimately to two doctorate degrees from the Sorbonne: one in science (1952) followed swiftly by another in philosophy (1954), the latter under the supervision of Gaston

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[5] Abraham Moles, "Essai de vocabulaire graphique international de l'acoustique musicale et l électroacoustique," *Gravesaner Blätter* 1 (July 1955): 46–61. For an overview of the activities at Gravesano, see Manfred Krause, "Das Gravesaner Studio und seine Ausstrahlung," in *Hermann Scherchen, Musiker 1891–1966: Ein Lesebuch.*, ed. Hansjörg Pauli and Dagmar Wünsche (Berlin: Akademie der Künste; Edition Heintrich, 1986), 116–20. See also, Dennis C Hutchison, "Performance, Technology, and Politics: Hermann Scherchen's Aesthetics of Modern Music." (PhD diss., Florida State University, 2003), http://purl.flvc.org/fsu/fd/FSU_migr_etd-3384, 104–112.

[6] For a snapshot of Moles's already forbidding bibliography by the middle of the 1960s, see , "Abraham A. Moles Bibiliografija/Abraham A. Moles Bibliographie," *Bit International*, 1968, 109–14. Two more bibliographies have been prepared since his death in 1992; both are available in online Web archives: Jean-Luc Michel, "Site de la distanciation - Bibliographie des articles d'Abraham Moles" (distanciation, July 4, 2008), https://web.archive.org/web/20080704174100/http://www.cetec-info.org/jlmichel/Moles.bibliographie.html; Jacques Dedeyan and Victor Schwach, "Biblio des articles: bibliographie; Liste des articles connus d'Abraham Moles" (L'Association Internationale de Micropsychologie et de Psychologie sociale des Communications, September 30, 2009), https://web.archive.org/web/20090930082025/http://micropsy.ifrance.com/moles/molesbiblio.html.

[7] Colloquiua held in 1994, 2000 and 2017 have reflected on and attempted to consolidate his legacy, not only as a scholar of communications and media but as an engineer, sound technician, and cybernetician. "Communication, espace et société" was held at the Conseil de l'Europe, Strasbourg on 7–8 April 1994. "Moles 2000. Un aspect de la pensée d'Abraham Moles: les "arts visuels," actualité et perspectives" was held at the *Ecole supérieure des arts décoratifs de Strasbourg* 18–19 January 2000. "Abraham Moles et l'Ecole de Strasbourg" was held at *Groupe de recherches expérimentales sur l'acte musical* (GREAM) at Université de Strasbourg on 28–29 September 2017.

Bachelard.[8] He had also worked as an electroacoustics specialist at the *Laboratoire d'acoustique et de vibrations* for the French national scientific agency immediately after the Second World War, and, from 1953, for the Paris-based *Centre d'Études de Radiotélévision* of the state broadcaster, *RTF*. There he worked alongside engineers Jean Tardieu and, at the *Club d'Essai*, with Schaeffer.[9] After Gravesano, Moles held appointments at both the left-leaning Ulm School of Design in Germany (1961–1968) and the University of Strasbourg (1966–1986).[10] At the Department of Information at Ulm, he lectured students of architecture and design on sociology, information theory, and physics. At Strasbourg, he founded the *Institut de psychologie sociale des communications de Strasbourg* in 1966, remaining its director until 1986.[11]

Work by Adriana Knouf and Melle Kromhout has succeeded in placing Moles's research in the larger context of twentieth-century signal processing and noise control but is, at best, ambivalent about his much longer career as a sociologist of mass communications.[12] Media scholar Martha Schwendener rightly claims that "Moles is an interesting, if overlooked media theorist": a media theorist and sound technician with polymathic tendencies who, among others, counted Vilém Flusser as an interlocutor and defender and Guy Debord as an

[8] Before its reform in the 1960s, the French "*doctorat d'État*" required two theses of its candidates; the (usually) shorter *thèse supplémentaire* was a relic of the requirement for a second thesis in Latin.

[9] Michel Mathien, "L'approche physique de la communication sociale: L'itinéraire d'Abraham Moles," *Hermès* n° 11-12, no. 1 (1993): 331, https://doi.org/10.4267/2042/15504, 332–333.

[10] Mathien, ibid, 335. On the Department of Information at Ulm, see David Oswald, "The Information Department at the Ulm School of Design," 2014, 46–50, https://doi.org/10.5151/design-icdhs-011. See also, Herbert W Kapitzki and Linde Kapitzki, *Herbert W. Kapitzki: Gestaltung, Methode und Konsequenz ; ein biografischer Bericht* (Stuttgart; London: Menges, 1997), 34.

[11] Mathien, "L'approche physique de la communication sociale", 337.

[12] N. Adriana Knouf, "Noisy Fields: Interference and Equivocality in the Sonic Legacies of Information Theory" (Ph.D. thesis, Cornell University, 2013), https://hdl.handle.net/1813/39023; Melle Jan Kromhout, *The Logic of Filtering: How Noise Shapes the Sound of Recorded Music* (New York: Oxford University Press, 2021). See also, Melle Jan Kromhout, "Noise Resonance: Technological Sound Reproduction and the Logic of Filtering" (PhD diss., University of Amsterdam, 2017), https://hdl.handle.net/11245.1/0e027b1c-79ce-4458-906b-96a88a1f2fc9. See also, but beware mathematical idiosyncrasies in, Christian Benvenuti, "Sound, Noise and Enthropy: An Essay on Information Theory and Music Creation." (Ph.D. thesis, University of Surrey, 2010), https://epubs.surrey.ac.uk/854839/.

adversary.[13] Accounts of Moles within media and communications studies in English are equally cursory; those in other languages (reflecting his popularity in France and Brazil) that grapple with his experience with *musique concrète* in Paris and *elektronische Musik* in Gravesano generally underestimate the significance of these movements to developments in sound culture later in the century.[14] Moles's work on sound is therefore neither fully accounted for in the context of his life as a media scholar nor treated in musical detail by his later advocates within media and communications studies. In this article, I begin to address this gap by rendering an account of Moles's monograph that is perhaps most widely cited by music and sound historians: his *Théorie de l'information et perception esthétique* (1958) [*Information Theory and Esthetic Perception*].

In this article, I offer a path into of Moles's line of cybernetic musical reasoning, as it is expressed in his *Théorie*, that draws on Moles's published works up to and including the first French edition of the *Théorie* (1958), its English translation (1966), and its subsequent revised French edition (1972). I focus on how Moles's text appears to draw a distinction between two kinds of information: semantic and aesthetic information, perhaps the most distinctive (if not the most idiosyncratic) claim of his treatise. To understand how Moles differentiates between them, I first discuss the major influences on Moles's text ("Toward an information theory of (aesthetic) perception") and then rehearse basic elements of Shannon–Wiener information theory as interpreted by Moles ("Information in action"). Moles's distinctive differentiation between semantic and aesthetic information ("Distinguishing semantic from aesthetic information")—or indeed, between any *kinds* of information at all—appears at variance with the premises of the strict, communications-engineering understanding of information theory's remit. Drawing on more recent theories of scientific knowledge-production that are rooted in the ideas of Gaston Bachelard ("A brief detour into historical epistemology"), I explain how the semantic–aesthetic distinction, like many of the claims in Moles's treatise, is grounded not so much in

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[13] Martha Schwendener, "The Photographic Universe: Vilém Flusser's Theories of Photography, Media, and Digital Culture" (The City University of New York, 2016), https://academicworks.cuny.edu/gc_etds/693/, 86 fn 294. For Flusser's written defense of Moles, see Vilem Flusser and Jean-Marie Manoury, "A propos d'Abraham Moles. La communication : science ou idéologie ?" *Communication & Langages* 20, no. 1 (1973): 35–52, https://doi.org/10.3406/colan.1973.4049.

[14] Michel Mathien and Victor Schwach, "De l'ingénieur à l'humaniste: l'œuvre d'Abraham Moles," *Communication & Langages* 93, no. 1 (1992): 84–98, https://doi.org/10.3406/colan.1992.2381; Mathien, "L'approche physique de la communication sociale"; Jean Devèze, "Abraham Moles, un exceptionnel passeur transdisciplinaire," *Hermes, La Revue* n° 39, no. 2 (2004): 188–200, https://doi.org/10.4267/2042/9482; Michel Mathien, "Abraham Moles: affronter scientifiquement la quotidienneté de la communication humaine," *Hermes, La Revue* n° 48, no. 2 (2007): 101–8, https://www.cairn.info/revue-hermes-la-revue-2007-2-page-101.htm.

information-theoretic orthodoxy as it is in the manipulation of audio recordings using studio equipment (“Demonstrating the distinction”), by focusing on Moles’s use of reverse playback and fixed-bandwidth filtering to study listener responses to processed sound signals. I end with some remarks about the possible afterlives of Moles’s text in the context of the contemporary orthodoxies of cognitive psychology and music theory.

Toward an information theory of (aesthetic) perception

Moles was well qualified to set about constructing media-technical theory of aesthetic perception grounded in the experience of sound. He had specialist knowledge of musical and non-musical acoustics: Moles once collaborated with Pierre Schaeffer on an early incarnation of an explicit theory of Schaeffer’s *objet sonore*. Moles had been hired by Schaeffer to work at the *Club d’Essai* during the summer of 1951. The final chapter of Schaeffer’s *À la recherche d’une musique concrète* (1952) is titled “Equisse d’un solfège concret, en collaboration avec [Abraham] André Molès [*sic*].”[15] In it, Moles developed the notion of the “trihedron of reference,” which articulated a multidimensional conception of the basic sound and anticipated his description of the quantizing ear that animates his information aesthetics of listening, described in detail below.[16] After working with Schaeffer, Moles received financial support from the Rockefeller Foundation to extend the reach of information theory to the understanding of the arts. Moles visited the United States in the mid-1950s, spending part of his time at MIT where he met the doyen of communications engineering, Claude Shannon.[17] The creation and perception of art furnished a bevy of sociocultural problems that engendered the “expert-driven rational solutions” of which the Foundation became known as a financial supporter.[18] Indeed, financial support for these activities from American philanthropic foundations was a regular source of revenue for working composers and technicians.[19] Moles also visited the Department of Music at Columbia University in New York as a guest of Vladimir Ussachevsky some years before he and Otto Luening secured Rockefeller Foundation

[15] See Thom Holmes, *Electronic and Experimental Music: Technology, Music, and Culture*, Fifth edition (New York; Abingdon, Oxon.: Routledge, 2015), 48–52.

[16] Schaeffer, North, and Dack, *In Search of a Concrete Music*, 211.

[17] Abraham Moles and Elisabeth Rohmer, “Autobiographie d’Abraham Moles: Le cursus scientifique d’Abraham Moles,” 1996, https://www.infoamerica.org/documentos_pdf/moles_autobiografia.pdf, sec. 7.

[18] Bernard Dionysius Geoghegan, “From Information Theory to French Theory: Jakobson, Lévi-Strauss, and the Cybernetic Apparatus,” *Critical Inquiry* 38, no. 1 (September 2011): 96–126, https://doi.org/10.1086/661645, 102; 102–104.

[19] Rachel S. Vandagriff, “American Foundations for the Arts” (Oxford Handbooks Online, April 7, 2015), https://doi.org/10.1093/oxfordhb/9780199935321.013.112.

support for the Columbia-Princeton Electronic Music Center, which became a favored site for such exercises in cultural diplomacy that supported the exchange of artists and scientists between Europe and the United States.[20]

Moles’s trip resulted in a report for the Foundation, which was translated into French by Daniel Charles and published as *Les musiques expérimentales* (1960); this publication included additional material drawn from contemporary journal and magazine articles by Moles.[21] Moles’s *Théorie de l’information et perception esthétique* (1958) was much more widely cited than *Les musiques expérimentales*, though many who have read it have found it arcane, outdated, and speculative. On the publication of its English translation in 1966, Moles was accused of dilettantism and dilated prose, of drawing on outdated psychoacoustical research, of factual inconsistencies, and, worst of all, of a propensity for faddish jargon.[22] In contrast, I find the *Théorie* to be the generative and provocative work of a cybernetic humanist, despite its organizational and theoretical weaknesses. By 1958, Moles had arrived a description of a listener whose access to sound culture is characterized as message reception: a truism of many cognitive-scientific accounts of listening today. He deployed the mathematical, information-theoretical model of communication that is the hallmark of what we now call first-order cybernetics to demonstrate that information theory could and ought to be applied to “aesthetic perception.” In it, Moles outlined a program of aesthetic research founded on the information-theoretic study of so-called “natural” communication systems. Moles’s later litany of the pioneers of communication science serves to triangulate his work within the more mathematically minded modelers of

[20] Brigid Cohen, “Sounds of the Cold War Acropolis: Halim El-Dabh at the Columbia-Princeton Electronic Music Center,” *Contemporary Music Review* 39, no. 6 (2020): 684–707, https://doi.org/10.1080/07494467.2020.1863006, 688. Knouf, “Noisy Fields”, 80. Their meeting led to a paper advocating the sonogram as a musical representation greatly superior to “utterly inadequate” conventional notation. Abraham Moles and Vladimir Ussachevsky, “L’emploi du spectrographe acoustique et le problème de la partition en musique expérimentale,” *Annales des Télécommunications* 12 (1957): 299–304, https://doi.org/10.1007/BF03013730.

[21] Abraham A. Moles, *Les musiques expérimentales : revue d’une tendance importante de la musique contemporaine*, trans. Daniel Charles (Paris: Éditions du Cercle d’art contemporain, 1960).

[22] David Kraehenbuehl, “Review of Abraham Moles, Information Theory and Esthetic Perception,” *Journal of Music Theory* 11, no. 1 (Spring 1967): 149–51; Arthur B. Wenk, “Review of Information Theory and Esthetic Perception, by Abrahm Moles, Trans. Joel E. Cohen,” *Notes* 25, no. 2 (December 1968): 249–50. For a particularly devastating though lightly researched take-down by a fellow Harvard student, see Wilson Lyman Keats, “Review of Abraham Moles’s Information Theory and Esthetic Perception, Trans. Joel E. Cohen,” *The Harvard Crimson*, March 18, 1966, https://www.thecrimson.com/article/1966/3/18/the-joel-e-cohen-translation-of/.

the broader cybernetic matrix: "Wiener, Shannon, [Ralph V.] Hartley, [George] Zipf."[23] Moles drew on others who did not readily self-identify as information theorists, who nevertheless lent support to the notoriously amorphous cybernetic project: communications researchers in Britain and France, classical psychophysics, Gestalt psychology, more modern behavioral psychology, and contemporary psychoacoustic research.

Moles's text was first published by the French publisher Flammarion in 1958.[24] Around the same time it was being translated into German by Hermann Scherchen; translations into Spanish, Russian, Portuguese, Italian, and Hungarian then followed. An English edition by Joel E. Cohen was published in 1966 as *Information Theory and Esthetic Perception* by the University of Illinois Press: This is the version of the text commonly cited in English-language histories of electronic and computer music.[25] In the Preface to this edition, Cohen admits rewriting and updating some of Moles's proofs, revising his bibliography, and even deleting entire sentences and paragraphs.[26] Cohen's translation is therefore best understood as a revised edition (albeit one authorized by Moles) rather than a direct translation of the first French edition. Moles went on to prepare a second, updated edition in French with additional text and diagrams, which was published in 1972 by Editions Denoël.[27] Notably excluded from the English edition (but present in both French editions) was a thematic discography listing almost 50 recordings, which appears below for the first time in English as Appendix A; most of them were commercially available and all were ready for consultation at the sound library at *la Radiodiffusion française*.[28]

Moles's forebears in quantitative approaches to aesthetics include the mathematician George Birkhoff (1884–1944) and, before him, the experimental psychologist and psychophysics pioneer Gustav Fechner (1801–1887).[29] Where Birkhoff expressed the

[23] Quoted in Mathien, "L'approche physique de la communication sociale", 337.

[24] Abraham A. Moles, *Théorie de l'Information et perception esthétique* (Paris: Flammarion, 1958). For what appears to the doctoral these from which it was developed, see Abraham André Moles, "Théorie de l'information et perception esthétique" (Thèse complémentaire, Paris, n.d.).

[25] Abraham Moles, *Information Theory and Esthetic Perception*, trans. Joel E. Cohen (Urbana, IL: University of Illinois Press, 1966), Preface.

[26] Moles, ibid, "Translator's Preface."

[27] Abraham A. Moles, *Théorie de l'information et perception esthétique*, Second edition (Paris: Denoël/Gonthier, 1972).

[28] Moles, *Théorie de l'Information et perception esthétique*, 215–217.

[29] Fechner's outline of an experimental aesthetics is can be found in Gustav Theodor Fechner, *Vorschule der Aesthetik*, Second edition (1897; repr., Cambridge: Cambridge

overall aesthetic measure of an artifact as a simple ratio, capturing a trade-off between the "order" and the "complexity" of its constituent symbols, Moles—like his contemporary Max Bense (1910–1990)—used information theory to take statistical patterns that structure the likelihood of symbols in the hypothesized symbol set (Moles's repertoire) into account.[30] The "empirical aesthetics" movement, led in English by the Canadian psychologist Daniel Berlyne, would later draw inspiration from Birkhoff and Fechner and sought to ground human aesthetic judgments using the resources of experimental psychology.[31] A darker thread runs through this history of empirical aesthetics: the music psychologist Carl Seashore (1866–1949) and his students—most notably among them, Norman C. Meier (1893–1967)—deployed tests of musical and artistic proficiency to identifying student's latent talent for further training or, absent that, remedial work or exclusion.[32] Seashore's explicitly eugenic bequest to empirical music research is only lately being examined by those working within and without that field.[33] Moles, for his part, was less interested in standardizing musical experience with recourse to statistics than in using information theory in a materialist study of communications that would surface individual differences

University Press, 2013). See also, Alexandra Hui, *The Psychophysical Ear: Musical Experiments, Experimental Sounds, 1840–1910*, Transformations: Studies in the History of Science and Technology (Cambridge, MA: MIT Press, 2013), ch 1. Birkhoff is less well studied within musicology, despite the fact that Birkhoff treated music at some length in George Birkhoff, *Aesthetic Measure* (Cambridge, MA: Harvard University Press, 1933), chapters 5–7.

[30] Claus Pias notes that Bense's mathematical maneuver is analogous to Shannon's refinement of Ralph Hartley's earlier, non-probabilistic measure of information; as for Bense, so for Moles. Claus Pias, "'Hollerith "Feathered Crystal"': Art, Science, and Computing in the Era of Cybernetics," *Grey Room* 29 (October 2007): 110–34, https://doi.org/10.1162/grey.2007.1.29.110, 118.

[31] See Daniel E Berlyne, *Aesthetics and Psychobiology*, Century Psychology (New York: Appleton-Century-Crofts, 1971).

[32] See, for example, Carl E. Seashore, "The Measurement of Musical Talent," *The Musical Quarterly* 1, no. 1 (1915): 129–48, https://doi.org/10.1093/mq/I.1.129; Norman C. Meier, "A Measure of Art Talent," *Psychological Monographs* 39, no. 2 (1928): 184–99, https://doi.org/10.1037/h0093346.

[33] Johanna Devaney, "Eugenics and Musical Talent: Exploring Carl Seashore's Work on Talent Testing and Performance," *American Music Review* 48, no. 2 (Spring 2019), http://www.brooklyn.cuny.edu/web/academics/centers/hitchcock/publications/amr/v48-2/devaney.php; Alexander Cowan, "Eugenics at the Eastman School: Music Psychology and the Racialization of Musical Talent" (Annual meeting of the American Musicological Society, Rochester, NY, 2017), https://cowanaw.wordpress.com/2017/11/07/eugenics-at-the-eastman-school-music-psychology-and-the-racialization-of-musical-talent/.

and embrace their status as a central problematic of the theory.[34] In the article version of *Sur la structure physique du signal en musique microphonique* (1952), one of two thesis documents defended by Moles for his first doctorate in physics, Moles acknowledged the work of Charles Lalo (1877–1953) who advanced a sociology of art as an exact science that sought to rebut contemporary "vitalist" accounts of art, mediating between a Durkheimian approach to the social facts of art and the more empirical attitude adopted by Fechner.[35] Moles's later remarks about the "structuralist" perspective embodied in the *Théorie* bespeak the exchange of ideas between anthropology, linguistics, and cybernetics typical of its age and of Moles's French milieu.[36]

Evidently more familiar with the physiological and psychological features of the ear than with those of the visual or motor systems, Moles repeatedly returned to sonic examples in the first edition of the *Théorie* (though additional visual examples were added to the second edition). For Moles, a listener who hears a live or recorded performance of art music stood as a paradigm case for the analysis of human aesthetic perception more generally: he considered musical messages "the epitome of temporal aesthetic messages," and his text depends heavily on examples involving music at the expense of visual art—despite its pretensions to generality.[37] Yet during the last years of the 1950s the book came to be viewed as a core text in the inchoate area of "information aesthetics," a European movement in art and criticism that sought to adopt information or entropy as an empirical and objective measure of aesthetic content and as a tool for its creation.[38] Less surprisingly, music researchers found the *Théorie* generative. As Brian Miller discusses, the influential

[34] Moles, *Information Theory and Esthetic Perception*, 188; 192ff. ("Conclusion").

[35] [Abraham] André Moles, "La structure physique du signal musical," *Revue Scientifique* 3324 (1953): 277–303, 303. The original thesis document is A. Moles, "Comment peut-on «mesurer» le message parlé?" *Folia Phoniatrica Et Logopaedica* 4 (1952): 169–98, https://doi.org/10.1159/000262622. On Lalo, see , "Charles Lalo," *Trivium. Revue franco-allemande de sciences humaines et sociales/Deutsch-französische Zeitschrift für Geistes- und Sozialwissenschaften*, 2010, http://journals.openedition.org/trivium/3671. Moles's research agenda was strikingly equivalent, if given the required updates to reflect contemporary European trends in the human sciences: his account had no place for metaphysics, its sketch of a sociology of art bent toward structuralism, and its empirical basis was a behaviorist strain of psychological research that ultimately fed into cognitivist orthodoxy.

[36] Moles, *Théorie de l'information et perception esthétique*, 7. See Bernard Dionysius Geoghegan, "Textocracy, or, the Cybernetic Logic of French Theory," *History of the Human Sciences* 33, no. 1 (2020): 52–79, https://doi.org/10.1177/0952695119864241. See also, Geoghegan, "From Information Theory to French Theory"; Céline Lafontaine, "The Cybernetic Matrix of 'French Theory'," *Theory, Culture & Society* 24, no. 5 (2007): 27–46, https://doi.org/10.1177/0263276407084637.

[37] Moles, *Théorie de l'information et perception esthétique*, 107. My translation.

music psychologist Leonard Meyer—whose engagement (in print) with information theory began in 1957—would later cite Moles's research in a 1961 essay from the collection along with many other sources later to appear in Cohen's influential literature review on information-theory applications to music, which appeared in the following year.[39] And although Moles's research would generally appeal more to those who were to analyze music than create it, the composers Lejaren Hiller and Iannis Xenakis were enthusiastic readers—Hiller sustaining correspondence with him from 1957 through to the early 1960s,[40] and Xenakis taking the principles of granular theory from Moles (he would also later mount a criticism of serialism in terms compatible with those of the *Théorie*).[41]

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[38] Christoph Klütsch, "Information Aesthetics and the Stuttgart School," in *Mainframe Experimentalism*, ed. Hannah Higgins and Douglas Kahn (University of California Press, 2012), 65–89, https://doi.org/10.1525/9780520953734-007. For an overview of information aesthetics in the context of the Zagreb-based New Tendencies movement, in which Moles became involved, see Armin Medosch, *New Tendencies: Art at the Threshold of the Information Revolution (1961–1978)*, Leonardo Book Series (Cambridge, MA: The MIT Press, 2016), 82–87. See also, Margit Rosen et al., eds., *A Little Known Story about a Movement, a Magazine and the Computer's Arrival in Art: New Tendencies and Bit International, 1961–1973* (Karlsruhe, Germany; Cambridge, MA: ZKM [Center for Art and Media]; MIT Press, 2011); Margit Rosen, "'They Have All Dreamt of the Machines—and Now the Machines Have Arrived': New Tendencies—Computers and Visual Research, Zagreb, 1968," in *Mainframe Experimentalism: Early Computing and the Foundations of the Digital Arts* (Berkeley: University of California Press, 2012), 90–111, https://doi.org/10.1525/9780520953734-008. Reviewing the English translation for *Leonardo*, the British cybernetic artist Gordon Pask hailed Moles's book as "a pioneering work that is likely to become a classic in this field." Gordon Pask, "Review of *Information Theory and Aesthetic Perception* by Abraham Moles," *Leonard* 1, no. 2 (April 1968): 205–6, https://muse.jhu.edu/article/596566/pdf, 205.

[39] Brian Andrew Miller, "Enminded, Embodied, Embedded: The Concept of Musical Style from Leonard Meyer to Machine Learning" (Ph.D. diss., Yale University, 2020), https://www.proquest.com/docview/2544457380/, 129. Joel E. Cohen, "Information Theory and Music," *Behavioral Science* 7, no. 2 (1962): 137–63, https://doi.org/10.1002/bs.3830070202.

[40] Lejaren Hiller and Leonard Isaacson, *Experimental Music: Composition with an Electronic Computer* (New York: McGraw-Hill, 1959), 29; Lejaren Hiller, "A Report on Contemporary Music," Technical Report (Urbana, IL: Experimental Music Studio, 1962), https://monoskop.org/File:Hiller_Lejaren_A_Report_on_Contemporary_Music_1961.pdf, 75–76. According to Cohen, Hiller was instrumental in arranging for the publication of his English translation by Illinois University Press. (Pers. comm. with author, April 2019).

[41] Makis Solomos, "The Granular Connection (Xenakis, Vaggione, Di Scipio...)" (The Creative and Scientific Legacies of Iannis Xenakis, International Symposium,

Information in action

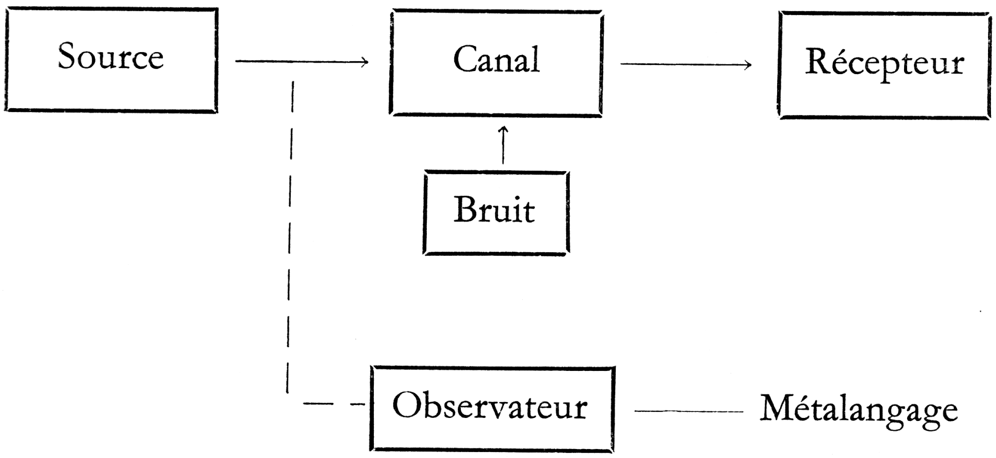

Figure 1*: Moles's diagram of a communications system, adapted from Colin Cherry. Original context: "In addition to the normal source-receptor channel, the observer who examines the signals received from the source constitutes an auxiliary channel. This observer, considering the signals discrete and free of noise, describes them in a universally intelligible metalanguage." Moles, Théorie de l'Information et perception esthétique, 135.*

Moles began his text with the now-familiar communications model articulated by Shannon, whose importance to twentieth-century literary and artistic culture has been long established: transmitter–channel–receiver.[42] From the first chapter of *Théorie*, Moles

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Guelph/Waterloo/Toronto, Canada, June 10, 2006), https://hal.archives-ouvertes.fr/hal-00770088, 7.

[42] See, for example, N. Katherine Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (Ithaca, N.Y: Cornell University Press, 1990). There is a good exposition in Luciano Floridi, "Semantic Conceptions of Information," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Winter 2019 (Metaphysics Research Lab, Stanford University, 2019), https://plato.stanford.edu/archives/win2019/entries/information-semantic/, S 2.1. Expositions of information theory are ubiquitous; they vary wildly in both quality and mathematical accuracy. For the clearest historical view, it is hard to recommend anything other than the primary source of Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana, IL: University of Illinois Press, 1949). See also, Bernard Dionysius Geoghegan, "Architectures of Information: A Comparison of Wiener's and Shannon's Theories of Information," in *Computer Architectures: Constructing the Common Ground*, ed. Theodora Vardouli and Olga Touloumi, Routledge Research in Design, Technology (London: Routledge, 2020), 135–59, https://dx.doi.org/10.4324/9780429264306-8.

applied information-theoretic measures and principles to an eclectic selection of problems. Information theory—often manifest in Moles's text in the invocation of these particular measures, almost always Shannon information (sometimes called "entropy")—figures as but one (if crucial) part of what Geoffrey Bowker creatively called cybernetics' "distributed passage point": a feature of cybernetics' constitutive networks at which actors convene, albeit one that is dispersed and nonlocal and resists ready identification as a constituent of one particular field or discipline.[43] Moles set out to determine "the sociocultural originality of musical programs" by analyzing records of past symphonic concert programs;[44] to measure the "structural complexity" of social groups;[45] to speculatively rank the "structural complexity" of organic and mechanical organisms;[46] to estimate the information rate of musical patterns transmitted by a hypothetical score;[47] and, in a classic application of information theory due to Shannon, to estimate the redundancy of the written Hebrew and French languages.[48]

Extending Shannon's communications-theoretic model after the work of the British cyberneticist Colin Cherry, Moles paid specific heed to the "level of observation" at play in the study of communication: any experimenter who sets out to quantify information content always does so with respect to a particular frame of reference at any given time.[49] When information flows from sender to receiver in an artificial communications system, the idealized receiver discriminates between discrete symbols drawn from a finite alphabet, or what Moles calls the system's "repertoire" [*répertoire*]. An artificial sender (a computer keyboard) can only communicate effectively with an artificial recipient (the computer's operating system) when their repertoires overlap. Information, in its technical sense, can be loosely understood as a quantitative expression of the degree of surprise experienced on the part of the receiver when it is (or they are) given a particular message. Information theorists are therefore concerned with the relative likelihoods that symbols will appear in messages typical of the given communications system under study.

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[43] Geof Bowker, "How to Be Universal: Some Cybernetic Strategies, 1943-70," *Social Studies of Science* 23, no. 1 (1993): 107–27, https://www.jstor.org/stable/285691.

[44] Moles, *Information Theory and Esthetic Perception*, 27. This is a remarkably early example of an attempt to "optimize" concert program generation based on historical listenership data, which is comparable to playlist generation today.

[45] Moles, ibid, 32.

[46] Moles, ibid, 33. This example does not appear in the French original (Moles, 1958).

[47] Moles, ibid, 35.

[48] Moles, ibid, 42.

[49] Moles, ibid, 129.

The liquidation of large bodies of texts into statistical distributions of characters and words does not begin with information theory, but the latter’s appetite for data meant that its popularity accelerated the demand for such corpora.[50] As a computable quantity, information is continuous, non-negative, and conventionally expressed in bits. The mathematical shadow of information, redundancy, is also key here. This concept captures a notion of how compressible information is, implying that information-dense messages are in some way less redundant than information-sparse messages.[51] The redundancy of a particular communications set-up can be defined in relation to how far it falls short of the theoretical maximum amount of information that it might otherwise contain. Estimates for the redundancy of written language computed in this way vary widely, since they depend on the corpus of material used to prepare them. However, psychology furnished quantitative data about how humans behave at the boundary between the sensible world and the senses themselves, suggesting that the scene of redundancy estimates could be moved from inference from static corpora to psychophysical experiment.

Experiments described by Shannon others suggested to researchers that empirical redundancy of written language could be measured experimentally by systematically modifying written text at the character and word levels and asking participants to recover the original, unmodified text in the manner of a parlor game or Cloze test.[52] We will later see how Moles designed analogous trials that involved the manipulation of sound sources. Yet because our tacit prior knowledge of the relative probabilities of letter frequencies as they appear in representative corpora determines, in part, our ability to read through such degraded messages, the measure of a particular set-up’s empirical redundancy will be ultimately related to measures of its statistical redundancy. By analogy, then, studying how listeners hear through manipulated studio recordings might shed light on the information-theoretic features of musical signals more generally. Moles sets out to “account for” this relationship in referring to “constraints” on the behavior of the transmitter.[53] Despite being

[50] Brian Lennon, *Passwords: Philology, Security, Authentication* (Cambridge, MA: The Belknap Press of Harvard University Press, 2018). Here, we can only gesture toward the thorny issue of what counts as a “representative” sample of language or music. For an attempt to do so, see Justin London, “Building a Representative Corpus of Classical Music,” *Music Perception: An Interdisciplinary Journal* 31, no. 1 (September 2013): 68–90, https://doi.org/10.1525/mp.2013.31.1.68.

[51] Mara Mills, “Deaf Jam: From Inscription to Reproduction to Information,” *Social Text* 28 (March 2010): 35–58, https://doi.org/10.1215/01642472-2009-059, 50–51.

[52] Claude Shannon, “Prediction and Entropy of Printed English,” *The Bell System Technical Journal*, January 1951, 50–64; Edwin B. Newman and Louis J. Gerstman, “A New Method for Analyzing Printed English,” *Journal of Experimental Psychology* 44, no. 2 (1953): 114, https://doi.org/10.1037/h0055693. See also, Lydia He Liu, *The Freudian Robot: Digital Media and the Future of the Unconscious* (Chicago: University of Chicago Press, 2010), ch. 3.

[53] Moles, *Théorie de l’Information et perception esthétique*, 62.

routinely framed as relating to suprisal, informativeness, or efficiency, the theory’s power lies less in its purported ability to model experiences—which often betrays a lurking anthropomorphism with regard to technical systems—than in its capacity to digest the complex patterns into such singular and well-behaved measures. This was information’s advantage: it allowed Moles to confabulate capacities as diverse as linguistic ability, acuity of sound production or vocalization, and even such abstract notions as musical style into a single measure.

Distinguishing semantic from aesthetic information

Perhaps Moles’s most distinctive contribution to information theory was his effort to distinguish between two “kinds” of information: what he called semantic information and aesthetic information. This distinction is comparable to one drawn in the results of similar investigations carried out by Meyer-Eppler in the mid-1950s.[54] Neither was such a distinction without precedent in the history of communications science and information theory: its chief mathematical architect Claude Shannon notoriously viewed the place of semantics in his theory with deep suspicion.[55] The philosopher of information Luciano

[54] Composers and studio technicians have long been interested the relationship between meaning and music, and the availability of sound-recording technology and new developments in phonology made new empirical comparisons and contrasts possible. For example, in the case of Stockhausen and his circle, M. J. Grant traced the source of this expertise by Meyer-Eppler and acknowledges the similarity between Moles’s distinction and Meyer-Eppler’s. Grant, *Serial Music, Serial Aesthetics*, 134. Meyer-Eppler distinguished between the “’semantic’ aspects of music” and its “emotional-aesthetic qualities” in the article “Statistic and psychologic problems of sound,” which appeared in the pages of *Die Reihe*. Werner Meyer-Eppler, “Statistic and Psychologic Problems of Sound [Statistische Und Psychologische Klangprobleme],” *Die Reihe (English Version)* 1 (1958): 55–61. Meyer-Eppler’s article, first prepared in either 1954 or 1955 (and published in English in 1958) also notably suggests that statistical methods might be useful not only for the composition of music but also for its analysis. In this article, however, Meyer-Eppler stops short of realizing this distinction using the apparatus of information theory: a more detailed treatment is reserved for later writing, in which Meyer-Eppler opts for an alternative and less freighted opposition between “semantic” and “ectosemantic” information; Moles would acknowledge a similarity to his preferred terminology in print only after the publication of the *Théorie*. Abraham A. Moles, “Théorie de l’information et sémantique,” *Communication & Langages* 5, no. 1 (1963): 15–36, https://doi.org/10.3406/colan.1963.4795, 32. See also, Iverson, *Electronic Inspirations* 127–129; Mark Carroll, *Music and Ideology in Cold War Europe*, Music in the Twentieth Century (Cambridge; New York: Cambridge University Press, 2003). 97–98.

[55] “[T]hese semantic aspects of communication are irrelevant to the engineering problem.” Shannon and Weaver, *The Mathematical Theory of Communication*, 31. See also Shannon’s

Floridi explains that, in the narrow, technical sense defended here by Shannon that the mathematical theory of communication "is not interested in the meaning, 'aboutness,' relevance, reliability, usefulness or interpretation of information, but only in the level of detail and frequency in the uninterpreted data, being these symbols, signals or messages."[56] Yet some analytic philosophers had attempted to ground theories of meaning in information-theoretic ideas in tandem drawn from formal logic and model theory.[57] Floridi notes that, despite some interesting attempts, contemporary philosophical consensus finds that Shannon's model, in its narrowest sense, is insufficient to furnish a sufficiently complete and of how information systems produce meaning.[58] We might then set aside this more technical tradition of "semantic information," though not without noting the influence of researchers like Donald MacKay on Moles's work, who attacked the meaning problem head on at a time when the inadequacies of Shannon's model for the task were less clear than they are today.[59] MacKay was one of many researchers based in the UK, including Cherry and Gabor (already mentioned above), who sought applications for Shannon's model beyond the strict confines of the engineering context and represented a non-US tradition of cybernetics with which Moles was familiar: Knouf points out that Moles attended at least of the London conferences in information theory at which Cherry and others presented their perspective of information theory's remit.[60]

While researchers in the more technical tradition attempted to define semantic information in mathematical or probabilistic terms, Moles relied heavily on prose and intuition in the discussion of semantic information that appears in the *Théorie*.[61] According

remarks to the Macy Conferences on Cybernetics in 1951, cited in Geoghegan, "Architectures of Information", 139–141.

[56] Floridi, "Semantic Conceptions of Information", S. 4.

[57] As attempted in Rudolf Carnap and Yehoshua Bar-Hillel, "An Outline of a Theory of Semantic Information," Technical Report (Research Laboratory of Electronics, Massachusetts Institute of Technology, October 27, 1952), http://hdl.handle.net/1721.1/4821. See also, Yehoshua Bar-Hillel, "An Examination of Information Theory," *Philosophy of Science* 22, no. 2 (April 1955): 86–105, https://doi.org/10.1086/287407.

[58] Floridi, "Semantic Conceptions of Information."

[59] Donald MacCrimmon MacKay, *Information, Mechanism and Meaning* (Cambridge: M.I.T. Press, 1969).

[60] Knouf, "Noisy Fields", 80.

[61] Kline points out that Wiener did similarly in *Cybernetics* (1950), committing the original sin of conflating the common-sense meaning of "information" with its mathematical shadow. This despite the fact that Wiener generally was skeptical about the extension of information-theoretic measures to the problem of semantics. Ronald Kline, "What Is

to Moles, semantic information has “a universal logic,” is “structured, articulable, translatable into a foreign language” and “serves in the behaviorist conception to prepare *actions*” or decisions.[62] The semantic information of a recorded spoken sentence is deceptively straightforward: it is the meaning of that sentence, its *sense*. Moles offers examples of messages that are “*essentially* semantic”: “a military order, an electrical circuitry diagram, a coded message, instructions in case of fire, a technical manual, a musical score.”[63] Moles claims “semantic information” is “translatable” because we can imagine these utterances having the same effect when transposed to a cognate system of representation: a different language, a different circuit-design convention, and so on.[64] Moles notes that the International Phonetic Alphabet captures something of the repertoire of all possible utterances. So much for speech. Instrumental music, can be also understood to be bear semantic information, insofar as it serves to prepare action: specifically, the ability to foresee the evolution of a given musical message with reference to the constraints of music theory.[65] But Moles is not entirely clear as to whether such predictions are necessarily mediated with reference to written music (i.e. scores in common Western musical notation) or whether music’s semantic information is independent of notation. Moles elsewhere considers the semantic aspects of music to be whatever is “‘intelligible’ in the musical message, whatever constitutes a net of logically or symbolically apprehensible relations”[66] This somewhat begged this question of what counted as intelligibility, asserting unhelpfully that what is intelligible is apprehensible.

What counts as semantic information for Moles is perhaps clearer when presented in opposition to what it is not: aesthetic information. Unlike semantic information “*aesthetic* information, which is untranslatable, refers to the repertoire of knowledge common to [*communes au*] the particular transmitter and particular receptor”; rather than preparing action, it “shapes states of mind.”[67] Let us take up again the example of a military order, delivered vocally. For Moles, “aesthetic” information is carried in the speaker’s individual

Information Theory a Theory of?: Boundary Work Among Scientists in the United States and Britain During the Cold War,” in *The History and Heritage of Scientific and Technical Information Systems*, ed. W. Boyd Rayward and Mary Ellen Bowden (Proceedings of the 2002 Conference, Chemical Heritage Foundation, Medford, NJ: Information Today, 2004), 15–28, 19.

[62] Moles, *Information Theory and Esthetic Perception*, 129. Emphasis original.

[63] Abraham A. Moles, “Théorie de la complexité et civilisation industrielle,” *Communications* 13, no. 1 (1969): 51–63, https://doi.org/10.3406/comm.1969.1185, 130.

[64] Moles, *Information Theory and Esthetic Perception*, 130.

[65] Moles, ibid, 137.

[66] Moles, ibid, 136–137.

[67] Moles, ibid, 128–129.

vocal timbre or in minimal variations of their intonation—essentially, everything that lies in excess to understanding the literal sense of the speaker’s utterance as a command.[68] In a separate study of the effects of transmission and recording on the perceived quality of vocal expression, reported in 1956, Moles noted: “a good speaker is not only a perfectly intelligible speaker, but is also one whose voice seduces us and convinces us.”[69] Moles located precisely such talents in the aesthetic domain, since they related less to the clear and distinct reception of the words spoken than they did to how those words were spoken.

Attending to aesthetic information in music means paying attention to those “deviations [that] are responsible for the factors which formerly were vaguely called ‘color,’ ‘life,’ ‘warmth,’ in performance,” so that an analytical method that could practically separate these two kinds of information with the help of recording technology would have value for the study of musical interpretation.[70] Indeed, music is typified by how composers and performers execute a dynamic adjustment of the amounts of semantic and aesthetic information, relative to one another to produce “a sort of semantic-aesthetic counterpoint.”[71] It may seem striking that Moles believed that musical examples could illuminate the distinction between semantic and aesthetic information, when music’s capacity for semiosis was (and remains) so poorly understood relative to that of speech. But this is precisely what makes Moles’s investigations so provocative: they claim, by deferring prevailing orthodoxies about meaning, that research methods suited to speech and language are equally useful for the analysis of music. Quite apart from their co-presence in contemporary cultural forms (like the radio drama or *Hörspiel*), recorded speech and music existed as equals in the world of the *Théorie* for technological reasons: the material–technical analysis of both domains—through the representational bottleneck of the mathematics of information theory—made their respective objects measurable and comparable.

Moles drew three conclusions from the comparative study of speech and music in these terms. First, Moles remarks that speech is generally roughly balanced in the semantic and

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[68] Moles was not only interested in these qualitative aspects of speech: his research based on this distinction strove toward automatic speaker analysis by the factor analysis of observations made on the “aesthetic” level of speech. Abraham Moles, “Sur la ‘caractérisation’ du discourse et de la diction,” *Cahiers d’Acoustique* 76 (1956): 21–32, https://doi.org/10.1007/BF03021800, 22–25. For a recent account of the emergence of speech-recognition technology from the domain of speaker identification, see Xiaochang Li and Mara Mills, “Vocal Features: From Voice Identification to Speech Recognition by Machine,” *Technology and Culture* 60, no. 2 (2019): S129–60, https://doi.org/10.1353/tech.2019.0066.

[69] Moles, “Sur la ‘caractérisation’ du discourse et de la diction”, 26.

[70] Moles, *Information Theory and Esthetic Perception*, 140.

[71] Moles, ibid, 153.

aesthetic information that it offers. Music, on the other hand, is imbalanced: music contains a greater proportion of aesthetic information than semantic information. He argues that the semantic information of a musical work, capture in its symbolic representation in a score, is relatively constrained by the affordances of notation and of the rules of the applicable music theory more generally.[72] As such, it affords little capacity for surprise—and, consequently, information—when compared to other sonic features of the performance which are left underdetermined by the score, including: latitude for expressive interpretation (tempo, dynamics, and so on), variations in the manufacture of instruments, and performance conventions.[73] Second, the distinction appeared to explain an apparent paradox about the repeated experience of artworks under an information-theoretic account of perception. In music, it provided for experiences on the part of the listener–receptor which exceed mere recollection or prediction of the music's trajectory.[74] Moles explained that we can enjoy repeatedly relistening to the same musical work (despite the apparent redundancy of such an aesthetic decision) because each time it is performed, even in recording, novel aesthetic information arises thanks to the interpreter's changing life experiences which refines the listener's repertoire of symbols, and in turn the flow of information. We therefore never fully exhaust the total information content, even if we become so familiar with its semantic-informational content. Third, and finally, it points towards the possibility of experimental method to approximate the separation of semantic and aesthetic information within a given sound stimulus, which is described in more detail the following sections.[75] If every actually existing aesthetic message contained a mix of semantic and aesthetic information, and every such message was in reality a sequence of irreducible symbols drawn from a given repertoire and materialized in a communications channel, then the symbols corresponding to each class of information could be manipulated and filtered to modify their relative proportions.

Moles's formulation of the semantic–aesthetic distinction had to be carefully contained, lest it pose a challenge to orthodox information theory, at least as it was represented in the narrow, mathematical form expressed by its American progenitors Shannon and Wiener. Despite this, Moles recognized the importance of making clear that the distinction between semantic and aesthetic information was not incompatible with the explanatory remit of MTC, which made no claims about the particular material or metaphysical qualities of information.[76] *A fortiori*, MTC certainly did not support a distinction between different "kinds" of information. To address this concern, Moles observes that in practice every

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[72] Moles, ibid, 136–137. Though Moles concedes that there are populations for whom the semantic content of music (in the score), such as music analysis, and that some musical messages—radio theme songs—are only valued for their semantic content. Moles, ibid, 141.

[73] Moles, ibid, 137–138.

[74] Moles, ibid, 127–128

[75] Moles, ibid, 147–148.

human communication decomposes into several superimposed messages, each at a different level of coherence or complexity. Consider, following Moles, the marks of ink on a page of newsprint. As read by a child, the basic informational units of the page group in one way, perhaps erring where words are not recognized by memory; as read by the typesetter, the sense data is grouped a different way, perhaps according to the runs of type used in compositing the page. To Moles, this was a straightforward consequence of by then well-established *Gestalt* principle of perceptual grouping.[77]

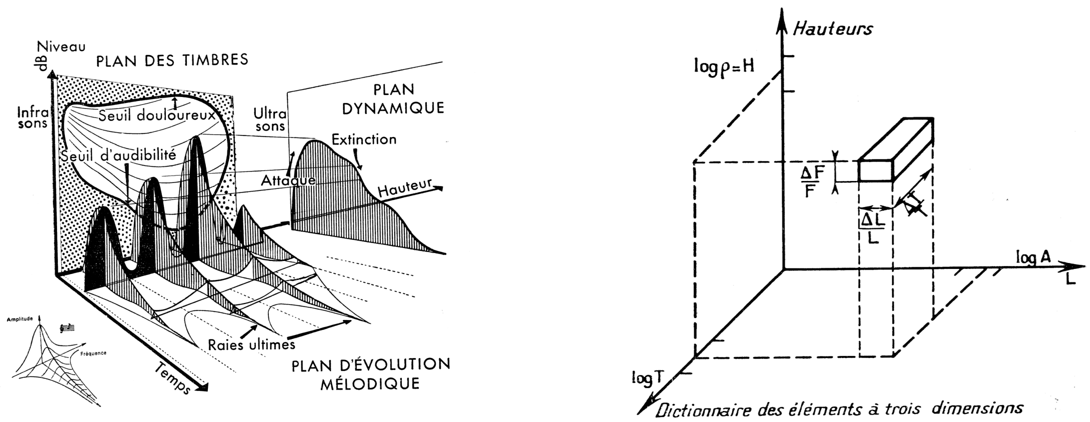

Figure 2. *Left: (Original caption) Fig. IV-3 — The three-dimensional representation of the objet sonore L.H.t. In the diagram, the LH plane projects the instantaneous spectrum of the sound onto the acoustic area; the evolution of this traces, as a function of time, a volume representative of the objet sonore. Moles,*Théorie de l'Information et perception esthétique, *115. Each slice of the thickness of the present contains a recognizable "sound symbol." Right: (Original caption) Fig. I-4. The three dimensions of the sound channel: these are depicted here in a repertoire of domains : level = logarithm of amplitude, pitch = logarithm of frequency, duration = logarithm of time. Moles,* Théorie de l'Information et perception esthétique, *24.*

By 1958, Moles had come to understand how any sound could be represented as some portion of a three-dimensional space with three orthogonal axes: pitch, duration, and intensity. As Curtis Roads notes, such a quantal theory of sound was first advanced by the physicist Denis Gabor, who in 1945 developed a mathematical alternative to the ubiquitous

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[76] This is more or less consistent with N. Katherine Hayles's claim that first-order cybernetics gave researchers a language to decouple form and matter.^ N. Katherine Hayles, *How We Became Posthuman*, 1999, https://www.press.uchicago.edu/ucp/books/book/chicago/H/bo3769963.html, 28–29.

[77] Moles, *Information Theory and Esthetic Perception*, 39; 150–151.

Fourier transform, directly inspired by recent developments in quantum physics.[78] Moles does not cite Gabor's research himself, suggesting instead that Gabor's approach to quantizing sound may have been known to Moles indirectly.[79] The mathematical measure of information Shannon defined was especially amenable to the calculation of information measures on systems that made use of discrete and finite sets of symbols. Hence the importance of the discreteness of sounds so postulated: such a move afforded ready computation and calculation *as if the sounds were alphabetic characters*. This perspective also emphasized that in any given listening set-up there is but one repertoire of basic sounds in play, from which more complex sounds could be successively built up.

Moles's model, unlike the mathematical model described by Gabor, was not entirely formal: it did not purport to describe sounds as they exist independently of a perceiving subject.[80] In the *Théorie*, the three-dimensional model is put to use as a scaffold for describing and computing results about perceptible sound. Psychoacoustic laws of masking, translated into a *solfège* of basic sounds, specifies how these elements aggregate into what Moles's called *objets sonores* (following Schaeffer), and how, in turn, these aggregate into what Moles called "cells" [*cellules*].[81] Moles coined the term "supersign" [*supersymbole*] to refer to a complex of basic sounds so aggregated by the listener, which can be subject to equally valid analyses at multiple levels. Consideration of each level amounted to a reconfiguration of the metalanguage used by Cherry's observer function described above. "Each level," writes Moles, "has its own signs, its code, its repertoire, hence its rate of information per sign, and its redundancy."[82] Empirical results describing the psychoacoustic phenomenon of masking at various levels are then converted into *solfège* of basic sounds, specifying

[78] D. Gabor, "Theory of Communication," *Journal of the Institue of Electrical Engineers* 93/III, no. 26 (1946): 429–57. Such a quantum (or, properly, "quantal") view on sound influenced composer Iannis Xenakis's conception of statistical form, the principles of granular synthesis, and, ultimately, the late-twentieth century interest in the digital-first genre of "microsound." Curtis Roads, *Microsound* (Cambridge, MA: MIT Press, 2001).

[79] It is possible that Moles came to it through Werner Meyer-Eppler, an avid reader of Gabor whom Moles does cite.

[80] In a separate paper, Gabor speculated about a theory of auditory perception that was suggested to him by the structure of his new mathematical tool. Unlike the earlier paper, which was concerned with the technique of signal processing, Gabor hypothesized the existence of neurobiological mechanisms that performed a kind of fleshly analysis of sound signals into discrete packets. D. Gabor, "Acoustical Quanta and the Theory of Hearing," *Nature* 159, no. 4044 (May 1947): 591–94, https://doi.org/10.1038/159591a0.

[81] Moles, *Information Theory and Esthetic Perception*, 120–121.

[82] Moles, ibid, 125. Moles's student Helmar Frank would further develop Moles's notion of the supersign in closer relation to aesthetics. Klütsch, "Information Aesthetics and the Stuttgart School", 86 fn. 32.

which combinations of basic sounds—the smallest quasi-alphabetic units of sound—lead to perceptually distinct sensations, and which do not.[83]

Taking all this together, Moles concluded that what appear to be two distinct kinds of information to be recovered from sounds are, in fact, alternative groupings and concatenations of the same stream of fundamental acoustical quanta. This meant their identity as such was a joint function of the perceptual capacities of the listener and the productive capacities of the sound source. Thus, what Moles introduces as a definitive difference between “semantic” and “aesthetic” information is immediately qualified as a difference of “viewpoint”: simply two different (and complementary) levels of analysis of the same communications system. In this way, Moles ensured the compliance of his theory with the assumptions of mainline information theory, whose advocates, as we have seen, were averse to extensions of the theory beyond communications engineering that did not retain the theory’s original ontological parsimony. Though Moles would occasionally refer to “aesthetic information,” and “semantic information,” there was but one “kind” of information; these tags were useful shorthand for particular perspectives or viewpoints on the same stream of sonic symbols: its basic sounds. This allows us to understand how he arrived at an operational method to determine the relative proportion of semantic and aesthetic information in a given audio signal (relative to a particular listener) while preserving what Floridi calls the “ontological neutrality” of mainstream information theory, to which Moles’s treatise is, as a rule, largely faithful.[84] According to Moles, even if such strong positions as he adopts in *Théorie*—for example, its materialism, the axiomatic difference between information and redundancy, and, of course, the apparent distinction between semantic and aesthetic information—are not always completely justified in the text, they remain of value because they serve a science in what he calls a “dialectic” mode, which begins with stark oppositions and works toward synthesis based on the inadequacies that reductive or schematic viewpoints draw out of a candidate theory.[85]

A brief detour into historical epistemology

We are now prepared to broach the following question: what gave Moles the confidence to postulate a distinction between semantic and aesthetic information, if distinctions of that kind were not envisaged by mainline theories of information? Moles’s distinction between semantic and aesthetic information was grounded in experiment, and, as a consequence, how theoretical or logical consistency with regard to a strict interpretation of the remit of some pre-existing and singular theory of information was not always a paramount concern. Claus Pias has already noted that Moles envisaged his information aesthetics as a practical, lab-based enterprise, that began in the experimental psychology laboratory and made its

[83] Moles, *Information Theory and Esthetic Perception*, 112–114.

[84] Floridi, “Semantic Conceptions of Information”, S. 1.6.

[85] Moles, *Information Theory and Esthetic Perception*, 195–196; 206–207.

way to the mainframe computer installation during the 1960s.[86] The present emphasis on equipment and the practicalities of cybernetic research into sound is also partly inspired by Moles's own remarks, as well as Gaston Bachelard's notion of phenomenotechnique. Bachelard (Moles's doctoral advisor) offered an account of the philosophy of scientific knowledge that shares features with more recent (and not necessarily mutually compatible) theories of knowledge formation that have lately found a certain appeal for historians of music, including the symmetric social constructionism advocated by Bruno Latour, and Hans-Jörg Rheinberger's historical epistemology.[87]

If what was required was a mere change in "viewpoint" in order to observe the different levels on which sound's semantic and aesthetic information-content could be differentiated, the question is: what experimental techniques did Moles make use of to effect such a change? Moles's experimental practice is drawn from the techniques of mid-century sound-studio expertise, evidenced by the several years' worth of empirical research described in the *Théorie* as well as in the scientific journal articles by Moles and his collaborators that precede its publication. Moles himself recognized this point in the *Théorie*: "the difference between semantic and aesthetic information, no matter how justifiable logically, has no interest if it is not operationally based, that is, if it cannot be tested experimentally."[88] Reflecting on his experiments with sound many years later in the 1990s, Moles recalled how he had settled upon

> *une méthode très générale, celle de la déformation ou de la destruction systématique d'un signal, pour y suivre méthodiquement la disparition des propriétés perceptives, et par là, en assumer l'existence et l'analyse*.
>
> a very general method, that of the systematic deformation and destruction of a signal, in order to methodically follow the disappearance of perceptual properties, *and thereby assume their existence and analysis*.[89]

Here Moles states a defensible if complex position within the philosophy of scientific knowledge that is not easily reducible to "positivism" or "scientism," with which labels

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[86] Pias, "'Hollerith "Feathered Crystal"'", 122—123.

[87] Benjamin Piekut, "Actor-Networks in Music History: Clarifications and Critiques," *Twentieth-Century Music* 11, no. 02 (September 2014): 191–215, https://doi.org/10.1017/S147857221400005X; Alexander Rehding, "Three Music-Theory Lessons," *Journal of the Royal Musical Association* 141, no. 2 (July 2, 2016): 251–82, https://doi.org/10.1080/02690403.2016.1216025. See also, Alexander Rehding, "Instruments of Music Theory," *Music Theory Online* 22, no. 4 (December 2016), http://mtosmt.org/issues/mto.16.22.4/mto.16.22.4.rehding.html.

[88] Moles, *Information Theory and Esthetic Perception*, 136.

[89] Moles and Rohmer, "Autobiographie d'Abraham Moles", s. 3.

critics sometimes dub the use of empirical techniques by music researchers.[90] Very coarsely, empiricist accounts of knowledge privilege experience; rationalist accounts, logical deduction. In the face of this hoary philosophical problem, the grounds for scientific knowledge appear to give way. Are scientific objects “out there” in the world, prior to their perception as such? Or, as Moles comments suggest, does the fact that their representation and mediation is parasitic on laboratory technique imply that scientific objects—and the apparently durable facts about them—are epiphenomena of their context of observation? If the latter is the case, there are significant implications for the effect of historical change on scientific knowledge, which theretofore aspired to a certain transcendence. Moles was far from disinterested in such issues: indeed, the philosopher Gaston Bachelard (1884–1962) was Moles’s advisor in Paris, putting Moles in academic confraternity with other notable advisees including Georges Canguillhem and Louis Althusser. Moles’s second PhD (in philosophy) was earned not only for the manuscript that became the *Théorie*—in fact his *thèse complementaire*—but also another document entitled “La création scientifique,” which explores the pragmatics of scientific discovery and was published in 1957.[91]

As Hans-Jörg Rheinberger has pointed out, since the 1930s Bachelard had attempted to transcend this central dichotomy within scientific epistemology, which hinged on the relationship of scientific observation to the notional external world. Bas De Boer explains how Bachelard strove towards “a synthesis of rationalism and realism that takes into account the constructed nature of scientific objects”; he would refer to this mediating position as “applied rationalism” or “technical materialism.”[92] In 1933, Bachelard stated the case in a pithy, if reductive catchphrase: “In modern science, the instrument is veritably a reified theorem.”[93] Important to his counterproposal is the synthetic concept of phenomenotechnique: the idea conceives of “technology not as the eventual byproduct of scientific activity, as a derivative product through which science manifests itself in society, but as constitutive of the contemporary scientific *modus operandi* itself.”[94] All this raises the

[90] Iverson, *Electronic Inspirations*, 21.

[91] Abraham Moles, *La création scientifique* (Genève: Kister, 1957).

[92] Bas De Boer, “Gaston Bachelard’s Philosophy of Science: Between Project and Practice,” *Parrhesia* 31 (2019): 154–73, https://www.parrhesiajournal.org/parrhesia31/parrhesia31_deboer.pdf, 161.

[93] Gaston Bachelard, *La formation de l’esprit scientifique: contribution à une psychanalyse de la connaissance* (Paris: J. Vrin, 1999), 140. Cited in Hans-Jörg Rheinberger, “Gaston Bachelard and the Notion of ‘Phenomenotechnique’,” *Perspectives on Science* 13, no. 3 (September 2005): 313–28, https://doi.org/10.1162/106361405774288026, 320.

[94] Rheinberger, “Gaston Bachelard and the Notion of ‘Phenomenotechnique’”, 315. See also, Teresa Castelao-Lawless, “Phenomenotechnique in Historical Perspective: Its Origins and Implications for Philosophy of Science,” *Philosophy of Science* 62, no. 1 (March 1995): 44–59, https://doi.org/10.1086/289838.

epistemic status of laboratory equipment, which serves not so much to materialize a visible —or indeed audible—correlate of the somehow ontologically prior state of the object under study, than it is to dialectically "instruct" it materially.[95] Moles, much like any scientific researcher, cannot be said to have merely *applied* information theory to his objects of study. It is more accurate to say he worked at the limits of the experimental systems *afforded by* a turn to information theory, and, we might say, cybernetics more generally.

In this light, the studio equipment and media of Moles's research milieu take center stage. Keeping in mind his advisor's influence, which anticipates aspects of Rheinberger's own philosophy of scientific knowledge as well as the sociology of scientific knowledge to become more popular later in the 20th century, we might say that Moles's conclusions about the distinction between semantic and aesthetic information in the *Théorie* were not determined or inspired, but "instructed"—following Bachelard—by the manipulation of sound recordings in the various electroacoustic studios where Moles and his colleagues worked. The way Moles accommodated his interpretations of the empirical research he conducts within the constraints of a relatively eclectic experimental program can appear unsystematic, especially in the light of subsequent research into music cognition. The ebb and flow of the logical or musical coherence of Moles's efforts from our vantage point is less a marker of his inadequacy or the irrelevance of his theory to modern accounts of the psychology of listening than it is a characteristic feature of the processes of knowledge creation under contexts of what Rheinberger calls "differential reproduction."[96]

Indeterminacy of this kind is a both a specific hallmark of cybernetic applications of studio technology to speech and music research in the postwar decades and also, most generally, a feature of creation in not only scientific and artistic contexts, but also of their fruitful intersection in which Moles's *Théorie* squarely lies.[97] Strikingly, from this perspective, a thematic discography Moles had included as an appendix to the original 1958 edition was excluded from Cohen's English edition. This despite the fact that these recordings were cited implicitly and explicitly as supporting evidence for many of the topics discussed in the *Théorie*, and are implicated in the text's credibility as a whole. The discography, reproduced here in full for the first time in English (Appendix A), serves as a reminder that Moles's research program was at base a practical one: it mobilized recordings and recording-studio technology to assert new knowledge about hearing under the cybernetic framework he espouses throughout the text.

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[95] Rheinberger, "Gaston Bachelard and the Notion of 'Phenomenotechnique'", 320.

[96] Hans-Jörg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford, CA: Stanford University Press, 1997), ch. 5.

[97] Hans-Jörg Rheinberger, "Epistemics and Aesthetics of Experimentation: Towards a Hybrid Heuristics?" in *Practicing Art/Science: Experiments in an Emerging Field* (Routledge, 2018), 236–49, http://hdl.handle.net/21.11116/0000-0002-4CC9-7.

Demonstrating the distinction

Intelligibility and manipulated speech

The progressive distortion of visual and aural stimuli was a well-established procedure for determining the limits of intelligibility of processed signals. Mara Mills has recently described how 1950s researchers had recognized the limits of studying the properties of communications channels using simple phenomena—acoustically "pure" tones, and so on—and sought to ground empirical studies of recording media in speech, unwittingly retracing a program of research advanced as early as 1890.[98] A turn to what would now be called more "ecologically valid" stimuli, usually human speech, was accompanied by the institutionalization of the concepts like "articulation," "detectability," and "intelligibility" by researchers working in the Bell Telephone System in the 1920s.[99] Further pioneering hearing research in the United States was funded by the defense establishment—intensifying during the Second World War—and sought both to optimize man-machine systems and to rehabilitate those whose hearing faculties had been damaged, sometimes irreversibly, by combat.[100] Werner Meyer-Eppler, among many other former Nazi *Mitläufer*, led comparable psychoacoustic research from within the German war machine; as radio communication and other acoustic defense technologies became routine matériel, understanding the role of the listener became strategically important.[101]

The goal of this research was to discipline human bodies and couple them to the emergent proto-digital communications networks of their moment; for their designers, as Maddalena and Packer explain, "the corpus of human sensation was an untapped cornucopia of

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[98] Mara Mills, "Testing Hearing with Speech," in *Testing Hearing: The Making of Modern Aurality*, ed. Alexandra Hui, Mara Mills, and Viktoria Tkaczyk (New York, NY: Oxford University Press, 2020), 23–48, https://dx.doi.org/10.1093/oso/9780197511121.001.0001.

[99] Mills, ibid, 25. Intelligibility, notably, was the concept most closely associated with the study and design of test recordings that contained speech.

[100] Gascia Ouzounian, *Stereophonica: Sound and Space in Science, Technology, and the Arts* (Cambridge, Massachusetts: The MIT Press, 2021), 96–103. A considerable proportion of this research is summarized in Mark R. Rosenzweig and Geraldine Stone, "Chapter VI: Wartime Research in Psycho-Acoustics," *Review of Educational Research* 18, no. 6 (December 1948): 642–54, https://doi.org/10.3102/00346543018006642.

[101] Jennifer Iverson, "Fraught Adjacencies: The Politics of German Electronic Music," *Acta Musicologica* 92, no. 1 (2020): 93–111, http://muse.jhu.edu/article/758208. See also, Elena Ungeheuer, *Wie die elektronische Musik "erfunden" wurde–: Quellenstudie zu Werner Meyer-Epplers musikalischem Entwurf zwischen 1949 und 1953*, Kölner Schriften zur neuen Musik, Bd. 2 (Mainz; New York: Schott, 1992).

semiotic capacity."[102] Developments in physics and the design of electronics components allowed for increasingly sophisticated manipulation of sound, which could be used to create new stimuli for empirical research.[103] J.C.R. Licklider, who conducted psychoacoustic research at Harvard using the latest such technology made a striking analogy in describing research into the question of "intelligibility," which shows the conflation of the biological and the artificial and a surprising appeal to contemporary neurophysiology. His researchers found it

> useful to employ a procedure analogous to that based upon surgical lesions and tests of performance in the study of brain functions. It is instructive, for example, to operate upon the speech-wave—i.e. to distort it—and to determine the effect upon intelligibility by comparing pre-operative and post-operative articulation scores. In this way, distortion is useful as a tool with which to study the nature of speech.[104]

Rachel Mundy has attended to comparable remarks by the comparative musicologist Erich von Hornbostel, who, speaking of the need to subject melodies to the dissecting table of analysis invoked a similar conflation of scientific and cultural object.[105] Laboratory technology, on this view, promises the direct and unmediated manipulation of sonic phenomenon, where the opposite is in fact the case: -iatric technologies (such as those of lesion and of dissection) produce the representations of the objects under study, and engender interpretation of cultural phenomena in the normative language of deficiency, disability, and dismemberment.

Once stimulus sounds had been manipulated with the help of the studio equipment, human auditors would be looped into the experimental circuit: the experimental subjects ability to hear through these distortions became the measuring device. Moles apparently drew on George Miller's textbook *Language and Communication* (1951) to understand the state of the art in speech manipulation experiments, as most of Moles's citations to this particular body of research—such as the earlier work of Licklider—can be found there.[106] Moles covers much the same ground described by Miller, describing in the *Théorie* a total of five

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[102] Kate Maddalena and Jeremy Packer, "The Digital Body: Telegraphy as Discourse Network," *Theory, Culture & Society* 32, no. 1 (January 2015): 93–117, https://doi.org/10.1177/0263276413520620, 103.

[103] Roland Wittje, *The Age of Electroacoustics: Transforming Science and Sound* (Cambridge, Massachusetts: The MIT Press, 2016).

[104] J. C. R. Licklider and Irwin Pollack, "Effects of Differentiation, Integration, and Infinite Peak Clipping Upon the Intelligibility of Speech," *The Journal of the Acoustical Society of America* 20, no. 1 (January 1948): 42–51, https://doi.org/10.1121/1.1906346, 1.

[105] Rachel Mundy, *Animal Musicalities: Birds, Beasts, and Evolutionary Listening*, Music/Culture (Middletown, Connecticut: Wesleyan University Press, 2018), 84–85ff.

techniques for manipulating recordings speech and music by deliberately manipulating them: masking, filtering, “infinite” peak-clipping (a kind of non-linear distortion), reverse playback, and time-stretching.[107] Moles was confident in the novelty of his use of information-theoretic analysis of human-subject experiments to disentangle semantic and aesthetic content in recorded music.[108] Moles’s claim was largely justified: Miller’s text was mostly silent on the question of music, and neither Licklider nor Pollack had devoted much time to music. Their research on hearing had emphasized the intelligibility of speech using simulations of war-functional radio transmissions with carefully prepared databases of stimulus sentences, and not art. Presenting his own work on distorted speech at the Seventh (“Macy”) Cybernetics Conference in March 1950, Licklider noted in response to a question by Wiener that research into clipping and music remained informal and underdeveloped.[109] I briefly examine just two of the five studio techniques used by Moles to manipulate sound in order to estimate the relative information content of speech and music: parametric filtering and reverse playback.

Albis *Terzfilter* experiments

In 1956, Moles published a German summary of his book in the *Gravesaner Blätter*, the periodical publication of the Swiss electronic music studio where he would serve as director.[110] This summary was accompanied by a recording from Moles’s experiments with

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[106] And, of course, Moles cites Miller. Abraham A. Moles, “Cybernétique, information et structures économiques,” *Communication & Langages* 19, no. 1 (1968): 37–55, https://doi.org/10.3406/colan.1968.5034, 91ff. Key research by Miller, whose earliest mature research was carried out at the Harvard Psychoacoustic Lab, drew on information theory to better understand these research problems and would go on to develop an information-processing model of the mind at the Center for Cognitive Studies, which he founded at the same university in 1960. Hunter Crowther-Heyck, “George A. Miller, Language, and the Computer Metaphor of Mind,” *History of Psychology* 2, no. 1 (1999): 37–64, 45–47.

[107] Admittedly, telephone companies had experimented with the transmission of live music and record manufacturers and enthusiast consumers alike would put records to the test—sometimes using purpose-made test discs—to assess the audio-definitional quality of their favored systems. Moles had even played a role in the development of the High Fidelity discourse in France himself, establishing the audio consumer magazine *Revue du son* with Georges Ginieaux in 1953. Mathien, “Abraham Moles”, 103–104.

[108] Moles, *Information Theory and Esthetic Perception*, 148.

[109] Claus Pias, ed., *Cybernetics – the Macy Conferences 1946-1953: The Complete Transactions*, First printing (Macy Conference, Zürich; Berlin: Diaphanes, 2016), 229. Licklider’s contribution to that conference was entitled “The Manner in Which and Extent to Which Speech Can Be Distorted and Remain Intelligible.”

filters; some with speech and others with music.[111] These recordings evidence how Moles took “control” recordings of speech and music and passed them through the Albis *Terzfilter*, a device resembling a fixed-bandwidth graphic equalizer that used a bank of passive inductive–capacitance (LC) filters, controlled by precision sliders.[112] This device was manufactured in Zürich and, in 1960 it cost DM 4,650. The Gravesano studio had access to a 24-band model (very similar or identical to the Albis 502/74, shown here in Figure 3 (a)), with filter center frequencies spaced approximately one-third of an octave apart ranging from 98Hz to 6250Hz, and up to 60 dB attenuation.[113] In 1956, one unit was recorded as being on loan to the studio, perhaps in exchange for benefit-in-kind; *Albiswerk* equipment was regularly advertised in the pages of the *Gravesaner Blätter*. It allowed studio users to filter out various audible frequency components within the frequency range affecting the perception of vowel sounds.

Moles had already argued in print (in 1952) that filtered speech can be used to estimate the proportions of semantic and aesthetic information in a given recording.[114] His experiments at Gravesano extended these findings to musical recordings. The musical example, included in the record that accompanies his report, was a seventy-second excerpt from an orchestral work by Franz Liszt. Each time the excerpt was repeated, the Albis *Terzfilter* was adjusted to filter out different combinations of frequency bands; diagrams of the filter configurations used in the examples recording accompanied Moles’s report (Figure 3 (b)). Moles clearly believed that when the sense of a sentence—as reported by experimental subjects—is preserved, so is the semantic information contained in the recording of that sentence. Modifying the settings on the *Terzfilter*, Moles would note how the accuracy of subject’s responses changes in response to the different spectral modifications of the recording that each setting encodes. Moles concluded that particular configurations of the

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[110] André Moles, “Informationstheorie und äesthetische Empfindung,” *Gravesaner Blätter* 6 (December 1956): 3–9.

[111] [Abraham] André Moles, “Filterversuche: Bericht über die 2. Stipendatsperiode in Gravesano (15. Dezember bis 21. Januar 1955/66) I,” *Gravesaner Blätter* Jahrg. II, no. 6 (December 1956): 10–14. Thanks to Kees Tazelaar for posting these here: http://keestazelaar.com/gravesaner-blatter/. Also see the AdK for the printed journals: https://archiv.adk.de/bigobjekt/44596.

[112] See the partial electrical schematic included in A. Scerri and Karlhans Weisse, “Centro Sperimentale Elettroacustico « Dr. Hermann Scherchen », Gravesano,” *Gravesaner Blätter*, no. 1 (July 1955): 5–21.

[113] “Aus dem Inventar des Experimentalstudios Gravesano,” *Gravesaner Blätter*, no. 4 (May 1956): 64.

[114] André Moles, “Étude et représentation de la note complexe en acoustique musicale,” *Annales Des Télécommunications* 7, no. 11 (November 1952): 430–38, https://doi.org/10.1007/BF03021975.

bandpass filters under which semantic information was recovered most reliably indexed to the regions of the sound spectrum responsible for bearing the majority of this information (Figure 3 (c)).

Sociologists of science and technology following Latour might focus on the status of the two printed inscriptions (Figures 3 (b) and 3 (c)) as “immutable mobiles”: stable but portable records that pass between research contexts and sites.[115] Rheinberger, on the other hand, adopts a more capacious understanding of inscription: extending the site of scientific representation to the apparatuses of research themselves: “it is […] unnecessary to distinguish between machines that ‘transform matter from one state and another’ and apparatuses or ‘inscription devices’ that ‘transform pieces of matter into written documents.’ […] The whole experimental arrangement […] has to be taken as a graphematic articulation.”[116] Taking this view, the specific configuration of the *Albiswerk* filterbank (Figure 3 (c)), its affordances to its operators, and its semiotic weight (as an expensive apparatus on loan) within the Gravesano community all form part of the archive that attests to Moles’s research.

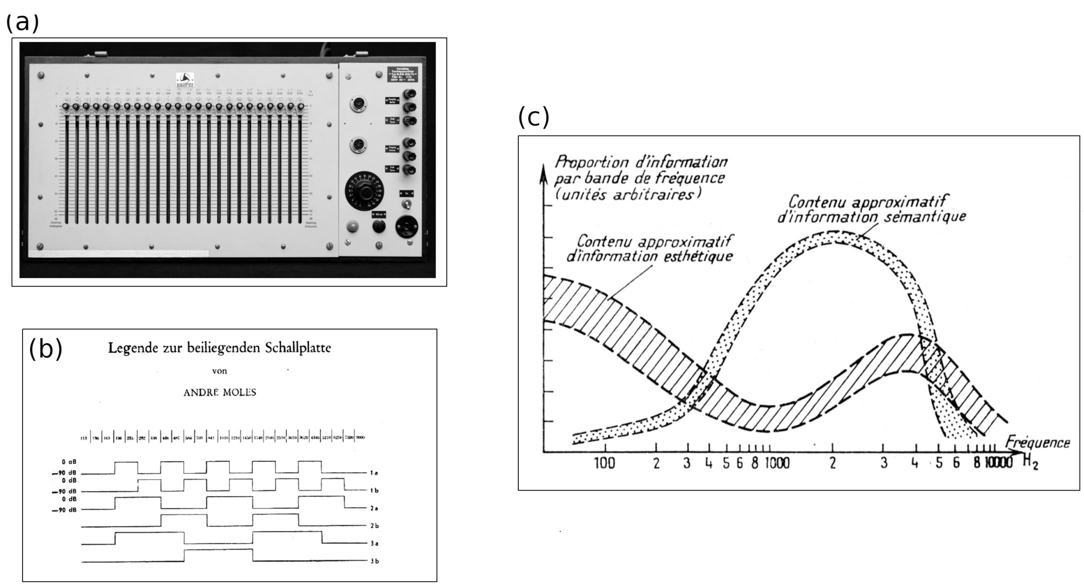

Figure 3: (a) *(N)WDR composer Hermann Hieß’s Albiswerk Terzfilter 502/74, which is similar if not identical to the model used by Moles at Gravesano. Credit: © Johanna Diehl/Zentrum für Kunst und Medien (ZKM), Karlsruhe. Source: http://https://zkm.de/en/das-heiss-studio-im-zkm.* ***(b)*** *Diagram showing* Albis *filter configurations used in Moles’s experiments with speech and music, reported in Gravesaner Blätter. Moles,“Filterversuche.” 15. Digitized by the Akademie der Künste, Berlin as part of the*

[115] John Law and Vicky Singleton, “Object Lessons,” *Organization* 12, no. 3 (May 1, 2005): 331–55, https://doi.org/10.1177/1350508405051270, 335-336.

[116] Rheinberger, *Toward a History of Epistemic Things*, 111.

*Hermann-Scherchen-Archiv and available at https://archiv.adk.de/bigobjekt/44596. (c) A diagram typical of those used by Moles to represent the relative proportions of aesthetic and semantic information in recorded sound vs. frequency bands corresponding to those on the Albis filter, derived loosely from the results of his filter experiments. Moles,*Théorie de l'Information et perception esthétique, *152*.

Reverse playback

Reverse playback [*inversion*], argued Moles, preserves the overall timbral features of a recorded musical work, while completely disrupting its temporal progression.[117] Reverse playback stymies the listener's capacity to act in response to or in prediction of the music's flow, which Moles identified with the transfer of semantic content. As it was for the media theorist Friedrich Kittler, so it was for Moles of: phonographic technical media and their inscriptions of sound afford time-axis manipulation.[118] Reverse playback was possible with phonographic records and magnetic tape, and, again, Meyer-Eppler anticipated Moles's use of the technique in the study of speech.[119] The Gravesano studio had access to three reel-to-reel tape recorders: two Telefunken M5 recorders (like those at the NWDR studios at Cologne and the Siemens electronic studio in Munich) and a portable Ampex 350P stereo recorder.[120] Though neither player supported normal-speed reverse playback using their push-button interfaces, it was trivial to reverse the tape's playback direction: the open-reel

[117] This is basically true, if timbre is understood primarily as a feature of the harmonic domain. However, timbre is a bit more complex and few would agree today that timbre is not affected by temporal manipulation. (Cohen confusingly translated this as "inversion")

[118] "Time is not reversible […] [.] But the mapping of time into space makes time share space's reversibility." Moles, *Information Theory and Esthetic Perception*, 108. On Kittler and technical media, see Sybille Krämer, "The Cultural Techniques of Time Axis Manipulation: On Friedrich Kittler's Conception of Media," *Theory, Culture & Society* 23, no. 7-8 (December 2006): 93–109, https://doi.org/10.1177/0263276406069885.

[119] W. Meyer-Eppler, "Reversed Speech and Repetition Systems as Means of Phonetic Research," *The Journal of the Acoustical Society of America* 22, no. 6 (November 1950): 804–6, https://doi.org/10.1121/1.1906693.

[120] "Aus dem Inventar des Experimentalstudios Gravesano". The NWDR installation is depicted in Holmes, *Electronic and Experimental Music*, 59. The Siemens installation is reported in Stefan Schenk, *Das Siemens-Studio für elektronische Musik: Geschichte, Technik und kompositorische Avantgarde um 1960*, Münchner Veröffentlichungen zur Musikgeschichte 72 (Tutzing: Schneider, 2014), 115–118. Ampex recorders were a popular choice for electronic music centers well in to the 1960s, even if they were underused. One commentator went so far as to diagnose "Ampex" syndrome in the majority of new university installations in the US. Robert Ceely, "Electronic Music Three Ways," *Electronic Music Review*, no. 1 (January 1967): 18–21, https://www.ubu.com/media/text/emr/periodicals/EMR1.pdf, 16.

layout afforded the switching of left and right tape reels, so that the tape would unspool in the opposite direction.[121] Such “tricks” with recording equipment were long familiar to audio professionals; indeed, a patent was sought in 1943 for reverse “re-recording” as technique for improving the quality of phonographic recordings dubbed from a telephone-line source.[122]

On Moles’s two-level information-theoretic account, reverse playback stripped music of its semantic information precisely because it liquidated those components of the original signal that represent music’s progression in time: its moment-to-moment syntax, which afforded listeners’ expectations and predictions. Reversed speech, argued Moles, lost more semantic information than did reversed music, however, implying that in the musical case this process of erasure was far from total.[123] Describing experiments where listeners played reversed recordings of a selection of Western art music from the classical, modern and experimental genres, he evidently asked his subjects to report their preference between unprocessed and reverse recordings. Moles reported that in connection with the music of Igor Stravinsky (probably a recording of *The Rite of Spring*, see Discography item 9), the composer’s focus on timbral richness (i.e. aesthetic information) over temporal progression (i.e. semantic information) meant that its aesthetic richness as a whole “remains totally intact” on reverse playback—to the extent that a significant proportion of young subjects preferred the reversed form of the excerpt.[124]

Moles boldly claimed that “temporal inversion reveals the cultural and social aspect of musical structures.”[125] He investigated the effect of reverse playback on what he called “exotic” music, “from beyond the Moslem frontier” and reported that no clear aesthetic preference between the straight-ahead and inverted recordings was noted by participants.[126] The items 14 and 15 in the accompanying discography suggest that Moles used ethnographic recordings of Javanese *gamelan* and Japanese *Nō* theater performances made by von Hornbostel. On the basis of such experiments, noting that his subjects were all

[121] Andrea F. Bohlman and Peter McMurray, “Tape: Or, Rewinding the Phonographic Regime,” *Twentieth-Century Music* 14, no. 1 (February 2017): 3–24, https://doi.org/10.1017/S1478572217000032, 16–17.

[122] Lincoln Thompson, Reverse re-recording system, 47901843A, issued April 5, 1949. See also the very informal remarks about the effect of reverse playback on speech and music in E. W. Kellogg, “Reversed Speech,” *The Journal of the Acoustical Society of America* 10, no. 4 (April 1939): 324–26, https://doi.org/10.1121/1.1915995, cited in Meyer-Eppler, “Reversed Speech and Repetition Systems as Means of Phonetic Research”, 804.

[123] Moles, *Information Theory and Esthetic Perception*, 168

[124] Moles, ibid, 145–146.

[125] Moles, ibid, 146.

[126] Moles, ibid, 147.

"European," he reasons that listeners naive to the structures of a musical tradition appreciate musical material "directly on the aesthetic level."[127] The cultural assumptions baked into these investigations are staggering but they are beside the point: these judgments were, of course, unreliable and prejudiced. Experimenters have long used recordings to putatively foreign musical cultures in faulty bids to generalize about listening cultures in general; this is a project that, despite ample critique, continues today in more-or-less ameliorated forms.[128] What is at issue here is how Moles used sound recording media in tandem with the edifice of information theory in order to engineer a new space of representation in which these kinds of judgments can be made: this is Moles's legacy.

Conclusion

By the time Cohen's English translation was published, interest in applying information theory to music was experiencing one of its temporary nadirs, which Elizabeth Margulis considers typical of the enterprise.[129] For Robin Maconie, 1968 marked the end of music composition's official interest in cybernetics because composers and technicians' pleas for yet more computational resources began to fade in credibility, since their compositions could scarcely keep pace with the rapid technological developments in the field.[130] This accords with the wane in scientific interest in cybernetics during the 1960s before it was "reinvented as a systems science and as second-order cybernetics in the 1970s."[131] Subsequent research in the burgeoning field of music cognition during the twentieth century, pioneered by researchers such as Irène Deliège, Diana Deutsch, Carol Krumhansl and David Huron, made Moles's texts fade further in relevance: its already dated findings could not compete with the avalanche results that the cognitivist approach to music was generating. Moles ruminations about learning and memory, two perennial concerns of human psychology, received limited attention from psychologists.[132] Moles's contributions are largely underspecified and behavioristic in a conventional way: Moles does postulates

[127] Moles, ibid, 147.

[128] Mundy, *Animal Musicalities*.

[129] Elizabeth Hellmuth Margulis and Andrew P. Beatty, "Musical Style, Psychoaesthetics, and Prospects for Entropy as an Analytic Tool," *Computer Music Journal* 32, no. 4 (November 19, 2008): 64–78, https://doi.org/10.1162/comj.2008.32.4.64.

[130] Robin Maconie, "Care to Listen: Milton Babbitt and Information Science in the 1950s," *Tempo* 65, no. 258 (October 2011): 20–36, https://doi.org/10.1017/S0040298211000362.

[131] Ronald Kline, "How Disunity Matters to the History of Cybernetics in the Human Sciences in the United States, 1940–80," *History of the Human Sciences* 33, no. 1 (February 2020): 12–35, https://doi.org/10.1177/0952695119872111, 14.

[132] Moles, *Information Theory and Esthetic Perception*, 96–100.

neither neural nor biological mechanisms for many of the psychological processes he accounts for in the *Théorie*, despite the fact that biophysics and neurophysiology were crucial sites of cybernetic research into human behavior during the late 1940s and into the 1950s, coeval with the psychoacoustic research Moles does cite.[133] As Jean Devèze remarks, the term “*psychologie*” does not appear in the titles of Moles’s many publications until 1960, while his ultimate self-identification as a social psychologist would have to wait until most of his research with acoustics and music was complete.[134]

It is for some a frustrating feature of the *Théorie* that its impressionistic results are almost always advanced by Moles as provisional: his findings await further refinement or come with the caveat that limited sample sizes constrained their power to generalize to the listening behavior of the population at large. But this empirical humility was a characteristic of Moles’s own philosophy of scientific investigation and Moles admitted as much himself. Cohen’s preface noted that the “role of information theory […] is mainly heuristic: suggestive and exploratory”; the text, in Moles’s own words, “offers not only properly new results, but a new method of presentation, a synthesis of known facts in a new structure, making evident the gaps, destined to be filled, in our knowledge.”[135] As a result his investigations came to be viewed as fatally underdetermined as scientific experiments, especially those that involved human subjects. They were difficult to replicate and Moles’s use of data is anecdotal rather than systematic. Despite its uncertain status as hard science, in the *Théorie* Moles had enumerated a set of tools for thinking about sound and music that could be bent toward what coalesced into the cognitive-scientific project. Moles’s text remained an influence for decades, as it became a key citation for other information-theoretic research into music by researchers like Hiller and Ramon Fuller, Joseph Youngblood, David Lewin and, later, Darrell Conklin and Ian Witten.[136] The *Théorie*

[133] Ronald R. Kline, *The Cybernetics Moment: Or Why We Call Our Age the Information Age* (Baltimore: Johns Hopkins University Press, 2015), 44–55. See also, Orit Halpern, *Beautiful Data: A History of Vision and Reason Since 1945*, Experimental Futures (Durham: Duke University Press, 2014), ch. 3 (“Rationalizing: Cognition, Time, and Logic in the Social and Behavioral Sciences.”).

[134] Devèze, “Abraham Moles, un exceptionnel passeur transdisciplinaire”, 192.

[135] Moles, *Information Theory and Esthetic Perception*, Preface; 32.

[136] Much of this research is surveyed in Alan Marsden, “New Prospects for Information Theory in Arts Research,” *Leonardo* 53, no. 3 (June 2020): 274–80, https://doi.org/10.1162/leon_a_01860; Marcus T. Pearce, “Early Applications of Information Theory to Music” ([Unpublished MS], 2007), http://webprojects.eecs.qmul.ac.uk/marcusp/notes/music-information-theory.pdf; Moreno Andreatta, “Formalizing Musical Structure: From Information to Group Theory” (Undergraduate research paper, University of Sussex, 1997), http://recherche.ircam.fr/equipes/repmus/moreno/DissSussexMAndreatta.pdf. An important contemporary source is Cohen, “Information Theory and Music”. See also, Miller,

is most often cited in this orbit not as source of scientific fact, but as a source of inspiration for much information-theoretic work on aesthetics that followed. When it is cited, it is most often cited as the first text to address this area programmatically, rather than as the concern of another field or discipline. This seems fair.

It is sometimes assumed that essays in the cybernetic human sciences like Moles’s treatise are necessarily behavioristic, which raises the hackles of diligent liberal humanists who are taught to recognize and resist the reduction of human subjects to inscrutable, Skinnerian black boxes. In fact, classically opposed viewpoints in psychology—for example, behaviorism and mentalism—can co-exist in information-processing theories of cognition.[137] This synthesis was not always principled, but it certainly complicates simple equations between cybernetics and an aversion to the inner lives of human subjects.[138] In his later *Treatise on Musical Objects*, Pierre Schaeffer disavowed what he called Moles’s “simplistic model” of the *objet sonore* which both men had worked on in the “Esquisse,” and which Moles developed further in the *Theorie* along the lines sketched here.[139] Despite this dismissal, Moles’s approach is not entirely without its own phenomenological program. He asserts the status of information theory as an “inspiration” that serves to defamiliarize the apparently natural act of communication. In Moles’s glosses on his tape experiments, he extolled the virtues of reverse playback in particular: “shattering the normal view of the temporal object, reverse playback aims to recover an intrinsic appreciation forbidden to us by our mental habits.”[140] “[T]he theory [of information] appears as a huge *Gedanken* experiment,” continues Moles in a more general vein, “attempting to re-create the

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“Enminded, Embodied, Embedded”, 129 and the bibliography in Sarah Elizabeth Culpepper, “Musical Time and Information Theory Entropy” (M.A. thesis, The University of Iowa, 2010), https://doi.org/10.17077/etd.xe2tdyvf.

[137] Crowther-Heyck, “George A. Miller, Language, and the Computer Metaphor of Mind”.

[138] Almost as soon as it is cybernetics is introduced, it takes in quite incompatible theories of subjectivity. For a rich account of cybernetics’ complicated relationship to both behaviorism and a post-war “cognitive liberalism,” see Danielle Judith Zola Carr, “‘Ghastly Marionettes’ and the Political Metaphysics of Cognitive Liberalism: Anti-Behaviourism, Language, and the Origins of Totalitarianism,” *History of the Human Sciences* 33, no. 1 (February 1, 2020): 147–74, https://doi.org/10.1177/0952695119874009. See also, in connection with Gordon Pask and sound, Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2010), ch. 7.

[139] Pierre Schaeffer, Christine North, and John Dack, *Treatise on Musical Objects: Essays Across Disciplines*, California Studies in 20th-Century Music 20 (Oakland, California: University of California Press, 2017), 38–39. See also, Brian Kane, “The Fluctuating Sound Object,” in *Sound Objects*, ed. James A. Steintrager and Rey Chow (Durham: Duke University Press, 2019), 53–70, https://doi.org/10.1515/9781478002536-005, 61.

[140] Moles, *Information Theory and Esthetic Perception*, 147.

strangeness of communication by making evident its material aspect. It was specifically this point of view which led us to the concept of sonic objects."[141] It is perhaps surprising that cybernetics, maligned by its ready association with behaviorism, looms so large an influence in Moles's project to denaturalize communication. Moles's relationship to phenomenology offers another thread to pull on, worrying accounts of information theory's influence on sound culture that characterize the enterprise as anything other than disunified and heterogeneous.

If Schaeffer's phenomenology was concerned with the *objet sonore*, Moles's phenomenology is not so much an account of the empirical encounter with the *objet sonore* but of scientific inquiry in general, which is to say an account of how the sound object is constructed *as such*: namely, as an object. Notwithstanding his often-confused use of scores as empirical data, Moles ultimately viewed score-bound music theory a moribund enterprise "retarded by dogmatism," which could be revived by helping itself to contemporary phenomenotechnique.[142] By making use of new forms of inscription, such as the sound spectrogram or the very sliders of a LC filterbank, researchers could deliver a shock to listeners whose epistemologies of sound remain yoked to symbolic representational schemes of music and wrest them from the specious conflation of music-as-notated with music-as-sounded. I have intimated that this was partly due to the phenomenological influence of his advisor Bachelard, an influence which is recursively thematized in this article with a swerve towards Rheinberger's more recent historical epistemology. On this view, Moles's information theory is in fact situated, local, and contextual (like all operative technoscientific theories). The cybernetic subjects at the heart of Moles's *Théorie* cannot be truly said to be given in advance by the parameters of a singular information theory, a unified cybernetic viewpoint. Rather, as we have seen, they emerge in the creative application of post-war sound-studio technique: this was not the mere or slavish application of an already-ramified scientific or "scientistic" theory to the field of cultural production. With this in mind, the resolved image of Moles's project becomes slightly less blurry; its preemption of still-contested issues in the contemporary media-technical landscape as they relate to sound and music, even more uncanny; its critical promise, slightly clearer.

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[141] Moles, ibid, 208.

[142] Moles, ibid, 5.

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Appendix A: Discography

This discography is compiled from the 1958 Flammarion edition and the 1972 Denöel edition of Moles's *Théorie*, and translated by the author.[143] A handful of recordings were added in the second edition (indicated here by a †), while some catalog/matrix numbers that appear in the first edition were removed (for no apparent reason) in the second edition. I have tried to preserve the "feel" of discography as best as I can, by not normalising all but the most egregious variants of spelling, keeping Moles's citiations to musical works intact (and sometimes incomplete), and other infelicities.

My ref.	Entries
	D1) Example of variations in dynamics that are gradually introduced, to compare. Finale of Borodin's "the seventeenth Polovtsian dance" performed by:
1	a) Wolff, Polydor 78 rpm, Lamoroeux concerts
2	b) Stokowski, Gramophone 78rm, Philadelphia Orchestra
	D2) Example of variations of absolute speed in performance (average length), Beethoven, Symphony No. 9
3	: Toscanini His Masters' Voice [VSM] FALD 190/1
4	: Van Otterloo Phil. A 00145/6
4a†	Furtwangler
	D3) Different interpretations of the same piece
	Borodin : Polovstian Dances, from Prince Igor. Compare :
5	a) Wolff : Polydor 78 rpm
6	b) Stokowski : HMV FALP 104 78 rpm
7	c) Fricsay (RIAS) : Phil. DG 16006 78 rpm
	D4) Systematic use of detuned instruments

[143] Moles, *Théorie de l'Information et perception esthétique*; Moles, *Théorie de l'information et perception esthétique*.

My ref.	Entries
8	Wanda Landowska : Recital for harpsichord : HMV [VSM] FALP 218 see [voir], in particular : Chambonnières, “Sarabande” and Scarlatti sonatas
	D5) Exploitation of the harmonic richness of the *objet sonore* (vertical reading; Wellek’s polar perception)
9	Stravinsky, The Rite of Spring, by Dorati, Mercury MLP 7520.
	D6) Piece[s] [morceau] of music susceptible to reverse playback :
10	a) Bizet : Serenade for flute, extract from l’Arlésienne, Phil A 00654
11	b) G[abriel] Fauré : Nocturne for violin, extract from Shylock Columbia 78 rpm
12	d) [sic] Khachaturian : Gayane Suite [No. 2] — [II.] Dance of the Girls, [V.] Lullaby, by Efrem Kurtz — Columbia FCX 153
13	d) [Mehdi] Barkechli : The Persian peasant [paysan] — solo for violin (private collection)
14	e) Musique of the Japanese Noh [Nô] theatre — von Hornbostel collection, Parlophone disc MO 1047
15	f) Javanese music, Parlophone MO 1038, Udan Mas
	D7) Example of systematic Klangfarbenmelodie :
16	Schönberg [sic], A Survivor of Warsaw — Magnetic tape recording of the Donaueschigen Festival [performance]. RTF Sound library [Phonothèque]. Paris
	D8) Examples of rhythmic play
17	a) Gamelan : Java — von Hornbostel collection — Parlophone disc M0 1049 “Sekar Gadung” [”Sekargadüng”]
18	b) Jazz : Singleton, drum improvisation — Vogue disc V 5115 (note the use of rhythmic and dynamic variations)
19	c) African music : Ogoué Mission, Congo — “Chant magique pour appeler les caïmans,” recorded by Didier (beginning). Note the emergence of a more and more complex rhythmic system (BAM 109)
	D9) Example of repetition with simple changing of the voice :

My ref.	Entries
20	Beethoven, Fifth Symphony — 1st movement (23 successive repetitions of the theme… —) von Karajan, Columbia disc CFX 965 (1)
21	Compare the variations in interpretation of this simple theme with the interpretation of Sir Malcolm Sargent Decca GAG 1126.
	D 10) (a) Example of the modification of a theme by changing the *objets sonores* constituting the cells without changing the Gestalt
22	M[aurice] Ravel : Boléro by Paul Klecki — Columbia FX 875, Side A [1er face]
23	Variations due to the instrument on a identical piece. Bach, Tocatta and Fugue [in D minor], performed by E. Power Biggs on 14 famous organs of Europe. Columbia LP 33, 30 cm. n° ML 5032.[144]
	D 11) Repetition with changes in the accompaniment : first 30 seconds of :
24	Schubert, “Unfinished” Symphony [No. 8] — by Thomas Beecham, LX 8942 (1).
	D 12) Repetition with variations of the other voices :
25	J.S. Bach: Fugue in D minor [ré mineur], by Löwenguth Quartet — D B 11182.
	D 13) Progressive [évolutive] repetition of the theme :
26	J.S. Bach : Fugue in A minor, by Boyd Neel Quartet — Decca X 247.
	D 14) Variations on an intial theme
27	a) J. S. Bach — 30 Goldberg Variations [Bach] by Wanda Landowska (clavecin) RCA Victor 118939 — 11944. The comparison of the aria and the variations in ascending order, then in a very different order (1-10 for example), highlights the differences from the theme;
28	b) Mozart–Beethoven — Variations on a theme from The Magic Flute by Cortot and Casals — HMV disc DA 915-916. Compare especially the openings of variations 1, 3, and 7, which demonstrates the passage from the style of Mozart to the style of Beethoven

[144] ML 5023 (incorrectly) in the 1972 edition.

My ref.	Entries
	D 15) Modular repetitions, separated by the insertion of another theme
29	J. S. Bach — Brandenburg Concerto, No. 3 by the Busch Chamber Players — Columbia LFX 480 1st movement.
	D 16) Examples of sonic elements with
30	a) Presentation of musical instruments made by Reynaldo Hahn — Ultraphone FP 1471–1472
31	B) Examples of increasing complexity of musical genres in the LP (33 [rpm]) Capitol SAL 9020. A Study in High Fidelity, comprising a selection of some essential kinds of musical messages.
	D17) Use of percussion to enlarge the [sound spectrum] [*dans l’élargissement spectral*]
32	Milhaud — Studies in percussion, Concerto for percussion by Hal Rees
33	Chavez — Toccata for percussion by Gatham, Urania URLF 7144
	Bartok — Music for strings. Capitol disc LP 33 [rpm] n° P 8299.
	Note in the second movement of Chavez’s [sic] Toccata (Side A, Track 2) an interesting example of the dissolution of a percussion [sound] spectrum into white noise.
	D18) Program music clarified [*explicitée*] by a narrative, significantly reducing the level of semantic information
35	Prokofiev — Peter and the Wolf, by S[erge] Koussevitsky — HMV DB 3900-3902
36	Arthuys — Le Crabe qui jouait avec la Mer. Boîte à Musique. BAM LD 305.
37	O[tto] Luening and V[ladimir] Ussachevsky : Suite from King Lear. Composers Recording CRI 112 33 rpm 30cm.
	D19) Role of the orchestra as a accompaniment to the singer
38	Montiverdi’s Orfeo, Act 2. HMV disc DB 5370.
	D 20) Expansion and contraction of musical time :
39	Hermann Scherchen’s Experimental studio, Gravesano — Ein akustischer Zeitraffer

My ref.	Entries
	— T 71380 — Telefunken 45 M 1) Robespierre’s last speech before the convention [*Robespierre letzte Worte vor dem Konvent*] 2) Beethoven, Egmont Overture 3) [Johan] Strauss [II], Die Fledermaus 4) Beethoven, “Die Trommeln gerühret” [from Egmont, Op. 84] (song) sped up and slowed down
	D21) Homogenization of the mix of singers’ voices and orchestra, tending to use song as an integral part of the orchestra at the high point [*à l’apogée*] of the opera
40	Mozart–da Ponte — Le Nozze di Figaro — Busch, DB 2475 no 3 “Esci omai” [” oria Esciomai “]
40a †	orff (c) Carmina Burana DGG LP 18303
40b †	orff (c) Antigonae DGG LP 18717-19
	D22) Separation of musical and vocal messages at the end of opera’s evolution
41	Verdi, Rigoletto, Act III “La donne è mobile…” — Decca disc LXT 5008 LP 33 30 cm
	D23) Tests of the synthesis of musical *objets sonores*
42	Olson, The Sounds and Music of the Electronic Music Synthesizer. RCA Victor disc LM 1922, LM 33, 30cm.
43	Panorama de Musique concrète. 2 discs. 30 cm. LP 33. Club National du Disque. CND 15 et 16.
44	O[tto] Luening and V[ladimir] Ussachevsky. A poem in Cycles and Bels for tape recorder and orchestra. Composers Recording CRI. 112, LP 33, 30 cm.
45	V[ladimir] Ussachevsky. A piece for tape recorder. Composers Recording. Chim LP 33, 30 cm.
	D24) Separation of semantic and aesthetic information in the musical message
46	A[braham] Moles. Experimente mit dem Albisterzfilter Gravesano : 24 Filter

My ref.	Entries
	Versuche. Telefunken 45 rpm TM T 71489 Musik.
47	A[braham] Moles. Experiment mit dem Albisterzfilter : 36 Filter Versuche Disque Telefunken 45 rpm, T 71651.

	D25) Expansion of the orchestral palette and redundancy by electronic means
48†	Mayuzumi (Toshiro) Nirvarna [sic] Symphony Toshita JLC 5003.

	D26) Computer synthesis of sounds
49†	Matthews, Guttman, Pierce, Music for Mathematics Decca DL 9103

	D27) Experiments on the synthetic realization of a musical score:
50†	Music from Mathematics by Dr. Matthews Bell Labs (stochastic music experiments by the reconstruction of Markov probabilities, Side A)
51†	P. Barbaud. Honeywell Bull, Algorithmic music. Supplement to "Systèmes d'informatique" 33 T.
52†	P. Barbaud. Bull and algorithmic music. N° 38 Sonorama Sonopress

Note [AM]: All of these documents can be consulted at the *Discothèque de la Radiodiffusion française*, which we are pleased to thank here.