Two Musical Episodes at the Piano Keyboard in the Study of Human Information-Processing: Information as "Cognitive Good" in Interdisciplinary Research

October 9, 2021
rev. March 9, 2022 (add license)

In the early 1950s, the biologist Henry Quastler asked pianists to sight-read randomly generated musical scores as quickly and as accurately as possible. Quastler computed their performance as their "information transmission rate," measured in bits-per-second across a variety of related tachistoscopic tasks. Later, Walter Reitman and Marta Sánchez, working at the Carnegie Institute of Technology, made tape recordings of a composer "thinking aloud" as they composed a fugue at the piano keyboard. Reitman (1965) analyzed this data to inspire the design of Argus, a new computer model of "human information-processing" that complemented the paradigmatic early AI research of his colleagues Newell and Simon (1956). Drawing on archival material, I argue that it was "information"—perhaps the most fungible post-World War II "cognitive good" (Bod et al. 2019)—that facilitated such interdisciplinary research in human psychology during the heyday of first-order cybernetics, integrating music into the burgeoning cognitive sciences. Musical behavior is leveraged in both experimental systems (Rheinberger 1997) as a proxy for some facet of cognition otherwise indirectly observable: a presumed human "channel capacity" and the ability to creatively solve "ill-defined problems," respectively. Where Quastler standardized experimental subjects across sensory modalities and study cohorts using the mathematics of information theory, Reitman used the radically inter-subjective protocol study to probe reasoning as information-processing in a less explicitly quantitative way. The detail of such similarities and differences is disclosed by a tightly integrated view on the twinned fates of the humanities and the sciences, here afforded by the liaisons between music and cybernetics.

Presented as "Two musical episodes at the piano keyboard in the study of human information-processing: Information as 'cognitive good' in interdisciplinary research." Panel on Human-Computer Entanglements: Psychology, Computing, and Artificial Intelligence in the 20th Century at 2021 Meeting of the Society for the Social Studies of Science, Toronto, ON. 6–9 October 2021.

> This talk draws on (and in places expands on) material from my dissertation research, and presented at two separate invited talks in Frankfurt (2019) and online (2020).

In 2013, two researchers at the Max Planck Institute for Informatics, Anna Maria Feit and Antti Oulasvirta, presented a remarkable demonstration at the annual ACM Conference on Human Factors in Computing Systems: a new kind of musical typewriter called `PianoText`. Feit, then a doctoral student, claimed that a trained pianist "can produce 12 notes/sec *easily*" with their system.[1] `PianoText` readily exemplifies the passage of ideas from the study of music to other disciplines, showing how researchers in the sciences continue to

[1] Feit and Oulasvirta, "PianoText," 3044.

take musical performance—in this case, pianism—as a repository of skilled human behavior.

While the influence of cybernetics and cognitive science on music has been relatively well charted (by, for example, Christina Dunbar-Hester and Andrew Pickering, and in the accounts of countless composers), music's contribution—both as an academic discipline and as a fund of cultural experience—to these endeavors is less well understood.

Given the relative asymmetry of accounts of the relationship between these two fields, cases like `PianoText` recommend themselves to a program for the interdisciplinary history of knowledge articulated in a recent contribution by Rens Bod and others to *Isis*.[2] They introduce the notion of cognitive goods: "the shared epistemic tools of knowledge-making disciplines that can be transferred across disciplinary boundaries."[3] They argue in favor of a meso-level analysis that tracks the flow of these cognitive goods across disjunct times and places.

Cognitive goods include abstract "methods, concepts, models, metaphors, [and] formalisms," but also their embodiment in "modes of representation, […] demonstrative techniques, [and] technical instruments."[4] In respect of these latter kinds of cognitive good, Rheinberger's claim that "graphematic articulations"—or inscriptions–"channel the noise produced by the research arrangement and translate it into further traces" underscores the way that technique, and specifically techniques of writing, call into question the status of the classic topic of the history of science: the idea.[5]

Two complementary research questions arise: first (and primarily), in what contexts has the flow of knowledge between music and the cognitive sciences, represented in miniature by `PianoText`, been mediated by common "methods, concepts, models, metaphors, [and] formalisms" across distinct times and sites? Second (and secondarily), what is the role of inscription techniques (and media more generally) in these contexts, since they form the background against which this transfer has taken place?

The idea that underwrites `PianoText` is that musical behavior and typewriting are simply special cases of more general human capacity for information processing. This idea, hardly unique to this case, emerged from the profusion of cybernetic theories of information, disseminated among engineers and fellow-travelers after the end of the Second World War and eventually calcified into cognitive-scientific orthodoxy.

For the rest of the talk, therefore, I focus on two complementary scenes in the history of human information-processing between 1955 and 1965. Here, I identify the cybernetic

---

[2] Bod et al., "The Flow of Cognitive Goods".

[3] Bod et al., ibid, 488.

[4] Bod et al., ibid, 488.

[5] Rheinberger, *Toward a History of Epistemic Things*, 106.

concept of "information" as the cognitive good that facilitates interdisciplinary epistemic transfer between music and cognitive science, which I snapshot at two moments in time, separated by less than a decade.

The first scene dates from 1956, and involves Henry Quastler's studies of human "channel capacity" at the Control Systems Laboratory at the University of Illinois, Urbana–Champaign.[6] Quastler was an Austrian physician with a specialism in radiology, who emigrated to New York in 1939. In 1941, Quastler moved Urbana where he practiced medicine until his appointment to a assistant professorship in physiology at the lab in 1949.[7]

By the mid-1950s, Quastler's group was especially interested in determining the limits on the capabilities of human beings in the language of information theory, aligning them with the more well-known research led by George A. Miller. Research in this vein was undergirded by the apparent generality of information; its ostentatious claims to generality.[8] Quastler argued that if

> human information processing can be represented by a limited number of models, independent of the particular kind of information processes, then one can attempt to determine the human capabilities in a general way, not using those tasks which are ultimately of interest, but those that are most accessible.[9]

Quastler designed tasks that were specific and easy-to-measure—that is, operationally more convenient— that dispensed with the need for expensive and time-consuming simulations and potentially risky "field tests": a boon to the military planners who were interested in the results of Quastler's research.[10] Apparently innocuous tasks like typewriting, dial reading, and the recognition of flashcards, once accelerated, became proxies for other human information-processing behaviors at their limits.[11]

Quastler reasoned that human information-processing limits were correlated to the target speed of the tasks set, the range of symbols over which the subject must range to achieve

---

[6] Quastler, "Three Survey Papers."

[7] Kay, *Who Wrote the Book of Life?*, p. 116. For more on Quastler's biography, see Kay, ibid, p. 115–127.

[8] Bowker, "How to Be Universal".

[9] Quastler and Wulf, "Human Performance in Information Transmission: Part I and II," 62–63.

[10] Quastler and Wulf, "Human Performance in Information Transmission: Part I and II", p. 6.

[11] Quastler and Wulf, ibid, p. 15. The vast majority of these reports were digitally scanned and made available online in the last five years.

success, or their product (whichever is lowest).[12] The "piano playing" task described by Quastler must have had particular appeal, as musical stimuli afforded multiple independent variables: musical notation allowed the experimenters to independently vary each of the speed, order of complexity, and range of motion used in experimental stimuli.

In one experiment, Quastler asked three trained pianists to sight-read scores generated by hand following the outcome of controlled random processes.[13] During a typical session, Quastler describes "coaxing the subjects into greater and greater speed until they were obviously way beyond their capabilities."[14]

Quastler was evidently less interested in measuring the envelope of human perfomance in specific tasks than he was in determining the information bottlenecks at the input and output of each human subject, which he assumed were reasonably task-independent.[15] This assumption motivated Quastler's preference for information theory, because in provided a common unit—the "bit"—which could be used to compare results from different tasks and modalities to each other.

We might reflect at this point that both Quastler's and Feit and Oulasvirta's experimental systems materialize an informative vision of pianism, that "looks through" the contingencies of specific scenes of musical expertise and considers musical performance as just another skilled activity ripe for optimization.

The second case I want to present, partly because it appears at first glance to advance a contrastatively richer notion of musicality, is that of Walter Reitman and Marta Sánchez, two researchers who worked together at the Carnegie Institute of Technology in Pittsburgh in the early 1960s. Together, they explored how the particular case of music composition could yield insights into how human beings solved complex problems in general.

Reitman had joined the faculty at Carnegie Tech as an assistant professor of Industrial Administration and Psychology in 1957, where he developed his cognitive science course notes into the text-book *Cognition and Thought: An Information-Processing Approach* (1965). This text argued for computer programming as a tool for research into complex human behaviors like planning and problem-solving.[16] His collaborator Marta Sánchez was

---

[12] Quastler and Wulf, ibid, p. 14

[13] Quastler acknowledges Stanley Fletcher (Fletcher–Munson equal loudness curves), Burrill Phillips (a composer), and Ludwig Zirner of the Music Department at the University of Illinois for "their generous help and advice." Quastler and Wulf, ibid, 62-21 fn.

[14] Quastler, "Three Survey Papers," 14; discussed in Attneave, "Stochastic Composition Processes," 79–80.

[15] Quastler and Wulf, "Human Performance in Information Transmission: Part I and II", 62-5

[16] Sections of this book appear as a CIP Working Paper.

a Chilean pianist. Born in 1923 and raised in Santiago, she received her first degree in piano performance and music education there at the University of Chile.

Working Paper #37 (November 1960) of the "Cognitive Information Processing" Group at Carnegie Tech is credited to Reitman and Sánchez and is entitled "The Composition of a Fugue: Protocol and Comments". It documents the process of composing an example of a kind of musical composition called fugue. Fugue has long history as a highly technical genre of composition that demands a kind of musical literacy associated with intensive education in Western music conservatories and, at times, even genius.

This document, then, is a partial record of a protracted, multi-day conversation between a piano-playing composer and an experimenter. The working paper freely mixes verbal commentary and musical notation, using Western music-notational conventions to record the thoughts and actions of the performer-composer as they completed their composition. The preparation of such documents is not uncommon, especially in small-cohort studies of musical improvisation since the 1980s.[17] Usually, however, raw transcripts are rarely disseminated and are seldom discussed at length.

Newell and Simon, however, had pioneered the use of such "think aloud" studies in the late 1950s, in their computational cognitive science investigations into human problem solving; Reitman's work is fully contiguous with this tradition. In the excerpt shown here, the composer is near the start of the composition and is trying to write a "counter melody," which is supposed to complement the fugue's main theme according to the strict rules of counterpoint while retaining a distinct musical identity. He tries "[c]arrying out the idea of enlarged syncopation" but notes immediately, "that wont work, because it's repetitive of the theme itself."[18]

Later, in his textbook, Reitmann glossed this precise moment as follows: the current state of the composition has led the experimental subject to announce further stipulations for a valid solution is an example of "constraint proliferation." The problem of fugue composition, as Reitman operationalized it, seems to pose just one major—admittedly highly open-ended—constraint: "that the end product be a fugue."[19] For Reitman, the value of this think-aloud study lay in how it revealed the way that many different types of subsidiary constraints emerge in the solution of such loosely-defined problems as music composition.

Reitman's efforts toward a computational solution to such problems manifested in a new information-processing model he called Argus, described in a 1964 article in *Behavioral Science*.[20] Distinctive to Argus, and true to its many-eyed namesake, was its ability to work

---

[17] Roozendaal, "Psychological Analysis of Musical Composition", 315. See also, Sloboda, *The Musical Mind*.

[18] Sanchez and Reitman, "The Composition of a Fugue", 10.

[19] Reitman, *Cognition and Thought*, 169.

[20] Reitman, Grove, and Shoup, "Argus".

on "problems" out of sequence, unlike Newell and Simon's General Problem Solver (or so Reitman argued).[21]

Reitman explained that, like the composer he studied, "Argus is not at all single-minded, is much less in control of what it remembers and forgets, and also is much more prone to conflict and serendipity."[22] Inspired by the non-linearity of fugue composition, Reitman ensured "the assumption that work on a problem may and will be interrupted […] is built into the basic structure of the program."[23]

Crucially, to Reitman, it was a feature of the fugue problem itself that precipitated these innovations in cognitive modeling. Composing a fugue is, he wrote, an "ill-defined problem".[24] As part of his signal contribution to the understanding of these problems, Reitman claimed they demanded what he called "creativity" on the part of problem solvers.[25] If fugue composition represented a problem at the most "ill-defined" end of spectrum, then a problem-solving model that could successfully compose such a piece would have evidenced a particularly sophisticated grasp of computational creativity.

By yoking the notion of "ill-defined" problems to the competencies of "creative" computational machines to solve them, Reitman contributed to a complex and ongoing interplay between cognitive-scientific terms of art and more widely used (and broadly contested) terms like "creativity." As Jamie Cohen-Cole has demonstrated, creativity in particular bore a distinctive political charge in the Cold War academy. It was identified as an essential feature of ideal anti-authoritarian political subjects as well as a key personality attribute of the genuinely interdisciplinary researcher.[26]

It is tempting to arrive at a schematic conclusion: where Reitman and Sánchez develop a sensitive ethnographic-cum-computational reading of the highly solipsitic endeavours of the creative composer, Quastler's is, by contrast, an atomizing study that invokes musical

---

[21] Argus was designed so that several cognitive constructs could be updated at once by passing "activation" values around a semantic network: a design inspired by Hebb's work on neural assemblies and Oliver Selfridge's earlier Pandemondium model. Reitman, *Cognition and Thought*, 203. Hebb, *The Organization of Behavior*. Selfridge, "Pandemonium".

[22] Reitman, *Cognition and Thought*, 22.

[23] Reitman, ibid, 22.

[24] Reitman, ibid, 167.

[25] Reitman, ibid, 167.

[26] Cohen-Cole, *The Open Mind*.

performance only in so far as it reflects the human's capacity for Taylorisation as the optimal cog in the national war machine.[27]

But to accept such a ready binary would betray a naivety about twentieth-century cognitive-scientific research that Cohen-Cole does so much to counteract: behavorism is not uniformly illiberal; neither is cognitivism necessarily always its hopelessly well-intentioned rebuttal.[28] It is precisely the "interpretative flexibility" of the core concepts of the discipline—"information" a chief suspect here—that scaffolded the diverse political beliefs of cognitive-scientific actors during the remainder of the century.[29]

The lesson is: if information is the "cognitive good" that ties these pianistic encounters together—if cognitive goods are truly the missing historiographical construct which allows us to finally identify novel scenes of epistemic transfer between the arts and sciences—we would do well to account for power and politics in the "multilayered dynamic networks" that sum to the new vision this concept offers.[30]

---

[27] Quastler claimed in 1956 that "not nearly enough was known about the properties of the basic components" of teams of human beings—that is, "a single man processing information". Quastler, "Three Survey Papers", p. 4

[28] See also, Carr, "'Ghastly Marionettes' and the Political Metaphysics of Cognitive Liberalism".

[29] Cohen-Cole makes this argument with respect to the "flexibility" of the computer. Cohen-Cole, *The Open Mind*, 161. See also, Pinch and Bijker, "The Social Construction of Facts and Artefacts".

[30] Bod et al., "The Flow of Cognitive Goods", 495.

Works cited

Attneave, Fred. "Stochastic Composition Processes." *The Journal of Aesthetics and Art Criticism* 17, no. 4 (1959): 503–10. https://doi.org/10.2307/428223.

Bod, Rens, Jeroen van Dongen, Sjang L. ten Hagen, Bart Karstens, and Emma Mojet. "The Flow of Cognitive Goods: A Historiographical Framework for the Study of Epistemic Transfer." *Isis* 110, no. 3 (September 2019): 483–96. https://doi.org/10.1086/704673.

Bowker, Geof. "How to Be Universal: Some Cybernetic Strategies, 1943-70." *Social Studies of Science* 23, no. 1 (1993): 107–27.

Carr, Danielle Judith Zola. "'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 2020): 147–74. https://doi.org/10.1177/0952695119874009.

Cohen-Cole, Jamie Nace. *The Open Mind: Cold War Politics and the Sciences of Human Nature*. Chicago, Ill.: University of Chicago, 2014.

Feit, Anna Maria, and Antti Oulasvirta. "PianoText: Transferring Musical Expertise to Text Entry." In *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, 3043–46. Paris, France: ACM Press, 2013. https://doi.org/10.1145/2468356.2479606.

Hebb, D. O. *The Organization of Behavior*. New York: Wiley, 1949.

Kay, Lily E. *Who Wrote the Book of Life?: A History of the Genetic Code*. Stanford, CA: Stanford University Press, 2000.

Pinch, Trevor J., and Wiebe E. Bijker. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14, no. 3 (August 1984): 399–441. https://doi.org/10.1177/030631284014003004.

Quastler, Henry. "Three Survey Papers: 1) A Survey of Work Done by the Bio-Systems Group of the Control Systems Laboratory; 2) Studies of Human Channel Capacity; 3) The Informational Limitations of Decision Making." Urbana, IL: Control Systems Laboratory, University of Illinois, 1956.

Quastler, Henry, and V. J. Wulf. "Human Performance in Information Transmission: Part I: General Remarks; and Part II: Sequential Tasks (Overlearned Activities)." Urbana, IL: Control Systems Laboratory, University of Illinois, March 1955.

Reitman, Walter R. *Cognition and Thought: An Information-Processing Approach*. New York: Wiley, 1965.

Reitman, Walter R., Richard B. Grove, and Richard G. Shoup. "Argus: An Information-Processing Model of Thinking." *Behavioral Science* 9, no. 3 (1964): 270–81. https://doi.org/10.1002/bs.3830090312.

Rheinberger, Hans-Jörg. *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube*. Stanford, CA: Stanford University Press, 1997.

Roozendaal, Ron. "Psychological Analysis of Musical Composition: Composition as Design." *Contemporary Music Review* 9, no. 1-2 (January 1993): 311–24. https://doi.org/10.1080/07494469300640531.

Sanchez, M., and W. R. Reitman. "The Composition of a Fugue: Protocol and Comments." CIP Working Paper, November 1960.

Selfridge, O. G. "Pandemonium: A Paradigm for Learning." In *Proceedings of the Symposium Mechanisation of Throught Processes*, edited by D. V. Blake and A. M. Uttley. London: H.M. Stationery Office, 1959.

Sloboda, John A. *The Musical Mind: The Cognitive Psychology of Music*. Oxford: Clarendon Press, 1985.