Digital Analogies: The Keyboard as Field of Musical Play

ROGER MOSELEY

How oft, when thou, my music, music play'st
Upon that blessed wood whose motion sounds
With thy sweet fingers, when thou gently sway'st
The wiry concord that mine ear confounds . . .

Prompted by the sound and sight of the mysterious Dark Lady at the keyboard, Shakespeare’s Sonnet no. 128 revolves around the axis of play as topic and mode. Music issues from the motion of the Dark Lady’s “sweet fingers” while standing as a metaphor for the beloved herself: music at once plays and is played by music. At the material interface of the virginals (“that blessed wood”), her digital maneuvers are transduced into vibrations that delight the poet’s ear, leaving him tantalized and disoriented. The whimsy of Shakespeare’s textual play derives from the play of fingers and keys, the oscillation of strings and sonic waves; the to-and-fro of repetitive motion carries an erotic charge that throws distinctions between subject and object, cause and effect, into pleasurable disarray. Framing music and play together in this way suggests that musical activities can realize playful concepts and, conversely, that play might be conceived in terms of musical engagement. From this perspective, music is not merely the outcome of a certain type of play, but constitutes a set of cognitive, technological, and social resources for playing in and with the world through the medium of sound, its mechanisms, and its representations. Play, in turn, becomes the means by which such musical behavior is made audible.

This article was conceived while I was a Fellow at the Society for the Humanities, Cornell University, in 2011–12. Prototypes were presented at the Society, on the “Critical Organology” panel at the annual meeting of the American Musicological Society in 2013, at “Bone Flute to Auto-Tune: A Conference on Music and Technology in History, Theory, and Practice” at the University of California, Berkeley, in 2014, and as a colloquium talk at New York University later that year. I am grateful to all who convened and participated in those events, and to Jordan Musser, Mackenzie Pierce, Annette Richards, and David Yearsley. Special thanks are due to James Q. Davies, Emily I. Dolan, Andrew Hicks, Verity Platt, and this Journal’s anonymous readers for the insight and wisdom they have so generously shared.

1. Shakespeare, Sonnet no. 128, lines 1–4 (Shakespeare’s Sonnets, 371).
Although play has often been cited as an intrinsic attribute of humankind, it has long been observed that play is not exclusive to people, or even to gamboling mammals.² Play can also describe mechanical processes that animate inorganic matter by accident or design: we speak of the play of light, the play of a loosely fitting drawer, and the playing of chess by machines such as IBM’s Deep Blue. Navigating the shifting material and cultural formations that have regulated any given mode of musical play thus involves the traversal of both human and nonhuman realms. As the Dark Lady and her virginals suggest, such encounters and negotiations have often played out at the interface of the keyboard. Shakespeare’s sonnet reveals how the reciprocal relations of musical subjects and objects can pivot around play: “all playing is a being-played,” as Hans-Georg Gadamer phrased it.³ While keyboards invite us to play music, they have also long been invoked to illustrate how music can “play” us.⁴ They even help account for the way music seems to play on its own: the player piano testifies to the mechanical play of keys, levers, and switches that can enact musical recreation.

From the fourteenth-century chekker to contemporary digital games, the keyboard has operated as a field of play on which musical epistemologies have been allegorized, tested, and challenged.⁵ When activated by human digits, however, the keyboard’s mechanisms also become entangled in play as psychological and social experience. As Johan Huizinga observed in his classic book *Homo Ludens*, the association between play and instrumental skill is embodied by “the nimble and orderly movements of the fingers.”⁶ While such motion requires effort, it need not involve toil or strain: Sigmund Freud conjectured that the infantile origins of play have less to do with the arduous accomplishment of a particular task than with the pleasure taken in shaping, ordering, and repeating bodily movements that convert anxiety into security.⁷ Across numerous northern European languages, however, the roots of both “game” and “play” are etymologically associated with movements that give rise to communal joy as well as personal pleasure.⁸ The gestural qualities of such motions also reflect the social connections between playing, dancing, and miming observed by both Theodor W. Adorno and Gadamer in the context of the word “Spiel.”⁹ Insofar as it reiterates such motions, even solo play depends on the play of other bodies.

---

2. On the ethology of play across the animal kingdom, see Burghardt, *Genesis of Animal Play.*
4. From John Locke to David Hartley and beyond, the keyboard played an important role in philosophical accounts of associationism, habit formation, and the flow of unconscious actions, as Carmel Raz observes in “Reverberating Nerves.”
As is most obvious in its theatrical sense, play is also bound up with make-believe, the exercising of the imagination, and the fantastic possibilities afforded by the subjunctive mood: without consciously simulating or dissimulating, one nonetheless plays “as if.” The phenomenological characteristics of play have less to do with intention and emotion than with entrainment and affect. As a performative mode, play preempts and subverts questions predicated on linguistic concerns with communication, meaning, truth, and sincerity. More enactive and simulative than semantic or representational, it insists on the reality of pretense, allows for the simultaneous acceptance and circumvention of constraints, and thrives on the inevitability of uncertainty.

Before analyzing musical play and the ends to which it has been put, we should first acknowledge the ways in which its chiastic configurations supplement the oral, literary, and numerical methods by which subjects have been formed and cultivated. In other words, we should take seriously Huizinga’s idea that play is constitutive rather than illustrative of knowledge, and that this knowledge is typically produced at interfaces between limbs and objects. From the clavichord to the Moog synthesizer, the keyboard has established conditions under which musically playful and playfully musical (henceforth “ludomusical”) behavior can emerge. But in what terms can these conditions and the unfolding of play be described? At the most literal level, addressing this question entails examining the relationship between keyboard and gameboard, conceiving of both as fields of tactical calculation and action: as we shall see, a thread of historical evidence bears this analogy out. More broadly, it involves thinking archaeologically, with the notion of the keyboard as an interface that has operated across a range of media systems. This approach is not primarily concerned with the content and interpretation of specific musical signs or signals, taking as a given that these vary widely in accordance with shifting historical, cultural, organological, and repertorial parameters. Rather, it focuses on the keyboard’s rules of engagement and codes of conduct, reflecting functions of mediation that operate both analogically, by translating mechanical input into a corresponding sonic output, and digitally, insofar as such input is typically initiated by the play of fingers.

11. “Thus competitions and exhibitions as amusements do not proceed from culture, they rather precede it”: Huizinga, Homo Ludens, 47. My own formulation of play also draws on the discursive terms of Kulturtechniken (most commonly translated as “cultural techniques”), an increasingly rich and diverse stream of German scholarship departing from the premise that “there never was a document of culture that was not also one of technology,” as Geoffrey Winthrop-Young puts it: “Cultural Techniques,” 6. For definitions and examples of Kulturtechniken, see Krämer and Bredekamp, Bild, Schrift, Zahl, and Siegert, Cultural Techniques.
12. On ludomusicality and ludomusicology as phenomenon and method respectively, see Moseley and Saiki, “Nintendo’s Art,” and Moseley, “Playing Games with Music.”
13. Some keyboard instruments (such as the carillon) and techniques (such as the performance of clusters) require the use of fists and other configurations of the hand; see Vaes, “Three Centuries.”
Across its multifarious instantiations, the keyboard negotiates between the digital and the analog to the extent that, via digital acts of selection and activation, input and output enter into an analogical relation. Accounting for these maneuvers involves arraying analog and digital modes in chiastic formations that reflect the ambiguity of ludomusical phenomena. In an attempt to capture their qualities, I will identify these formations as, and by way of, a constellation of “digital analogies.” As its name suggests, a digital analogy seeks to relate its constituent elements in ways that both register and resist binary oppositions. Accordingly, this essay will frame relations between “music” and “technology” by seeking to expose not the impact of one on the other, but rather the ways in which technologies can be understood as always already musical—and vice versa.

The terms “digital” and “analog” have long and complex histories. While the oldest meanings of the classical Latin “digitus” refer to the finger, it can also signify a finger’s breadth, thereby indexing both the body’s presence and its trace.14 (This ambiguity is evinced by the archaic use of “digitals” to refer to keys on an instrument, objects designed to accommodate fingers.)15 Plautus, Cicero, Ovid, Pliny the Elder, and Quintilian all associated fingers with counting, reckoning, and computation, and by the twelfth century “digitus” had come to denote a decimal number.16 Procedures of calculation involving binary and duodecimal operations were also made imaginable by hands and fingers, going to show that “counting is older than numbers,” as Thomas Macho puts it.17 As Aden Evens astutely notes, what we understand by the digital, from the principles of discretely dividing and partitioning the world to the manipulation and combination of the elements thus derived, both issues from and takes the form of embodied knowledge.18 Digits embody processes of enumeration while enumerating embodied experience: we were digital _avant le chiffre._

If digits indicate how the apprehension, tallying, and manipulation of objects inform their mental ordering and classification, then a corresponding claim can be lodged with regard to the ancient Greek “ἀνάλογος” (analogos), which has to do with the derivation of proportional relations between objects and phenomena from sensory perception rather than

16. See Plautus, _Miles Gloriosus_ 2.2; Cicero, _In Q. Caecilium Oratio Quae Divinatio Dicitur_ 14.45 (in _Verrine Orations_) and _Letters to Atticus_ 5.21; Ovid, _Fasti_ 3.123; Pliny the Elder, _Natural History_ 34.8 and 2.23; and Quintilian, _Orator’s Education_ 11.3.86.
17. Macho, “Zeit und Zahl,” 179: “Das Zählen ist älter als die Zahl.” (All translations are my own unless otherwise indicated.) The ancient Sumerians deployed a duodecimal system based on the twelve phalanges (finger bones) in each hand; the medieval mnemonic device of the Guidonian hand relies on the same physiological features.
from abstract or rational thought. Analog modes trace continuity, registered via the delineation of vector, contour, or waveform; at the same time, like metaphors, they span and measure the gap that separates the resembled from the resembling. They thus represent both continuity within a medium and the rupture of transduction, of technical and imaginary transfer between senses and media.

Today, certain aspects of the meanings of “digital” and “analog” have eclipsed many of their other historical connotations. Beyond routine semantic drift, an impetus behind this shift can be located in a sequence of technological developments. Over the latter decades of the twentieth century, the digital and the analog served as lightning rods for debates concerning “the practical processes by which the world was represented in machines and by which those representations were made effective in the world,” as David Mindell puts it. According to this narrative, the relentless march of technology fused the digital and the analog into a mutually constitutive dyad. Digitality became a far-reaching principle governing the rational operations of distinguishing, ordering, and calculating, while the analog assumed the role of the digital’s “other,” serving as complement, antithesis, outmoded paradigm, or bastion of resistance. The problem, as McKenzie Wark points out, is that distinguishing between the analog and the digital in this way involves the recognition of a “clear distinction” rather than a “slippery difference,” which is to say that it relies on a marked binarism that itself articulates and enforces digital logic. Evens exposes the same problem when contrasting the sterile formalism of digital partitioning with what he asserts to be the “ontological fuzziness inherent to actuality itself.” Suggesting that digitality can offer only an approximate rendering of the world, Evens implies that the infinite gradations of the analog somehow describe it wie es eigentlich ist. But this contention itself reflects a binary choice between the digital and the analog, divided along the line of thought that separates arbitrary epistemological distinctions from irreducibly fuzzy ontology. In Anthony Wilden’s terms, such formulations reveal that “without the digital, we could not speak of the analog.”

While recognizing our digital predicament as an acute symptom of modernity, Vilém Flusser drew attention to its ancient lineage. In an essay that

21. See, for instance, Sterne, “Death and Life.”
24. Wilden, *System and Structure*, 168; see also 166n8, 191–95. Conversely, “reality” for Wilden “has no purpose in explanation, no purpose to explain” (178).
asked “Why Do Typewriters Go ‘Click’?,” posthumously published in 1993, Flusser provided first a heuristic answer (because digital clicking “is more easily mechanized” than analog sliding), and then an ontological one: because, as Democritus asserted long ago,

> everything there is in the world (and the whole world itself) stutters. . . . Everything quantizes. Thus numbers, but not letters, correspond to the world. It is open to calculation but not to description. . . . Letters (if they want to survive) have to simulate numbers. This is why typewriters go “click.”

Flusser proceeded to consider whether the quantization of the world via atomic theory, calculus, or quantum theory accounts for its workings or merely corresponds to them. Does our perception of vectors and signals simply reflect the ways our senses transform quanta into continuously variable qualia, bending and warping the world after our own likeness? Or, as Evens suggests, is quantization itself the externalization of embodied digitality, a human bit-mapping of the world that makes it enumerable by brains and machines?

Caught between these seemingly unanswerable questions, we find ourselves bound once more by the binary logic of either/or. Thinking in terms of digital analogies, however, we might apprehend digitality by sliding it along a continuum that registers its metaphorical, musical, and mathematical meanings, which will in turn reveal how digital techniques can elucidate the processes by which analogies are materialized, embodied, and collated.

Flusser’s invocation of the typewriter draws attention to the ways in which the keyboard has staged cultural encounters between digital and analog phenomena. Via its own configurations as well as its operations in concert with other technologies, the keyboard is implicated in the performance of gender, violence, and disability. From the “wiry concord” of the Dark Lady’s virginals to the click of Flusser’s typewriter, the outcomes of play at the keyboard reflect and reveal the conditions of its noisy socio-technical channels: en route from symbol to signal, finger to ear, keyboard play is subjected to analog wow and flutter as well as digital judder and stutter.

The keyboard thus has much to contribute to our understanding of digitality and analogicity as both contemporary and archaeological formations, while the concept of the digital analogy offers a reciprocal means of articulating the channels, operations, and techniques associated with the keyboard. Moreover, the interface of the keyboard can be approached as a zone where the digital and the analog come together under the rubric of play. Digital play freely oscillates at the keyboard, limited only by the analogical extents to which its patterns can be realized or imagined. Likewise, analog play is subject only to the constraints of the digits that embody and enumerate it.

25. Flusser, Shape of Things, 62.
26. As Wilden observes, the question of whether a system is “digital” or “analog” is “never an objective fact, but the result of a definition made by some subsystem in the wider ecosystem”: Wilden, System and Structure, 159.
Of particular significance is the keyboard’s capacity to represent letters and numbers as well as pitches, thereby facilitating correspondences between literate scripts, algorithmic procedures, and sonic outcomes that are at once digital and analog. At the same time, the keyboard’s regulation of these literary, mathematical, and musical realms has inculcated a diverse array of cultural techniques with which to play—and even to challenge the prevailing social and political rules. If play mediates between the techniques by which human subjects are formed and those that bring the world to hand, then the keyboard is perhaps the paradigmatic instance of a ludomusical interface. In the context of play, keyboards are not merely input devices: they stage exhibitions of timing, rhythm, and dexterity that are as integral to games as they are to musical performance.

Instead of taking the form of a linear history or even the circumscription of a delimited area, this essay consists of five sweeps across different registers of the keyboard, each attuned to a particular bandwidth of ludomusical resonance. The first addresses the keyboard’s prehistory as well as the analogical and digital terms in which it has been engaged. Taking Apollo’s mythical contest with Marsyas as its point of departure, it considers the sublimated violence of musical play as well as various means of tallying and settling scores that extend from the realm of Greek myth to today’s digital games. The second is concerned with the keyboard’s materialization of notational concepts and its transcoding of letters, numbers, and pitches, focusing on the rendering and inscription of sound in the terms of both technē and logos. The third examines the keyboard as an interface at which subjects have been cultivated via the acquisition and demonstration of techniques associated with communication, while the fourth explores how keyboards constitute both material and analogical fields of play. Finally, after tracing a discursive thread that documents ways in which the playing of various keyboard instruments has been invested with recursive properties, the fifth section considers how two recent sonic art installations have invoked digital and analog modes of automated ludomusical behavior that recreate sounds heard or imagined in the past. Cumulatively, these five passes over the keyboard’s ludomusical terrain draw attention to the playful procedures by which music has been devised, realized, communicated, and recreated there. They amount to an effort to conceive of these acts not primarily in terms of textual transmission or interpretation, but in light of the ideological and material conditions that have sustained them.

When excavating the remnants of ludomusical play, we encounter keyboard instruments and interfaces at which digital concepts were materialized and embodied prior to their virtualization and abstraction. Historical modes of inquiry also reveal our own relationships with the past to be analogical, insofar as they rely on correspondences between objects and actions that echo, trace, or stand in for one another. If techniques of mediation can be parsed as functions or symptoms of historical processes, however, media archaeology reverses the proposition by asking how media make the recounting
of history possible. From the four-handed fort-da of Georges Bizet’s *Jeux d’enfants* to the dextrous permutations of a digital game player at her PC, ludomusical behavior at the keyboard can be understood in terms of its formal constraints, its material grain, its communicative tactics, and its phenomenal pleasure. As Wolfgang Ernst suggests, this invites us to rethink traditional models of temporality in order to acknowledge the spiraling and shuffling typical of analog and digital media, which offer ways of recognizing the differences and similarities between the keyboard’s diverse manifestations that exceed (or circumvent) the exigencies of historical narrative.

At the same time, the long view of media archaeology cautions against the reification of technology by revealing that even the most solid and stable configurations merely slow the rate at which change flows. There was musical life before the keyboard as we know it, just as there will come a time when the conditions that have sustained it no longer obtain. Even as they document the passage of time, moreover, media are themselves subjected to it. Musical media make this particularly clear: testifying to both durability and entropy, the historicity of instruments that capture and (re)produce sound enables them to operate as the kind of medium that connects the living and the dead. By “pass[ing] on to the senses of others what would otherwise fade away,” in Friedrich Kittler’s words, keyboards and their associated technologies allow us to play back, to construe musical recreation as reenactment as well as praxis in the present. In this sense, and in relation to both recordings and instruments, play is no less than the means by which music’s evanescence perdures.

**Apollo 1, Marsyas 0**

The oldest media-archaeological evidence for digital musical performance can be found in the realm of Greek myth, a milieu safely beyond the reach of historical investigation. In this context, the etymological history of the Latin “digitus” is itself telling, in that it points in two irreconcilable yet complementary directions. On the one hand, as Evens points out, its roots

---

27. For definitions and demonstrations of media archaeology, see Huhtamo and Parikka, *Media Archaeology*; Parikka, *What Is Media Archaeology?*; and Zielinski, *Deep Time*.

28. I refer specifically to “L’escarpolette,” the opening number of *Jeux d’enfants*, op. 22, in which the dreamy alternation of arpeggios in contrary motion evokes the hypnotic oscillation of a swing.

29. Ernst, “From Media History to Zeitkritik.”

30. As Manuel De Landa puts it, “the most stable and durable traits of our reality . . . merely represent a slowing down of . . . flowing reality”: De Landa, *Thousand Years*, 258.


might lie in the Greek term “δείκνυμι” (to show), associated with the word “deixis” and thus with the finger that indicates this, not that; on the other, they may be traced back to the term “δεχομαι” (dechomai), meaning to grasp or receive (just as “finger” derives from “fangen,” meaning to catch), thus implying accommodation rather than discrimination. The related term “δάκτυλος” (dactyl) takes its autological name from the relation between the three bones in each finger, illustrating how the ordering and measuring of music and poetry was accomplished via the use of the body to register and tally external phenomena as well as by the assertive extension of corporeal extremities.

Such acts of embodied enumeration were often performed in Apollo’s name. Callimachus’s Hymn to Apollo conflates the divine foot with which Apollo kicked Phthonos (the personification of envy), who had the temerity to criticize the orderly attributes of the paean that the hymn enacts, with the metrical foot of poetry itself. For his part, the Roman elegist Lygdamus dreamed of a visitation from Apollo, whose digits grasped an ivory plectrum that enabled them to “speak” alongside his sonorous voice. Lygdamus’s dream suggests how the logic of selection informed and ordered instrumental performance: during even the most dextrous strumming, Apollo’s plectrum was deployed to pluck that string at this moment, not any other. The kithara was thus closely associated with the lyrical (and digital) qualities of discernment, discrimination, and refinement.

But Apollo’s kithara also represented the pursuit of analogies, of systematic research into correspondences between musical and cosmological order. This line of interpretation can be traced back to the neo-Pythagorean
Aristides Quintilianus, who pursued it to justify Apollo’s mythical triumph over Marsyas. Marsyas, a satyr from Phrygia, picked up an aulos discarded by Athena, who had been disgusted by its distortion of her facial features when she played it. Having been inspired by the breath of a goddess, the instrument produced beautiful music as soon as Marsyas blew into it, which delighted and emboldened him. The satyr rashly challenged Apollo to a musical contest to be judged by the Muses: the winner, it was agreed, could do whatever he pleased with the loser. Apollo played the kithara while Marsyas played the aulos (or perhaps two auloi at once). After the first round, Marsyas seems to have held the advantage, forcing Apollo to resort to dubious tactics. In one version of the myth he added his voice to his kithara, while in another he played his kithara upside down, feats he knew Marsyas would be unable to match. The Muses thus ruled in Apollo’s favor; as punishment, Apollo had Marsyas bound to a tree and flayed alive. According to Ovid, his blood mixed with the tears of the satyrs and nymphs who mourned him to form a river that took his name, while others reported that Apollo repurposed the satyr’s hide as an askos, a flask or pouch, which served variously as a wineskin, windbag, or drum.

At first sight, this myth is hardly playful; on the contrary, it constitutes a stern object lesson on the dangers of hubris and the provocation of divine wrath. Aristides was among many who rebuked Marsyas for “dignifying his music beyond its worth.” It is nonetheless important to recognize that Apollo and Marsyas engaged each other in a form of play, as reflected by the inclusion of kithara and aulos competitions at the Pythian and Isthmian games.

38. Aristides Quintilianus, *On Music* 2.18–19. The standard version of the myth is passed down by the second-century CE mythographers Pseudo-Apollodorus and Hyginus, as translated in Smith and Trzaskoma, *Apollodorus’ Library*, 4 and 152 respectively; see also Ovid, *Metamorphoses*, trans. Miller, 6.382–400, and Fasti 6.697–710; Pausanias, *Description of Greece* 2.7.9; and Philostratus the Younger, *Imagines* 2, with further sources discussed by Visser, “Marsyas.” For my purposes here, it is neither possible nor desirable to draw a firm distinction between the myth’s origin and its later Greek and Roman reception history, on which see Feldherr, “Flaying the Other”; Maniates, “Marsyas Agonistes”; and Van Keer, “Myth of Marsyas.”

39. Pliny the Elder and Nonnus both associated Marsyas with the double aulos. See Pliny the Elder, *Natural History* 7.204: “adiecit . . . geminas tibias Marsyas” (Marsyas invented the twin aulos); and Nonnus, *Dionysiaca* 10.234: “διδυμόθροον αυλοίν Αθηνῆς” (the double-voiced aulos of Athena).

40. On the umpires’ initial leaning toward Marsyas, see McKinnon, “Rejection of the Aulos,” 213.


Throughout the ancient world, play was often as brutal as it was divine: from the *pankration* (a mixed-martial-arts staple of the Olympic Games that could bring death as well as glory) to the Roman *ludi* (which incorporated athletic events, chariot racing, and gladiatorial combat into votive offerings and funerary rituals), games could have consequences wholly disproportionate to their nominal stakes, especially when staged as public spectacles.

The Greek term “*agōn*” captures the notion of competitive struggle in terms of both its ludic structure and the physical toll it can exact. Although “*agōn*” was initially used simply to denote ludic events from races to musical contests, the word “agony” became synonymous with the writhing contortions of bodies—like Marsyas’s—that suffered the harrowing effects of play. Writing in the 1930s, Huizinga perceived the principle of *agōn*, which he construed as the exhibition of prowess in specially demarcated locations under rule-based competitive conditions, to lie at the heart of culture *sub specie ludis*: “play is battle and battle is play.” For Huizinga, play in the simultaneously primal and rarefied form of *agōn* was responsible for the flourishing of cultural practices, networks, and institutions from dialogical philosophizing to the adversarial legal system, from professional sports to the theater, and from love making to music making.

The ludic drama and lurid violence of Apollo vs. Marsyas has long fascinated artists and scholars, particularly those concerned with the establishment of hierarchical relations within and between artistic realms. It is in this light that Lydia Goehr ponders the larger metaphorical significance of *agōn*, observing that “the opposition between string- and wind-play can be used to forge a mythic, moral, and metaphysical sword for use in the general disciplining of humanity.” For Aristides Quintilianus, the kithara’s strings analogized the soul of the universe, while the breath animating the aulos was associated with the sublunary realm: Apollo’s victory thus bore out the superiority of the celestial over the mundane. Following Pythagoras, however,

---

45. On the *pankration*, see ibid., 37–39; on the deadly Roman reenactment of Greek myth for retribution and public entertainment, see Coleman, “Fatal Charades.”
Aristides also contended that music, human bodies, and divine souls all resonated in sympathy by virtue of such mimesis, since they all demonstrated the *harmonia* of number.\(^{51}\) In other words, through music the analogies of *harmonia* were revealed arithmetically, while arithmetic itself operated analogically by correlating the abstract and the tangible.

In this vein, Daniel Albright observes that the mechanism by which Apollonian correspondences were realized was numerical: “music [was] conceived as sounding numbers, numbers that can easily be transferred to any other medium.”\(^{52}\) Echoing Flussers, Albright thus identifies the formal fungibility of numbers as elemental to the digital paradigm of universal translat-ability that enables information to travel freely across all manner of media.\(^{53}\)

In the modern era, such digital transcoding owes an obvious epistemological debt to Gottfried Wilhelm Leibniz’s concepts of a *characteristica universalis* and an *alphabetum cogitationum humanarum*, which could be indexed by musical notes as well as other sets of discrete symbols.\(^{54}\) But for Kittler, it was ultimately attributable to the ancient Greek alphabet, which was the first system capable of representing not only letter and number but also musical tones and ratios, enabling the construal of relationships that were demonstrable by kitharedic and auletic performance.\(^{55}\) Channeling the Pythagorean philosophers Hippasus and Philolaus, Kittler could thus describe the lyre as a magical “plaything [Spielzeug] that connects mathematics to the domain of the senses,” instrumentalizing the analogies of *harmonia*.\(^{56}\)

Marsyas’s music was itself analog to the extent that it was rendered and described as continuous rather than discrete, consisting of “wind, breath, *pneuma*—animating spirit, feeling made sound,” as Albright expresses it.\(^{57}\)

As an instrument activated by a more or less continuous column of air, the

---

53. Flussers lauded such procedures for their ability to render mathematics tangible, even synaesthetic: “now that one can re-code numbers in the form of colours, shapes and sounds with the aid of computers, the beauty and depth of calculation are there for all to feel”: Flussers, *Shape of Things*, 64.
54. Leibniz, *Disertatio de Arte Combinatoria*. The principles of *ars combinatoria* had first been outlined by Ramon Llull in the thirteenth century before being systematized by Leibniz, musicalized by Athanasius Kircher, and satirized by Jonathan Swift. En route from Llull to Leibniz, Francis Bacon and John Wilkins played important roles in the development and dissemination of combinatorial thought and practice. See Siegert, *Passage des Digitalen*, 120–56, for an adroit description and contextualization of the activities of Bacon, Wilkins, and their fellow members of the Royal Society across the domains of algebra, cryptography, and logic.\(^{55}\)
55. This is a central thesis throughout Kittler’s *Musik und Mathematik*, vol. 1. On auletic epistemology, see Hagel, “Twenty-Four in Auloi.”
56. Kittler, *Technological World*, 265; Kittler, “Number and Numeral.”\(^{56}\) Kittler was presumably alluding to Philolaus’s Fragment 6a, reproduced and translated in Huffman, *Philolaus of Croton*, 145–47, which refers to the manual measurement of strings (if not explicitly to the lyre).
aulos did not conform to Pythagorean logic: its elemental unit (or monad) was neither a ratio nor a definably discrete quantity, but rather the *diesis*, an indefinitely small interval etymologically linked to the unpredictable leakage of air from the finger holes.\(^5^8\) Despite the involvement of digits, Marsyas’s overblown musical play thus defied quantization, which might help explain why the Muses initially had difficulty evaluating his performance in relation to Apollo’s. In the face of their indecision, Apollo had to secure his victory via a strange admixture of divine skill and cheap tricks, either by the performance of an instrumental inversion or by the addition of his voice to his kithara, techniques that were unavailable to Marsyas.

Was Apollo’s triumph a case of *adynaton* (the divine demonstration of the impossible), the outcome of a cunning ruse, or the prospering of a cheat? The question’s undecidability hints at the deceptive magic so often wrought by the machinations of media technology. Writing of the lament performed by Orpheus and Echo in Monteverdi’s *L’Orfeo*, in which the latter reproduces fragments of the former’s utterances, Klaus Theweleit spins the issue around this technological axis: “you may laugh, but . . . Orpheus is asking for [Thomas] Edison.”\(^5^9\) Depending on how it was rotated, Apollo’s inversion of his kithara would potentially have reversed the ordering of its input and output. This is a trivial transformation in digital terms, but Marsyas, like Orpheus, was unable to follow suit without the assistance of Edison, whose phonograph allowed for any sonic waveform not only to be captured and reproduced but also to be played backward. (As for singing and blowing simultaneously, Marysas would have needed to wait a little longer for Ross Snyder’s invention of multitrack recording.)\(^6^0\)

Ultimately, however, it is not so much Apollo’s reliance on media effects to bend the rules of play that arouses disquiet, but rather the gulf that yawns between the contest’s outcome and its gory aftermath. How can Marsyas’s agony be justified as a function of Apollo’s whimsy? According to Ovid, this discrepancy shocked Marsyas himself, who realized too late that “[a] pipe’s not worth the price!”\(^6^1\) While there seems to be no inherent reason why agonistic musical play should end in bloodshed, the prevailing semiosis of contemporary digital games reveals just how readily ludic logic and digital gameplay continue to give rise to sadistic representations.\(^6^2\) Such games

---

58. For Aristotle, the *diesis* constituted the musical monad despite the fact that it was not always numerically singular (see the translation of and commentary on *Metaphysics* 1016b, 18–24, and 1053a, 12–17, in Barker, *Greek Musical Writings*, 2:72–73). On the etymology of *diesis*, see Hagel, *Ancient Greek Music*, 443, and Benson, *Music: A Mathematical Offering*, 171n5.

59. Theweleit, “Monteverdi’s *L’Orfeo*,” 169; see also Chua, “Untimely Reflections,” 578–79.


demonstrate that, from a strictly ludological standpoint, the structure and dynamics of agonistic competition are more significant than its representational strategies or results. This is why Claus Pias can claim that the “discourse elements” of digital games “are not called ‘killing people’ or ‘catching gold nuggets’” but are instead instantiated through “timeliness, rhythm, or control.” While these latter three elements—all of which are, of course, fundamental elements of musical performance—require digital input from the player, the central processing unit remains utterly indifferent as to how this input is modulated and represented. Apollo’s impassivity to Marsyas’s fate is coeval with this arbitrariness: from the divinely inhuman perspectives of gods and machines, all meanings are semiotically interchangeable and endlessly deferrable.

Apollo’s treatment of Marsyas also lays bare the brutality lurking behind the musical technologies that enable such representations, which is to say instruments themselves. The materials on which Apollo’s play depended were scarcely less grisly than its consequences. Despite Roger North’s decorous belief that the lyre’s strings must have been “mettaline . . . or of twisted silk,” since only barbarians would have been so “rude and gross” as to handle “gutts and garbages,” countless sheep, tortoises, and oxen died alongside Marsyas for its sake. The lyre also reminds us that the twang of a string can index the discharging of a missile as well as the playing of an instrument. In 1846 Edward F. Rimbault remarked that “the employment of [catgut] in the warlike bow is supposed to have led to its adoption in the peaceful lyre, owing to the accidental discovery of its musical sound”; reciprocally, Apollo’s kithara sounded martial overtones when associated with the bow, his weapon of choice. Callimachus lauded Apollo’s mastery over both as well as their ability to hush the ocean’s roar when invoked: “Silent is even the sea when singers celebrate / either lyre or bow, the instruments of Lycorean Phoebus.” Likewise, the mouthpiece and narrow

---

Visual Culture.” Recent examples of digital games that explicitly map rhythmic input onto the graphic representation of agonistic conflict by merging elements culled from rhythm-action, shooting, and fighting genres include Harmonix Music Systems’ A City Sleeps (2014), SNK Playmore’s The Rhythm of Fighters (2014), and Zen Studios’ KickBeat (2013–14).

64. North, Memoirs of Musick, 59–60; see also Borthwick, “Riddle of the Tortoise.”
65. Edward F. Rimbault, annotation to Roger North’s Memoirs of Musick, 59n; see also Borthwick, “Wise Man.” Don Ihde notes correspondences in the practice of archery between prehistoric sub-Saharan Africa, ancient China, and medieval England, observing that where bows and arrows were prevalent in hunting and warfare there is often concomitant evidence that they also fulfilled musical functions: the play of the bow and the twang of the string combined to form what Ihde calls a “multistable” configuration of a set of objects and chains of actions that constitute a weapon in one hand and a musical instrument in another: Ihde, Embodied Technics, 21–26.
cylindrical bore of Marsyas’s aulos stand in morphological relation to the blowgun, which was also fashioned from reeds, according to Apollodorus of Damascus.67

The hammers, bows, beaters, and other weapons that populate the archaeological record of musical instruments thus stocked an arsenal that allowed for the simulation or reenactment of agonistic conflict via play. In the course of battle, Apollo and Marsyas were penetrated by sonic signals produced by the other that analogized ballistic missiles in the form of divine arrows or satyric darts. Their contest can thus be understood as a double engagement in sonic warfare between musical instruments as well as between aesthetic, cultural, and religious values. In agonistic terms, moreover, the relation between Apollonian analogies and the violence of the operations that materialize them is commensurate with that between the rational measurement of pitch and its impact on the battlefield, as observed by Archytas and Vitruvius.68 From this perspective, Apollo’s flaying of Marsyas can be construed as the logical continuation of physical hostilities as well as punishment for the latter’s hubris. By turning Marsyas inside out, Apollo demonstrated the horror of literal “ex-pression,” as Albright shrewdly notes.69 As he laid bare Marsyas’s insides, however, Apollo was also revealing the satyr’s kitharedic potential: in Ovid’s words, “you could count his twitching guts,” as if they were offering themselves to be strung and tuned.70 Aristides Quintilianus believed that the latticework of strands, sinews, and arteries in the human body analogized the orbits of the planets, just as the strings of the lyre did. In Thomas J. Mathiesen’s summary, “the human body is composed of membranes, sinews, and breath. In consequence, it has the capacity to respond through a kind of sympathetic resonance between the sinews and stringed instruments.”71 By making Marsyas’s lyric capacity enumerable, Apollo thus rendered him digitally assimilable as an object of harmonia. As with Phthonos, the metrical ordering of poetry was indistinguishable from the imposition of Apollonian punishment: Marsyas’s defeat was enacted and rationalized by the poetic form in which it was rendered.72

361. Significantly, Callimachus described both bow and lyre as “Ἐντεα,” which refers to both fighting gear and musical instruments.

67. See Apollodorus of Damascus, Poliortica, 268.
68. The Greek mathematician and political leader Archytas invoked the aulos in conceiving sound as a missile, the ballistic energy of which could be directly correlated with pitch; see Khaled, “Ψόφος und φωνή.” In De Architectura, Vitruvius recommended that architects should understand the physics of sound in order to ensure, among other things, that “catapult strings are stretched in unison”; quoted and translated in Williams, Organ in Western Culture, 235.
69. Albright, Untwisting the Serpent, 18.
71. Mathiesen, Apollo’s Lyre, 161.
In their *Theory of Games and Economic Behavior* (1944) John von Neumann and Oskar Morgenstern showed how the codification of the rules (whether implicit or explicit) governing formally regulated games of competition and chance can be expressed numerically. Any ludomusical battle is a zero-sum game: for there to be a winner, there must be a loser; for a point to be scored, it must be conceded. Ovid recorded Apollo’s victory as concisely as letters obeying the rules of Latin grammar could permit: “Phoebus superante pependit” ([Apollo] won, [Marsyas] hung).73 To register the result digitally requires even fewer resources, however: 1–0 will do. Recording Marsyas’s annihilation in this way depends on an important epistemological shift, as the term “zero-sum” implies. In order to denote more (or less) than an indivisible unit of construction or calculation within a given class of phenomena—the terms in which Aristotle defined its function—the number one had to be complemented by zero, a concept unknown to the ancient Greeks.74

In 1697, inspired by the mythical Chinese ruler Fu Xi as well as by Christian theism, Leibniz posited that all that the world contained—and all it did not—could be accounted for by the digits 1 and 0.75 A medallion he designed to commemorate his own “discovery” of binary is inscribed with the words “omnibus ex nihilo ducendis sufficit unum” (to make all things from nothing, unity suffices; see Fig. 1). But how could the world-making powers of binary be instrumentalized? In addition to its debt to the hexagrams of the *I Ching*, Leibniz’s formalization of binary owed much to Francis Bacon’s observation that any form of message could be encoded by binary means. In 1623, Bacon had remarked that

> a way is opened, whereby a man may expresse and signifye the intentions of his minde, at any distance of place, by objects which may be presented to the eye, and accommodated to the eare: provided those objects be capable of a twofold difference onely: as by Bells, by Trumpets, by Lights and Torches, by the report of Muskets, and any instruments of like nature.76

Bacon’s claim that instruments “capable of a twofold difference onely” could signify, encipher, and transmit over long distances anticipated Samuel Morse’s similar technique by more than two centuries, but it was hardly new: slit drums had carried messages along African and Asian valleys for millennia.77 Tellingly, however, Bacon’s acoustic triad of bells, trumpets,

---

73. Ovid, *Fasti* 6.707. I am grateful to Verity Platt for her translation of this line.
74. On the fraught history of “nothing” in Greek thought, see Rotman, *Signifying Nothing*, 60–63.
77. Aristides Quintilianus disclosed that the use of musical codes enabled Roman military commands to be relayed discreetly and immediately; cited in Mathiesen, *Apollo’s Lyre*, 546. In the American South, African slaves were denied access to musical instruments such as drums and
and muskets groups musical and ballistic devices as “instruments of like nature.” Indirectly, it also raises the question of how the name and function of the key is implicated in cryptography as well as in digital communication. As telegraphy would make evident, a single key can perform and relay a “twofold difference onely” by virtue of Leibniz’s codification of Bacon’s horns that were deemed capable of conveying signals in this manner; see Southern, *Music of Black Americans*, 172. See also Steve Goodman’s account of the use of sound as enciphered communication and affective weapon in the asymmetrical Jamaican conflict between native Maroons and English colonists that took place in the late eighteenth century: Goodman, *Sonic Warfare*, 65–66.

---

*Figure 1* Gottfried Wilhelm Leibniz’s design for a medallion commemorating his “discovery” of binary in 1697. Reproduced from the title page of Rudolf August Nolte, *Mathematischer Beweis der Erschaffung und Ordnung der Welt* (Leipzig: Langenheim, 1734), by permission of the Bayerische Staatsbibliothek, Munich (Res/4 Phys.sp. 304.25). This figure appears in color in the online version of the *Journal*. 

Downloaded from http://online.ucpress.edu/jams/article-pdf/68/1/151/276723/jams_2015_68_1_151.pdf by guest on 21 June 2020
insight: rather than two objects, only one is needed, in conjunction with its absence.\textsuperscript{78} (Here we might recall that “digital” can refer to either a finger or a finger’s breadth.) A key can represent two states: either it is depressed, or it is not. Like all digital media, the key thus offers a way to encipher or decipher, to lock, unlock, or transcode the meanings of notes and letters, and to evoke both plenitude and lack. To invoke Gregory Bateson’s famous formulation, the key has informational potential to the extent that it articulates “a difference which makes a difference,” whether sonic, symbolic, or both.\textsuperscript{79}

Just as the binary distinctions necessary for digital computation are arbitrarily derived from fluctuations of voltage, so the digital interface of the keyboard renders sonic materials artificially discrete in order to enable their processing. The keyboard typically filters the complexity of individual sonic phenomena and their generative mechanisms in order to grant its players comprehensive control over the processing of their spatio-temporal configurations.\textsuperscript{80} This does not simply represent the hegemony of the digital over the analog, however: on the contrary, the keyboard binds the two together, enabling nonprogrammable humans and sound waves to enter into programmatic relations.\textsuperscript{81} In Bateson’s terms, the keyboard, like the digital computer, takes the form of a difference-making system: the key is pressed (or not), the note sounds (or not) and is heard (or not). But in making audible the analog fluctuations that can be monitored as well as produced by digital operations, the keyboard also reveals the prerequisites and consequences of differentiation as an in(de)terminable process in which players, instruments, and listeners are inextricably enmeshed.

Notes on Keys

Negotiations between the properties of continuity and discreteness shaped Leibniz’s formulation of infinitesimal calculus as well as the metaphysical materialism of his monadology, just as they informed the twentieth-century theorizing of wave-particle duality alongside models of biological processes from evolution and ontogeny to human cognition and artificial intelligence.\textsuperscript{82} If tensions between what we now conceptualize as the digital

\textsuperscript{78}. I here take advantage of Bacon’s archaic spelling of “only.”
\textsuperscript{79}. Bateson, “Form, Substance, and Difference,” 459.
\textsuperscript{80}. As Wilden puts it, “translation from the analog to the digital often involves a gain in information (organization) but a loss in meaning”: Wilden, System and Structure, 168.
\textsuperscript{81}. On the maximal connectivity of waves and beings, in distinction to the relative isolation necessary for switching systems to operate effectively, see Kirtler, “There Is No Software,” 153–54.
\textsuperscript{82}. See Leibniz, La monadologie, and Deleuze, Fold, 12–13. With regard to biology, John von Neumann believed that both entire organisms and their internal systems combined digital and analog principles: Neumann, “Theory of Automata,” 296.
and the analog helped produce new forms of scientific and philosophical knowledge, occasionally to momentous effect, then the broader history of their long-standing relationship can be related in terms that are at once musical and cosmological. In The Fifth Hammer: Pythagoras and the Disharmony of the World Daniel Heller-Roazen summarizes how Pythagorean notions of arithmetic and harmony informed musical thought from Boethius to Kant. The broad arc of Heller-Roazen’s narrative outlines a story of both disenchantment and liberation: the fifth, dissonant hammer heard by Pythagoras in his legendary forge serves as a metonym for the irrational elements of musical temperament, amplitude, and timbre that defied all attempts to render them discrete and orderly, necessitating the construction and abandonment of a series of epistemological frameworks. Of particular importance throughout is the distinction Boethius drew between magnitudes, which are continuous and “not distributed in separate parts,” and multitudes, “such as a flock, a populace, a chorus, [or] a heap of things,” which are composed of discrete and enumerable elements. In concert with the complementary distinction between motion and stasis, music, defined as the science of multitudes, took its place within the medieval quadrivium alongside arithmetic (the science of multitudes in their own right), geometry (the science of static magnitudes), and astronomy (the science of mobile magnitudes).

Glossing Marie-Elisabeth Duchez, Heller-Roazen observes that her interpretation of notational developments between the ninth and the eleventh centuries “rest[s] on the principle that to be musically intelligible, sounds must be essentially discrete in quantity, like the old multitudes of arithmetic.” For Heller-Roazen, the symbol of the note thus stands as a neopythagorean musical monad: discrete, quantifiable, multipliable, nondivisible. It first inscribed the diastematic mapping of frequency onto the page’s y-axis before its representational principles were horizontally extended to the temporal domain via the development of mensural notation. As David E. Cohen points out, however, the sophisticated semiosis of medieval staff notation was initially grounded in the “iconic representations of instruments,” in that its horizontal lines depicted or alluded to strings. This suggests that the monochord’s pedagogical importance to Pseudo-Odo and Guido of Arezzo lay not only in its Philolaan function of making mathematical relationships sensible, but also in the labeling of tonal partitions by Latin letters. To aid the reader of music notation in the task of converting symbols into

---

83. Boethius, De Institutione Arithmetica 1.1.10, translated in Heller-Roazen, Fifth Hammer, 22.
84. See Hicks, “Pythagoras and Pythagoreanism,” 422–24.
sound, these letters operated as “claves” (keys) that “unlocked” the pitches of their corresponding “strings” when positioned at the beginning of the staff, where they became better known as clefs.\(^87\)

If a key thus decoded the symbolization of a material phenomenon, then the development of keyboard instruments enacted the rematerialization of such symbols. Keys first appeared as levers that operated organs: labels above the keys of the fourteenth-century instrument in Norrlanda, Sweden, one of the oldest extant examples, correlate the concepts and phenomena of letters, notes, pitches, and claves (see Fig. 2).\(^88\) In this regard, the keyed monochords described and illustrated by Johannes Keck (ca. 1442), Conrad of Zabern (ca. 1460–70), and their contemporary Johannes Gallicus are instructive insofar as they physically perform the Guidonian mapping of the string’s ratios.\(^89\) On a latter-day replica of Conrad’s instrument, built according to his detailed specifications, Pythagorean geometry is analogized, arithmeticized, and thus rendered digitally manipulable via a form of symbolic transcoding that relies on the intermedial functions of the ancient Greek alphabet by way of Guidonian theory and praxis (see Fig. 3).

If, as Wilden claims, digital communication has to do with the measurement, combination, and transmission of information, then the longue durée of Guidonian staff notation might be conceived as an era of digitization with regard to technē as well as to logos.\(^90\) Media technologies originally deployed to store, transmit, and standardize the musical practice of chant were co-opted in order to assemble and distribute otherwise inconceivable musical structures via the lattice of the staff, and this grid was most directly materialized at the matrix of the keyboard.\(^91\) In Max Weber’s judgment, the keyboard thereby facilitated the integration and differentiation of musical materials with unprecedented efficiency, making it the arch representative of “technical musical rationalization” within the church and throughout the cultural spheres of music orthography, theory, and pedagogy.\(^92\) The realization of music at the keyboard involved the digital performance of symbolic functions; throughout the hegemonic era of Guidonian notation and the keyboard, both thrived by virtue of their symbolic promiscuity. As well as


\(^88\) It is as telling as it is implausible that the very “invention” of the key has long been attributed to none other than Guido of Arezzo; see, for instance, Türk, *Klavierschule*, 4, and Brinsmead, *History of the Pianoforte*, 85.

\(^89\) On Johannes Keck’s instrument, see Brauchli, *Clavichord*, 42; on Conrad of Zabern’s, see Gümpel, “Das Tastenmonochord”; on Johannes Gallicus’s, see Mengozzi, *Renaissance Reform*, 146–48.


\(^91\) On the impact of the staff, see Cohen, “Notes, Scales, and Modes,” 308.

\(^92\) Weber, *Die rationalen und soziologischen Grundlagen*, 86: “[Die Orgel] drang aber dann in die Klöster und klosterartig organisierten Domkapitel, die Träger alles musiktechnischen Rationalismus innerhalb der Kirche, und wurde dort, scheint es—and das ist wichtig—namentlich auch für den Musikunterricht benutzt.” (See also 78, 88.)
plotting musical frequencies and durations, each could represent musical content and instructions as conveyed numerically (by figured bass and fingerings) and alphabetically (by note names, solmization, and musical ciphers). In conjunction with Bacon’s cryptographic insights, the concept and name of the clavis suggested how the keyboard was capable of encrypting, transmitting, and decoding information among senders, receivers, conspirators, and eavesdroppers.
Spanning the realms of music and literature, the keyboard’s media-agnosticism and capacity to encode information enabled it to trade in the symbolic currency of Kittler’s “discourse network 1800” via the permutation of letters as well as notes.93 As Jean Paul’s novel *Die Flegeljahre* chronicles such processes at the piano, so Robert Schumann’s “lettres dansantes” in *Carnaval*, op. 9, set them in ludomusical motion (see Fig. 4a),94 while *Carnaval’s* quasi-paratextual “Sphinxes” tacitly stand in the work’s margins as guardians and guarantors of the enciphered alphabetic meaning to be found in the various sequences and permutations of dancing letters that Schumann deemed noteworthy (see Fig. 4b).95 Drawing attention to the ludic overtones of the enigmatic strategies that both disguise and disclose *Carnaval’s* networks of signification, Schumann informed Ignaz Moscheles that “deciphering my musical masked ball will be a real game for you.”96

Yet if encipherment and revelation could become entangled at the keyboard, so too could comprehension and delusion, as demonstrated by the

---

95. Rosen, *Romantic Generation*, 221–22; see also Rosen’s discussion of Schumann’s *Humoreske*, op. 20, and his *Variations on the Name “Abegg*,” op. 1 (7–12).
96. Quoted and translated in Daverio, *Crossing Paths*, 75.
work of Eric Sams, who worked alongside Alan Turing as a cryptographer at Bletchley Park during the Second World War. While the exact point at which Sams’s zealous pursuit of correspondences between symbols and signification shaded into fanciful invention is up for debate, its deeper meaning lies in its obsession with deeper meaning, exemplary of the Romantic belief that nature and art are “bursting with hermeneutically accessible riches,” as Geoffrey Winthrop-Young puts it. For Kittler, the conditions of this discourse network were established by new techniques of linguistic acquisition centered on the maternal voice that guaranteed the semantic plenitude of utterances while making them available for literary concatenation and philosophical abstraction. Via the discrete continuum of the keyboard, Carnaval made sound—the very absence of which could be charged with sphinxian significance—available for hermeneutical processing along analogous lines.

The epistemological imbrication of notes and keys became particularly visible when it was identified as a locus of notational reforms. The nineteenth century witnessed a proliferation of orthographic and mechanical methods that promised to increase the speed and clarity with which music could be represented on paper. Some, such as those by Michel Eisenmenger (1838) and Juan Nepomuceno Adorno (1855), remapped the staff directly onto the topography of the keyboard in a manner that harked back to eighteenth-century technologies associated with musical improvisation and reproduction. In the terms of high Romanticism, however, such methods only emphasized how the note’s digital strengths of discreteness and fungibility exposed its analogical weaknesses, its inability to trace the audible temporality of the phenomenon it symbolized. Composers who came of age in the later nineteenth century were painfully aware of the fact that beyond scores and other literate texts, in Kittler’s words,

Europe had no other means of storing time. Both are based on a writing system whose time is (in Lacan’s terms) symbolic. Using projections and retrievals, this time memorizes itself—like a chain of chains. Nevertheless, whatever ran as time on a physical or (again in Lacan’s terms) real level, blindly and unpredictably, could by no means be encoded. Therefore, all data flows . . . had to pass through the bottleneck of the signifier.
The undulations of Édouard-Léon Scott de Martinville’s phonautograms hinted at the way sonic actualité might be registered via oscillographic waveforms.102 On the page’s y-axis, the analphabetic freehand of Scott de Martinville’s oscillography replaced the staff’s grid of frequencies with the registration of amplitude in all its illegible continuity.

But Scott de Martinville’s phonautograms were produced without the prospect of mechanical playback: just as the keyboard had digitally materialized the principles of Guidonian notation, so the discourse of phonautography was in need of a media technology that could translate and reproduce it analogically. It was, of course, Edison’s phonograph that ultimately provided a technical means of capturing rather than simply inscribing oscillographic qualia, of both storing and recreating time in its “blind and unpredictable” unfolding. In the wake of phonographic Realism, the days of recreating sound by discretely processing notes at the keyboard seemed numbered. Scott de Martinville himself claimed that to the extent that “phonautographic writing” foregrounded the oscillographic functions “of tonality, of intensity, of timbre,” it alone would constitute “living speech”: all other forms of inscription were moribund by comparison.103

This distinction illuminates historical factors behind the twentieth-century opposition of the digital and the analog insofar as they relate to affect and trauma as well as to the fidelity of competing recording technologies. Lacan and Kittler channeled Scott de Martinville in jointly observing that the analog is like the Real insofar as it has no “no” function, and is thus incapable of formally articulating absence.104 In this light, Jonathan Sterne has diagnosed the audiophilic ascription of natural, lifelike qualities to analog recordings and the “objective, prophetic gentleness of those who are soon to die—al . . . with doh, ray, me, fah, soh, lab, te, doh!!! What a profession!” Quoted and translated in Grayson, “The Opera,” 35. Pace Kittler, the predicament was not exclusively European: Charles Ives complained to Clifton Furness that once an idea had been written down “it’s no good. Why when I see the notes I write down on the page and think of what I wanted it to sound like—why—it’s dead! It’s lousy with maggots!” Quoted in Budiansky, Mad Music, 13–14.

102. With regard to oscillography, Scott de Martinville was following in the footsteps of Thomas Young (1807) and Claude-Servais-Matthias Pouillet (1850), as Patrick Feaster points out in Pictures of Sound, 85–89, 110–11. In turn, they had drawn on the signal contributions of Ernst Florens Friedrich Chladni to techniques and technologies of “writing” sound, as summarized by Levin, “Tones from out of Nowhere,” 38–39.

103. Scott de Martinville, Phonautographic Manuscripts, 44: “L’écriture ou sténographie naturelle, dont voici les premiers rudiments, en rend le rythme, l’expression: elle est fonction de la tonalité, de l’intensité, du timbre, de la mesure. A ce titre elle est appelée à jouer dans les relations de la vie intellectuelle un rôle nouveau et imprévu; elle sera la parole vivante; notre caligraphie à la main ou imprimée n’est que la parole morte.” (Translation from same edition.)

104. Kittler, “World of the Symbolic,” 139–40; see also Wilden, System and Structure, 162–63. The Lacanian corollary is that the dialectic between presence and absence so characteristic of analog recordings operates on the imaginary rather than the symbolic plane. On Lacan’s interpretation of the ludic and psychoanalytical implications of digital presence/lack as theorized by Freud avant la lettre, see Wilden, System and Structure, 145–52. On noise-reduction
concomitant association of digitality with mechanicity, deception, and death as symptoms of a nostalgic longing for plenitude that itself cries out for psychoanalytical intervention. While Sterne’s observations relate primarily to twentieth-century recording techniques, anxiety concerning the dehumanizing effects of storing and recreating music digitally has less to do with any particular technology than with the asymptotic approximation of “analog” phenomena marked as imperceptible, unrepresentable, vital, and spiritual in the discourse of Romantic Naturphilosophie.

In the early nineteenth century musical automata prompted the articulation of such fears, as recent scholarship has explored in a multitude of ways. What affronted the student Ludwig in E. T. A. Hoffmann’s tale “Die Automate”—and the real-life Georg Wilhelm Friedrich Hegel, for that matter—was not so much the mechanicity of automata as their analogicity, their repulsive attempts to mimic the human: “I infinitely prefer the commonest barrel organ, in which the mechanism attempts nothing but to be mechanical, to [Jacques de] Vaucanson’s flutist.” While all automata were, in Terrance Riley’s terms, “fundamentally musical machines” to the extent that they depended on the pinned barrels and clockwork mechanisms that had been associated with musical reproduction for centuries, one of the android automata built by Pierre and Henri-Louis Jaquet-Droz in the 1770s—a keyboard player known as La Musicienne—is unusually anthropic. The complex engineering of La Musicienne coordinates cams that direct the analog sweep of her forearms (and the rise and fall of her chest) with a studded barrel that does not directly activate sonic production, but rather operates her digits—and digitizes her operations—at the ergonomically curved keyboard. La Musicienne does not simply reproduce music but plays it. Her techniques and their problematization of Kittler’s Lacanian distinction between the digital/symbolic and the analog/Real, see Kromhout, “‘Soft Landing.’”

106. On the intellectual history of this process, see Veit Erlmann’s discussion of the terms “gradation” and “progression” in his Reason and Resonance, 120–22.
108. Hoffmann, “Die Automate,” 117: “eben darum ist mir gerade die nach mechanischen Begriffen vollkommenste Maschine der Art eben die verächtlichste, und eine einfache Drehorgel, die im Mechanischen nur das Mechanische bezweckt, immer noch lieber als der Vaucansonsche Flötensbläser.” Jackson aligns Ludwig’s and Hegel’s analogous sentiments in Harmonious Triads, 80–81. As Voskuhl (Androids in the Enlightenment, 15–21) and Riley (“Composing for the Machine,” 367–68) contend, the anxiety surrounding such automata is far more a phenomenon of the nineteenth century than the eighteenth.
110. See Voskuhl, Androids in the Enlightenment, 128–45, and Klotz, Kombinatorik, 327–47. Voskuhl notes that the keyboard played by La Musicienne today is not that of her original instrument, which was probably a harpsichord or a hybrid harpsichord-organ (130).
digital and analog technologies are intermixed in the interest of mechanizing human actions as well as humanizing their mechanical counterparts.

The intricacies personified by La Musicienne would have been anathema to Hoffmann’s Ludwig, for whom technology should always be plainly identifiable as such. Today, Ludwigs attitude lives on in nostalgic players of digital games who prefer the unpretentious contrivances of pixel art and chiptunes to dead-eyed three-dimensional avatars rendered in high definition and accompanied by the bathos of sampled orchestral strings, and thereby marooned in the Hoffmannian realm of the uncanny valley. Whether as simulation or simulacrum, and whether it conceals its representational means or draws attention to them, the digital game symbolizes imaginary worlds in a subjunctive mood that reveals much about the fears and desires haunting the contemporary unconscious. For Kittler, the epistemological breakthrough that made such fantasies technically conceivable took place in Turing’s mind as he lay daydreaming of a “universal machine” in Grantchester Meadows one afternoon in 1936. Kittler hailed Turing’s universal machine as nothing less than the harbinger of a technologically sublime new world order. In Kittler’s account, the machine simply scans for a sign or its absence on a paper strip, at which point

it depends on [the machine’s] reading whether [it] keeps the sign or erases it, or, vice versa, whether it keeps a space blank or replaces it with a sign, and so on and so forth.

That’s all. But no computer that has been built or ever will be built can do more. . . .

. . . All data streams flow into a state $n$ of Turing’s universal machine; Romanticism notwithstanding, numbers and figures become the key to all creatures.\textsuperscript{111}

In line with Flusser’s premillennial observations, a Turing machine processes and transcodes the world digitally: as it calculates the checksum of Hegel’s \textit{Phenomenology of Spirit}, each and every operation stutters or clicks.\textsuperscript{112}

For Kittler, Turing’s daydream enacted a stunning reversal whereby Leibnizian combinatoriality, ostensibly outflanked and outmoded by the superior sensitivity and verisimilitude of analog technologies, could render sounds, images, and even the Real itself susceptible to the representational strategies of symbolic logic, soon to be materialized by von Neumann’s computational architecture.\textsuperscript{113} But the melodrama of Kittler’s media

\textsuperscript{111} Kittler, \textit{Gramophone, Film, Typewriter}, 18–19.
\textsuperscript{112} In Kittler’s words, “the media age proceeds in jerks, just like Turing’s paper strip”: ibid., 18.
\textsuperscript{113} In this light, Slavoj Žižek found it necessary to reconfigure the Real recursively, subjecting it to further tripartition in order to protect its Lacanian function while acknowledging its infiltration by the symbolic discourses and imaginary technologies associated with computation: Žižek, \textit{On Belief}, 82.
eschatology is less relevant here than the epistemological and instrumental implications of the typewriter—and specifically its keyboard—in the system of thought that both he and Flusser reflect. Perhaps prompted by memories of his childhood, Turing conceived his machine as nothing less (and nothing more) than a drastically stripped-down single-keyed typewriter capable of performing Bacon’s “twofold difference only.”

114 Hinting obliquely at the keyboard’s long history of negotiating between the Lacanian realms of the Real and the Imaginary, Turing’s dream machine complicates traditional accounts of musical storage and transmission by supplementing them with the symbolic logic of automated computation.

In 1854, George Boole had encoded logical procedures using Leibniz’s binary notation, thereby subjecting propositions to algebraic calculation by means of conjunction, disjunction, and negation.115 Fifteen years later, W. Stanley Jevons instrumentalized his own system of logic in the form of the so-called “logic piano” that he presented to the Royal Society in 1870 (see Fig. 5). Acknowledging his predecessors from Aristotle to Boole, Jevons described his keyboard instrument as an organon “capable of exhibiting an answer to any question which may be put to it concerning the possible combinations that form any class,” and it is in this capacity that it has been identified as an early materialization of the principles governing computational functions.116 Substituting propositions for pitches, the “piano” keys labeled with lowercase letters perform the negation of their neighboring uppercase counterparts. There is thus a fundamental difference between the nineteen keys that are not labeled with an “A” on Conrad of Zabern’s monochord and the two keys identified as “not A” on Jevons’s keyboard. As Wilden puts it, negation “involves ‘not’ both in the sense of ‘zero’ and as a rule about zero.”117 Accordingly, the adjacent keys of “A” and “not A” on the “logic piano” do not merely articulate the matter of difference in the terms of Conrad and Bateson, but recursively reveal how the difference-making potential of digital technology is itself made (to) matter by the symbolic distinction between presence and absence.

The keyboard is an archetypal means of imagining and realizing such distinctions. For Jevons, its digital interface conspicuously displayed the processing of thought as “played upon the machine”; for Schumann,
musical meanings could be unlocked via keys both played and unplayed; for Turing, the keys that could inscribe and erase a sign were themselves present sous rature.118 Whether indexing Turing’s sign, Jevons’s propositions, or Schumann’s sphinxes, the keyboard and its notational analogs are thus implicated in the history of digitality in the form of material objects and ideational traces capable of representing and distinguishing between 1 and 0, A and not A, and even the chromatic ambiguities associated with the musical alphabetization of “As. C. H.” and “A. Es. C. H.” In addition to accounting for the epistemological principles according to which any given keyboard conveys information and confers knowledge, however, it is necessary to attend to the cultural conditions under which its functions are analogized. This entails approaching keyboards not merely as data buses, but as interfaces at which selfhood is (per)formed and agency (re)distributed via the digital making of differences.

**Interface Values**

Musical interfaces and the effects they produce are as complex as they are varied, and a detailed accounting of them requires technical knowledge spanning domains from dendrochronology to materials science. The pages of the *Galpin Society Journal* and the *Journal of the American Musical Instrument Society* testify to the painstaking accumulation of

different types of data that, taken as a whole, map out the intricately ramified discourse networks of organology. In many ways, organology’s attentiveness to specific instantiations of musical culture and its concomitant suspicion of generalizations derived from sweeping narratives can be seen to have anticipated the recent material and informational turns of the humanities at large. In other aspects, however, structural tensions persist between organology and its supposed sister disciplines of ethnomusicology and historical musicology, not to mention science and technology studies.119 In particular, ethnomusicologists and historical musicologists have resisted organology’s material preoccupations by insisting on interpretations, whether they concern social dynamics, historical forces, or transcendental aesthetics.

Whereas the Hornbostel-Sachs system classifies instruments according to their mode of acoustic production, the interface stands in an orthogonal relation to such taxonomical distinctions. As a schematic morphological principle, it can be put into play with any number of mechanisms—aerophonic (the organ, for example), chordophonic (the harpsichord, clavichord, and piano), idiophonic (the celesta), or electrophonic (from the eighteenth-century Denis d’or, which charged its metal strings and could shock the player on demand, to the Moog synthesizer)—in order to produce sound.120 Emily I. Dolan observes that the interface of the keyboard has remained a constant element across generations of musical experimentation, skeuomorphically imbuing the new with a comforting air of familiarity.121 That the keyboard’s ubiquity can render it virtually transparent both conceals and reveals the fact that an interface does not merely act as a conduit by which a musical thought is realized; it also conveys the force and inertia of a physical system of checks and balances that trains its players by establishing its affordances and mapping them onto a delimited range of sonic outcomes. Both ideologically and materially, the keyboard partitions and classifies sound, imposing discipline on the generation of acoustic material as well as the body of the player and the sensibility of the listener.122 As it orders and arrays musical knowledge, in other words, any given keyboard operates as an


120. As an experimental instrument, the Denis d’or, designed and built by Václav Prokop Divíš, can be considered alongside both the electrical trials to which the chemist, physicist, and philosopher Johann Wilhelm Ritter subjected himself, described by Erlmann (Reason and Resonance, 190–202), and, in a more public context, the eighteenth-century “electrical performances” enumerated by Ciara Murphy (“Shocks and Sparks”). The flux and polarities inherent in electrical phenomena gave rise to interpretations by Ritter that can be construed in analogical and digital terms respectively.

121. Dolan, “Musicology of Interfaces.”

122. On the politics of classification, see Foucault, Order of Things, and Bowker and Star, Sorting Things Out.
epistemological object that channels both human and nonhuman forces within a political ecology.123

The attribution of a degree of agency to keyboards has a distinguished pedigree in the form of mottoes inscribed on harpsichords and other instruments.124 Drawing on the classical tradition of epigrams that envoice objects, or oggetti parlanti, many such mottoes speak in the first person and are couched in the pedagogical terms of discipline and punishment. Some deploy overtly Foucauldian rhetoric, at once erotic and violent: “indocta manus noli me tangere” (unlearned hand, do not touch me) warns a seventeenth-century virginal, while an eighteenth-century spinet is more ambivalent: “intactum sileo percute dulce cano” (untouched, I am silent; strike me, I sing sweetly).125 Keyboards can instruct and delight even as they suffer at the hands of their assailants: on either side of the interface, “all playing is a being-played.”126

Harpsichords and their mottoes also suggest how integral digital processes can be to cultural narratives. As Ernst points out, the etymology of “telling” and “recounting” reveals that melodies, stories, and algorithmic processes are composed of signifying objects—notes, letters, or numbers—placed in serial order.127 In parallel, moreover, the use of digits to measure and calculate at the harpsichord informed musical thought and practice across Europe, serving a wide range of analytical as well as elaborative ends. This is manifested most obviously by figured-bass notation and the algorithmic procedures that brought about its mundane or fantastical realization in performance, but it also pervaded the theoretical domain in terms of the mathematical and philosophical ramifications of Rameau’s basse fondamentale, a layering of sonorities that is at once constitutive and fictive, real and imaginary.128

123. On how such ecologies can be registered as assemblages of human and nonhuman forces, see Bennett, Vibrant Matter.

124. See McGeary, “Harpsichord Mottoes.”

125. Cited in ibid., 23. “Noli me tangere” has scriptural resonances: by casting the virginals as Christ himself, the motto plays on the ambiguity of the divine body. As part of the longer riddle “Viva fui in sylvis, sum dura occisa securi, / dum vixi, tacui, mortua dulce cano” (I was alive in the woods, I was cut down by the hard axe. / While I lived I was silent, now that I am dead I sing sweetly), this motto has been associated with musical instruments since the Renaissance: see Borthwick, “Riddle of the Tortoise,” esp. 379–80, whence this translation is drawn.

126. Harpsichord mottoes imply that this type of chiastic mediation is not restricted to the domain of the living, in line with Nonnus’s description of how the wind envoiced Marsyas’s hanging hide (Dionysiaca 19.321–22). Tellingly, as Leppert notes, two paintings designed to adorn sixteenth-century harpsichord lids depict Apollo vs. Marsyas: Leppert, “Music, Violence,” 65n46.


128. On the relationship between the basse fondamentale and the basse continue, see Christensen, “Thoroughbass as Music Theory,” 20–28, and Christensen, Rameau and Musical Thought, esp. 103–9. The medium (if not the meaning) of such numerical signification can be traced back to sixteenth-century Spanish and Italian tablature that notated music via numbers placed in grids or tables that could be deciphered with the aid of illustrations mapping those numbers onto frets, keys, or strings, as in Luys Venegas de Henestrosa’s Libro de cifra nueva
The pedagogical materials and traditions of *partimenti*, which for so long eluded the attention of anglophone scholars on account of their lack of a literary rubric, also operated according to serial and parallel logic: rather than a text to be read, a *partimento* is both a puzzle and an algorithm, a concise script that must be uncompressed and processed via the hardware of a harpsichord, the interface of its keyboard, and the “wetware” of its player’s experience, skill, memory, and associations in order to become music. 129 Such computation need not be carried out consciously; as Leibniz put it, “music is a hidden arithmetic exercise of the soul, which does not know it is counting.”130 This helps explain the phenomenon noted by John Locke, Étienne Bonnot de Condillac, and Denis Diderot in which the cognitive burden of playing—or, in the latter’s case, improvising—at the keyboard is delegated from the brain to the digits, thus affording the Gadamerian sensation of being played even while playing.131

For all the keyboard’s efficacy as an interface, the notion of play reveals how its conversion of digital pressure into sound is less than optimally efficient. In this sense, the play of a key, like that of a steering wheel, allows a degree of free motion that is supplementary to that required for its normative function. While it has limited bearing on the instrumentality of the key, this wiggle-room yields haptic sensations that can deliver important feedback to the player: as well as affording the technical means of manifesting one’s musical will, instruments register and relay the input they receive.132 The clavichord is the most analogically expressive of digitally operated instruments, its code of conduct predicated on the almost unbearably intimate translation of touch into sound. Unlike the harpsichord, organ, or piano, the clavichord responds to the play of horizontal and vertical “aftertouch” at the limits of each key’s travel by way of *Bebung*, an intimate vibrato that results from the contact of tangent and string. The affective strength—and acoustical weakness—of *Bebung* lies in the simplicity and directness of its mechanism: the paradoxical immediacy of mediation via finger and key causes the player’s body to resonate in

129. On *partimenti*, see Christensen et al., “Partimento” and Continuo Playing; Gjerdingen, “Partimento, que me veux-tu?”; and Sanguinetti, *Art of Partimento*. On how the concept of wetware resonates between the eighteenth and late twentieth centuries, see Riskin, “Eighteenth-Century Wetware.”


132. It is in this sense that the “instruments” clustered on a car’s dashboard operate as such. (I am grateful to Brían Hanrahan for drawing this point to my attention.)
sympathy, and the clavichord is thus an instrument that measures the sensitivity of its operator with unrivaled precision. In his Versuch über die wahre Art das Clavier zu spielen, Carl Philipp Emanuel Bach asserted that “it is at the clavichord that a keyboard player may be most exactly evaluated.”

In this regard, the oscillographic traces of Bebung and the associated dynamic technique of Tragen der Töne could serve as a proto-phonautographic signature, measuring the player not merely in terms of her skillful application of these techniques, but by the seismic tremors of her very being.

Charles Burney famously remarked on this phenomenon in relation to Emanuel Bach and his beloved Silbermann clavichord: “In the pathetic and slow movements, whenever he had a long note to express, he absolutely contrived to produce, from his instrument, a cry of sorrow and complaint, such as can only be effected upon the clavichord, and perhaps by himself.”

Burney sensed the presence of Bach’s “voice” via the rhetorical, gestural, and timbral force exerted by the tangent on the string.

In his Versuch, Bach famously exhorted his readers to “play from the soul, and not like a trained bird.” In this regard, and along the Romantic lines that Hegel would later codify, Bebung might stand alongside cursive handwriting as a marker of personal identity:

If at first the specific nature and innate peculiarity of the individual, together with what these have become as a result of cultivation and education, are taken as the inner, as the essence of his action and his fate, then this essence has its appearance and externality to begin with in his mouth, hand, voice, handwriting, and the other organs and their permanent characteristics. Thereafter, and not till then, does it give itself further outward expression in its actual existence in the world.

133. Bach, Versuch, 1:12: “Das Clavichord ist also das Instrument, worauf man einen Clavieristen aufs genaueste zu beurtheilen fähig ist.”

134. The techniques of Bebung and Tragen der Töne were briefly described by Bach in the Versuch (1:150). On sentiment, melancholy, fantasy, and femininity as mediated by the clavichord, see Richards, Free Fantasia, 145–82.


136. On the relationship between voice and clavichord from a range of perspectives, including the technological and the psychoanalytical, see Scherer, “Die Stimme und das Clavicord”; Richards, Free Fantasia, 151–55; and Siegert, Passage des Digitalen, 265–66.


138. Hegel, Die Phänomenologie des Geistes, 250–51: “Wenn also zuerst die bestimmte Natur und angeboren Eigenthümlichkeit des Individuums zusammen mit dem, was sie durch die Bildung geworden, als das Inneres, als das Wesen des Handelns und des Schicksals genommen wird, so hat es seine Erscheinung und Auerschiefchaft zuerst an seinem Munde, Hand, Stimme, Handschrift, so wie an den übrigen Organen, und deren bleibenden Bestimmtheiten; und altdann erst drückt es sich weiter hinaus noch aussen an seiner Wirklichkeit in der Welt aus.” Translated in Miller, Phenomenology of Spirit, 189–90.
While Bach’s clavichord was not one of his own “organs,” Burney nonetheless perceived it as a prosthetic extension of his mouth and voice as well as his hand. Via the judicious application of *Bebung* and *Tragen der Töne*, the motions of Bach’s digits at the keys of his Silbermann could unlock his inner mysteries: the clavichord made his soul audible.

The *Versuch* stands as an important landmark in the lettering of digital activity, whereby keyboard techniques that had previously been conceived primarily in procedural, algorithmic terms were rendered literary—or, at least, amenable to literary representation. At the same time, the technical attributes of the clavichord helped create the conditions under which Bach’s *Versuch* could be written. Together with Bach’s fantasias, the *Versuch* proved the clavichord to be a true medium: like the ancient *tabula rasa* or the cinematic dream sequence, it was capable of serving as a model for the representation of consciousness and sensory experience. This process can be traced across the treatise’s final pages, where Bach presented a single fantasia in two radically different forms. A fully fleshed-out version, denoting the piece as realized in performance, and an X-ray of its “Gerippe” (skeleton), as Bach called it, stand side by side. The *Gerippe* consists of what Richard Kramer terms “the ‘pre-compositional’ calculus of a figured bass.”

The distance between the two versions is thus itself figured in terms of the skill set of the player able to transcode numbers into affective experience. In turn, this experience was subjected to an alphabetic transposition into the rapturous discursive register in which Burney described Bach’s fantasizing at the keyboard, a passage that attests to the clavichord’s ability simultaneously to construct subjectivity and to undo it: “During this time, he grew so animated and possessed, that he not only played, but looked like one inspired. His eyes were fixed, his under lip fell, and drops of effervescence distilled from his countenance.”

Generated from the subconscious calculation of figures, Bach’s fantasy was performed as a Leibnizian “hidden arithmetic exercise of the soul.”

Bach’s fantasizing was recounted by Burney in discursive terms that shade from *Empfindsam* sensibility into the rhetoric of possession associated with Romantic genius—and madness. Aesthetics aside, such pathological tinges imply that Bach’s and Burney’s numbering and lettering of musical experience were subject to codes regulating the performance of gender. For Anton Bemetzrieder, harpsichord instructor to Diderot’s daughter Angélique (a passionate devotee of Emanuel Bach’s music), the alphabetic functions of the harpsichord’s keyboard formed the basis of

141. In this context, it is telling that Bach strongly expressed his preference for figured bass lines over their unfigured counterparts: Bach, *Versuch*, 2:297.
an elaborate didactic analogy between music and language that left little room for wild fantasy.143

On a grander pedagogical scale, the blind Austrian pianist Maria Theresa Paradis, godchild as well as namesake of the Habsburg empress, demonstrated that language acquisition, letter writing, musical performance, and composition—even games of chess and cards—could be conducted exclusively via the manipulation of discrete objects and symbols, testifying to her dexterity and adaptability as well as to her intellect, memory, and refined sensibility. Paradis possessed substantial cultural and economic capital: her condition was treated by Franz Mesmer, the inventor Wolfgang von Kempelen designed a Handdruckpresse (a portable case of movable type) for her personal use, Mozart provided a piano concerto for her, and she studied composition with both Anton Salieri and Abbé Vogler.144 The development of media technologies by Paradis and her acquaintances compensated for the lack of vision and inability to write cursively that might otherwise have thwarted her cultivation of selfhood.

Far from confining her to the margins of society, as the same condition did for so many others, Paradis’s blindness confirmed Diderot’s philosophical contention that an enlightened subject could be constructed and represented by the manipulation of discrete elements—notes, letters, numbers, and keys—via haptic and digital means alone.145 Despite their emancipatory potential, however, these tactile technologies and bodily techniques were co-opted along gendered lines: if a man was heard to “play from the soul,” the dexterity of a woman at the keyboard was more likely to be dismissed as the trilling of a “trained bird.”146 In the nineteenth century, this tendency was materialized and accelerated via the pianistic skeuomorphism of telegraph and typewriter, as Ivan Raykoff has shown. Referring to an array of objects including Royal Earl House’s type-printing telegraph (1849) and Samuel W. Francis’s “literary piano” (1857; see Fig. 6), Raykoff expands

144. The Mozart concerto performed by Paradis was probably K. 456 in B-flat major. Kempelen’s *Handdruckpresse* is mentioned in Farrell, *Story of Blindness*, in which it is described as “perhaps the first machine that proved to be adequate for practical use” (120). Vogler developed an analogous system designed to enable Paradis to notate music; see Fürst, *Maria Theresa Paradis*, 33–35, 107–9.
145. See Diderot, *Lettre sur les aveugles* and *Lettre sur les sourds*. A wax bust of Paradis, created so that students at a Viennese school for the blind could touch her likeness, still survives.
146. Discussing the role played by the clavichord in eighteenth-century German love poetry and songs, typically performed by women, Richards describes the instrument as “a sonic mirror of the sufferer’s psyche” that could nonetheless “find its true voice only at the hands of the male Originalgenie, most particularly in his improvisations”: Richards, *Free Fantasia*, 156, 171. See also Head, *Sovereign Feminine*, 48–83.
upon Kittler’s mordant observation that telegraphy and typewriting repurposed the dexterity of generations of female pianists, capitalizing both on the fleetness of finger they had acquired through countless hours of practice and on their ability to digitize male utterances—whether musical or bureaucratic—dutifully and accurately.  

Although they can be traced back to the eighteenth century, the codification of expressive protocols and the gendered bureaucratization of piano technique were closely aligned with the manufacturing of musical and communicational instruments throughout the nineteenth century: as many have observed, the social impact of the piano must thus be calculated on no less than an industrial scale.  

Even as the piano became synonymous with bourgeois cultivation and leisure, its affordance of play hinged on a proto-Fordist ideology and division of labor.  


Steinway, the morphology and function of Apollo’s kithara remained, but multiplied, transformed, and devolved. The number of strings grew more than thirty-fold; the lyre itself, far too heavy to be supported by the human body, was sealed out of sight; the essential task of tuning was assigned to a trained professional, disconnecting mathematics from the domain of the player’s senses; the strings were not plucked by fingers nor even by the plectra with which Apollo endowed the harpsichord, but rather struck by felt-covered descendants of the hammers wielded by Pythagoras’s blacksmiths. The musical forge lay hidden behind the fallboard: as with the personal computer, only the interface of the keyboard provided sanctioned access to the instrument’s inner workings.\textsuperscript{150}

On the one hand, the proliferation of pianos throughout Europe and North America facilitated the rapid spread of the notion that the musical soul was digitally articulable; on the other, this proliferation relied on the technological and manufacturing resources of hammer mills and even knitting frames, exposing the mechanization that lay at the heart of the pianistic enterprise.\textsuperscript{151} The signature sounds of cultivated sensibility reverberated through every bourgeois household, produced and recognized via pedagogical methods that inculcated the performance of auditory discrimination, manual dexterity, and expressive gesture as fundamental cultural techniques, even if \textit{Bebung} had to be sacrificed for the sake of increased amplitude and lower maintenance costs.\textsuperscript{152} In its place, the free flight of the piano’s hammers, which detached human stimulus from sonic response, prompted innumerable attempts to account for the mysterious idiosyncrasy of touch by quasi-occult means.\textsuperscript{153} Supplementary meanings thus accrued on either side of the piano’s interface: beyond the matter of digital operations, acoustic signals were invested with meaning by extravagant gestures and wishful thinking that implored the instrument to perform the sonically impossible.

At the same time, the increasing standardization of repertorial software displaced responsibility for individuation from improvisatory facility onto the art of interpretation and the craft of reproduction. In this latter regard, even so great an exponent of transcription as Franz Liszt was ambivalent about the artifacts generated by the digital dithering of symphonies, string quartets, and operas at the keyboard’s dichromatic matrix, which could evoke

\textsuperscript{150} From this perspective, the history of piano “preparation” and the development of extended techniques at the instrument might be considered in terms of other hardware modifications that circumvent restrictions imposed by material limitations, laws, conventions, and taboos.

\textsuperscript{151} See Libin, “Progress, Adaptation,” 204; on the ironies behind the “mass-production of bourgeois selves,” see Voskuhl, \textit{Androids in the Enlightenment}, 229–30.

\textsuperscript{152} For an insightful framing of this process, see Blasius, “Mechanics of Sensation.”

\textsuperscript{153} For French pedagogue Marie Jaëll, for instance, touch could be decoded only by studying fingerprints as distinctive markers and traces of digital identity: see Kursell, “Visualizing Piano Playing,” and Davies, \textit{Romantic Anatomies of Performance}, 165–67.
tonal colors via chiaroscuro alone. Comparing transcriptions to mass-produced engravings of famous paintings, Liszt identified the practice with the economics of commodification: the popularity, portability, and fungibility of the four-hand transcription relied on the piano’s attributes as a highly efficient quantizer, compressor, and decoder of discrete data, benefits that came at the expense of timbral and temperamental nuances.  

Whereas the piano’s monopoly of the marketplace ensured that its interface sailed into the twentieth century virtually unchanged, the layout and function of the keyboard as media interface was subjected to thoroughgoing reform in response to the increasing demand for the serial processing of alphanumerical characters with the utmost speed and reliability. While it could be said that pianistic skeuomorphism was eventually rejected in favor of the typewriter’s QWERTY configuration, such an overview occludes both short-term ruptures and long-range continuities in terms of the intertwined development of keyboard interfaces and techniques. Jean-Maurice-Émile Baudot’s five-bit interface (1874), configured in the two-plus-three layout of the piano’s black keys, stands as a prime example of this interdependence (see Fig. 7a). As Raykoff notes, Baudot introduced it as the input device for his multiplexed telegraph system, but it was denigrated as unwieldy and inefficient before being rendered obsolete by the automation of its functions. More than a century later in Japan, however, Baudot’s long-defunct five-note keyboard returned, interleaved in black-and-white formation and set alongside the digital simulacrum of an analog turntable, as the interface for Konami’s *Beatmania* series of music-themed digital games (see Fig. 7b and 7c).

Baudot’s telegraph indexed the waveforms of spoken or imagined utterances in symbolic form for the purposes of storage and transmission; conversely, players of *Beatmania* convert stored symbols into sound via the same digital operations. In the process, unwieldy transmissive inefficiency is transformed into pleasurable ludomusical challenge, demonstrating that playing a game can be understood as “the voluntary attempt to overcome unnecessary obstacles,” as Bernard Suits defines it. Reinterpreting the performance of five-bit telegraphy in parallel and serial as the chords and sequences of musical recreation, “rhythm-action” games from *Beatmania* to *Guitar Hero* demonstrate that the logic governing both systems is chiastic,

154. Liszt, *Artist’s Journey*, 45: “[A transcription for piano] bears the same relation to an orchestral work that an engraving bears to a painting; it multiplies the original and makes it available to everyone, and even if it does not reproduce the colors, it at least reproduces the light and shadow.” See also Christensen, “Four-Hand Piano Transcription,” esp. 274–82.

155. On the contingency of the network effects that helped ensure the longevity of the QWERTY layout, see Liebowitz and Margolis, “Fable of the Keys.”

156. The epistemological basis for Baudot’s five-bit system of alphanumerical encoding was established by Wilkins in 1641; see Wilkins, *Mercury*, 130.

**Figure 7a** Keyboard of Émile Baudot’s multiplexed telegraph system (1874). Photograph reproduced courtesy of Fons Vanden Berghen, Halle (www.telegraphsofeurope.net). This figure appears in color in the online version of the *Journal*.

**Figure 7b** *Beatmania* DJ Station Pro controller for Sony’s PlayStation console (Konami Co. Ltd., 1998). Photograph reproduced courtesy of Takahito Saiki, Kobe Design University. This figure appears in color in the online version of the *Journal*.
reversible, and capable of engaging its players at a tactile and affective level even while ostensibly restricting them to the automatable task of mechanical reproduction.  

These latter-day extrusions of Baudot’s interface suggest a chronological narrative based on the way a communicational protocol was itself communicated. At the same time, they invite us to consider other modes of relating its various iterations to one another, even if—or perhaps especially when—our historicizing instincts are unsettled in the process. As is evident from Figure 7c, the notational history of Beatmania can be traced via the player piano, the musicography of Eisenmenger and Adorno, the punched cards with which Basile Bouchon first programmed a textile loom in 1725, and the water organ illustrated by the Huguenot engineer

158. On the “touching” attributes and effects of the telegraph as an instrument of desire and romance, see Raykoff, Dreams of Love, 27; on the social, performative, and affective potential of the Guitar Hero controller and its five-bit fret buttons, see Miller, Playing Along, 85–151.
Salomon de Caus in 1615 (see Fig. 7d). Moreover, this constellation of objects and principles represents a clustering of musical and industrial technologies implicated in the prehistory of digital computing.

In this regard, the keyboard, notational system, ludic principles, and computational technology that constitute Beatmania simultaneously enact and represent the game’s own media archaeology. It might be anachronistic to describe the pegs of de Caus’s barrel as bits, discrete units of information that can be both stored spatially in “memory” and executed in temporal sequence as “code,” but it nonetheless reveals how pitch and rhythm have been—and continue to be—quantified, mapped as Cartesian coordinates, and mechanically processed. Programmed by a latter-day studded barrel, the digits of the Beatmania player activate a keyboard in order to recreate music—as do those of La Musicienne, the Jaquet-Droz android. Evoking Jevons’s “logic piano” (insofar as the player’s input is evaluated according to a form of Boolean logic) while rehumanizing the automated operation of Baudot’s keyboard, Beatmania thus draws explicit attention to the digital interface that helped make computational processes conceivable and transmissible as well as manipulable.

With the keyboards of Baudot, Beatmania, and La Musicienne in mind, and thereby attuned to the temporal transformations that media technologies effect as well as undergo, we might detect the objections of musical objects to the uncritical application of historical narrative to describe their passage through time. For Michel Foucault, the task of registering such objections was both archaeological and genealogical: it had to do not only with the affordances and constraints of particular systems of thought (“epistemes”), but also with their temporally shifting formations. Foucault believed the generation and storage of knowledge to be governed by epistemological rules distinct from those that regulate grammar, logic, and history. While these rules delimit conceptual possibilities, their enforcement is effected via vectors of power and discipline that in ludic terms rehearse the dynamics of ἀγῶν, “the endlessly repeated play of dominations” and its

159. See Moseley, “Playing Games with Music,” 294–300, and Moseley and Saiki, “Nintendo’s Art,” 62–66. In Figure 7d, the machine-readable tablature of Alessandro Striggio’s madrigal “Chi farà fed’al cielo” takes the form of pegs that activate the keys at the bottom of de Caus’s illustration. De Caus credited “Pierre Filippe” (better known as Peter Philips) with the intabulation: Caus, Von gewaltssamen Bewegungen, 1:38–39.

160. In particular, the technologies of the player piano have been related to Charles Babbage’s Analytical Engine (1834–71), Herman Hollerith’s tabulating machine (1890), and Turing’s universal machine; see, for instance, Suisman, “Sound, Knowledge”; Goble, Beautiful Circuits, 169; and, in a literary vein, Gaddis, Agape Agape.

161. On the proto-computational attributes of the Jaquet-Droz automata, see Ifrah, Universal History of Computing, 176–77; on the complex “life mechanism” of La Musicienne, which operates via lengthy subroutines that are independent of her musical programming but that nonetheless frame her performances, see Voskuhl, Androids in the Enlightenment, 140–45.
Figure 7d  Salomon de Caus, “Abbildung eines musicalischen Steinradts,” *Von gewaltzahmen Bewegungen: Beschreibung etlicher, so wol nutzlichen als lustigen Machiner* (Frankfurt: Pacquart, 1615), 1.[83]. Reproduced courtesy of the Sächsische Landesbibliothek, Staats- und Universitätsbibliothek Dresden (digital.slub-dresden.de/en/workview/dlf/17325/83/0/). This figure appears in color in the online version of the *Journal*.
related maneuvers, tactics, and techniques.\textsuperscript{162} Adopting and adapting the term from Nietzsche, Foucault claimed that genealogy eschews the teleology and instrumentality associated with work and thus discovered playful recurrences where others sought evidence of serious progress. Genealogy “operates on a field of entangled and confused parchments, on documents that have been scratched over and recopied many times.”\textsuperscript{163} It traces archaeological methods as well as remains, taking as its subject matter not only archival evidence but also the discursive formations of the archive itself, which constitutes “the set of rules governing the range of what can be verbally, audiovisually, or alphanumerically expressed,” in Ernst’s formulation.\textsuperscript{164}

Ernst also critiques the predominance of teleological metaphors that frame the flight of time’s arrow in the organic terms of creation, maturation, and entropic decay.\textsuperscript{165} Although clearly indebted to Foucault, however, Ernst’s wording leads away from the episteme and toward Kittler’s discourse network, which Kittler defined as the assemblage of technologies and institutions “that allow a given culture to select, store, and process relevant data.”\textsuperscript{166} By focusing on media mechanisms and techniques, the work of Kittler and Ernst draws attention to the material conditions that make an utterance, transcription, or genealogical palimpsest possible. This is particularly important when it comes to ludomusical practices, since games and music cannot be directly accessed from within an archive or repository: insofar as their documentary traces are always fragmentary and static, they are always already archaeological, and their reanimation requires technologies of recreation (bodies, instruments, and other devices) as well as textual modes of transmission.

To register the ways in which bodies store and transmit cultural knowledge, we must apprehend how communicative media are themselves materialized and embedded. Both iterations of Baudot’s interface are digital in the narrow Leibnizian sense: their keys are discrete switches that can convey only the binary states of 1 and 0. That notwithstanding, their entanglement in cognitive, linguistic, social, and affective systems enabled them to communicate via encryption, to touch via mechanical processes, to give form to imaginative impulses: in short, to operate analogically. Their functions should thus be understood in terms of praxis, “a set of executions or actions in relation to a world,” as Alexander R. Galloway puts it in the context of computation, rather than merely in terms of formal ontology.\textsuperscript{167} The

\begin{thebibliography}{99}
\bibitem{Foucault150} Foucault, “Nietzsche, Genealogy, History,” 150.
\bibitem{Ibid139} Ibid., 139.
\bibitem{Ernst239} Ernst, “Media Archaeography,” 239.
\bibitem{Ernst140} Ernst, “From Media History to Zeitkritik,” 140–42.
\bibitem{Kittler369} Kittler, Discourse Networks, 369.
\bibitem{Galloway23} Galloway, Interface Effect, 23. Even within a single realm, such “possible actions” can be at once homologous and widely divergent. In the cryptographical sphere, for instance, Wilkins’s \textit{Mercury} contains a method for encoding communications musically (141–44), while the ostensibly musical \textit{Guitar Hero} controller and notational system have recently been adapted
\end{thebibliography}
ludomusical dimensions of Baudot’s interface as realized by *Beatmania* reveal ways in which the cultural techniques of communication can become playful when put into digital practice, embodied by “the nimble and orderly movements of the fingers.”

Thinking of digital interfaces not merely in terms of the work accomplished, or the information transmitted thereby, but as facilitators of play opens up a different perspective on their genealogical ramifications. Whether taking the form of the micro-timed desynchronization of melody and accompaniment in Chopin, the improvisation of a Hammond organ solo, the dextrous transmission of a text message, the expert playing of *Guitar Hero*, or the destruction of an enemy base, such play is predicated on *kairos* rather than *chronos*, on strategically seizing the right moment to syncopate the equal spacing of the matrix that partitions seconds and centuries alike. In corresponding spatial terms, the play of fingers over the keyboard allows for the creation of sonorous effects that simultaneously reinforce and defy the black-and-white gridding of frequency.

Any instance of play can be historically indexed and located only once its formal properties have been identified; conversely, such properties assume significance only when embedded in the historical and cultural milieux that furnish the terms on which their legitimacy is granted, demonstrated, and questioned. If, as Laurence Dreyfus suggests, the playful oscillation between seemingly incommensurable criteria can obviate the temptation to subjugate one set to the other, then the keyboard’s most explicitly ludic manifestations and associations offer the best chance of capturing the full range and variegated shades of its digital analogies.

*(Key)Board Games and the Matter of Temperament*

As objects of play, both music and games are part of quotidian life, and yet they tend to take place in realms where everyday protocols are suspended. From the tennis court to the concert hall and the sumo ring to the court of law, Huizinga noted that certain sites, which he dubbed “magic circles,” are reserved for the enactment of agonistic encounter and exchange. Magic circles constitute ritual frames wherein the internal coherence of

---


169. *Kairos* and *chronos* are here deployed following Piekut’s invocation of the dyad when distinguishing between indetermination and improvisation: Piekut, “Chance and Certainty,” 156.

170. Celebrating music’s ludic qualities, Dreyfus observes that “human beings are very good indeed at juggling masses of conceptual figures, each tugging at the other’s hegemony, enabling what we know and sparking how we act”: Dreyfus, “Interpretation of Music,” 272.

rule-bound systems is temporarily granted primacy over—or protection from—external exigencies. To be sure, magic circles are always materially and historically grounded, and their circumscription of territory is subject to interrogation and negotiation. Nonetheless, taking the illusory aspects of magic circles seriously can help us grasp the subjunctive logic by which play can render arbitrary objects and contingent events as absolute and necessary. As a field of play, the musical keyboard serves as a *tabula rasa* as well as a site for archaeological investigation. While it is always materialized in specific forms, it also exists *a priori* as a schema that affords a particular set of tactics for constructing relationships between sign and signal, body and sound, player and played.

From Handel vs. Scarlatti to *Beatmania*’s two-player battle mode, the trope of the musical duel resonates throughout music history by way of legendary contests based on the evaluation of *technē* at the keyboard.172 Operating as a means of quantization capable of unambiguously distinguishing identity from difference, the keyboard established the prerequisites for a fair contest that were conspicuously lacking from Apollo’s duel with Marsyas. Yet, as Pierre Bourdieu observed and the stakes of such contests bear out, the demarcation of such a field of play for the staging of duels typically serves the purposes of cultural elites. The keyboard is not only indicative of rationalization insofar as it ensures “predictability and calculability, beyond local differences and particularisms”; the very notion of the fair play that it regulates betrays the aristocratic pride taken in the conspicuous display of disinterest that measures the distance between play as “activity for no purpose” and the vulgarity of its material consequences in sport just as in art.173 In this sense, the very literality of analogies between music and games at the keyboard outlines the complexity of their social and political ramifications as well as the way they inflect the concepts of musical autonomy, form, and reference that are typically grounded in the ontology of the musical work.

172. Other storied clashes include those between J. S. Bach and Louis Marchand (who turned tail and fled to avoid the ignominy of defeat), Mozart and Muzio Clementi, Beethoven and both Joseph Wölfl and Daniel Steibelt, and Liszt and Sigismond Thalberg. Such contests placed a high value on improvisation as a measure of wit, ingenuity, and flexibility as well as skill: in competition, successful players read and responded to the game’s shifting state and the actions of their opponents in real time rather than according to a script. As Goehr notes, such duels are most commonly staged today within the overtly improvisatory genres (and economic frameworks) of jazz’s “cutting contests” and hip-hop battles conducted via microphones and turntables, which directly informed *Beatmania*’s initial billing as an “interactive DJ simulation game”: Goehr, “Improvising *Impromptu.*”

173. Bourdieu, “Sport and Social Class,” 824. Bourdieu proceeded to contrast the perceptions of sporting *Kenner* and *Liebhaber* in ludomusical terms: the connoisseur “find[s] in the promptness of a movement, in the unforeseeable inevitability of a successful combination or the near-miraculous orchestration of a team strategy, a pleasure no less intense and learned than the pleasure a music-lover derives from a particularly successful rendering of a favourite work” (829).
The genealogy of the keyboard’s explicitly ludomusical potential extends back to the chekker, a quasi-mythical fourteenth-century keyboard instrument whose form and function have generated much debate.\(^{174}\) No chekkers are extant, and the only iconographical material that has been presented as evidence for the instrument’s design, produced by Jean Gerson in 1424, postdates its heyday and is obscurely allegorical in nature.\(^{175}\) “At once musical and military,” it depicts a chessboard primed to stage an agonistic battle between vices and virtues (see Fig. 8). Underneath the board, strings are said to resonate when activated by the chekker’s keys, implying a clavichord-like mechanism that registers the pitch and position of each “piece” by “checking” (or fretting) the string corresponding to its file at the appropriate rank. The chekker thus combines a dichromatic matrix with an invocation of the ludic play characteristic of keyboard technologies and techniques in general, revealing that these elements were integral to the idea of the keyboard from its earliest days.

As Daniel Hobbins observes, Gerson’s musical allegory is “a morality play staged on a chessboard,” a zero-sum game that depends on both binary oppositions and elaborate analogies.\(^{176}\) Channeling the Apollonian triumph of order over chaos as well as echoing Aristides Quintilianus’s metaphors concerning the corporeal resonances of strings, Gerson pronounced that “in the chekker of our hearts the victory is melodious.”\(^{177}\) But the chekker is also etymologically linked to “exchequer,” a term that could refer to a table used for accounting or gaming, the checkered cloth that typically covered such tables, or an abacus.\(^{178}\) The chekker is thus implicated in the programming, execution, and representation of calculation, which is in turn imbricated with tallying and playing as algorithmic processes.\(^{179}\) Strengthening the notion that the clavichord’s keyboard originated as a means of partitioning strings in order to subject their sonorities to mathematical interrogation, this also suggests the means by which number could stand alongside note and letter as symbolic material to be processed at the keyboard.\(^{180}\)

---

175. Gerson, “Figura scacordi.”
176. Hobbins, Authorship and Publicity, 84–86.
179. In notational terms, the four-voice puzzle canon that constitutes Ghiselin Danckerts’s *Ave Maris Stella* (1535), presented on the page in the form of a chessboard, foregrounds similar ludic and algorithmic elements: according to Hans Westgeest, twenty-one viable motets can be derived by way of “systematic movements”: Westgeest, “Ghiselin Danckerts’ *Ave Maris Stella,*” 72.
180. For the hypothesis that the keyboard was devised to avoid the need to slide the bridge of the monochord to produce each pitch, see Montagu, Medieval and Renaissance Musical Instruments, 54–56. On the origins of the clavichord more generally, see Brauchli, Clavicord, 8–20; while acknowledging the historical role played by the keyed monochord, Brauchli is careful to
that Marin Mersenne and Athanasius Kircher referred to the keyboard as an “abacus”; Nicolas Meeus speculates that the analogy held because “the keyboard materialized the system of sounds much as the abacus

distinguish between it and the clavichord as instruments with interwoven histories that are nonetheless independent (41–42).
visualized that of numbers.” The calculating abacus was represented in terms redolent of musical notation, and vice versa: while Christopher Page observes the bead-like attributes of Guidonian notation, Meeùs draws attention to the “musical” typesetting of Balthasar Licht’s treatise on the algorithmic rules governing the operation of the abacus.

Not only did keyboards allow for human involvement in computational processes, as was most obviously the case with adding machines and cash registers; as we have seen, the typewriter provided Turing with the metaphorical apparatus capable of representing computation itself. Following Claude Shannon’s implementation of Boolean logic via electrical relays and switches in the 1930s, the computational leap from counting to reasoning enabled a new order of digital play predicated on the principles of Jevons’s “logic piano.” Accordingly, the five-note keyboard of Beatmania operates as a set of Boolean gates that map directly onto the game’s own logical determination of ludic outcomes. The player’s input is thus both registered and parsed by the very same Boolean means, ensuring that her digital propositions, conjunctions, and negations meet with the appropriate consequences.

Bringing these elements together, the Doom piano (2013) combines the ludomusicality of the chekker, the computational principles behind the “logic piano,” and the lurid violence of Apollonian agonistic conflict waged according to the principles of von Neumann’s game theory and materialized via his computational architecture (see Fig. 9). In the genealogical context of Beatmania, the Doom piano’s unexpectedly familiar interface also suggests that the adoption of the keyboard as the default input device for the personal computer was neither self-evident nor merely a matter of historical and cultural contingency: rather, it marks the unpredictable continuation of a long-running thread of digital techniques intertwined with music, fingers, communication, calculation, and the playing out of conflict.

181. Meeùs, “Chekker,” 9. The subtitle to Mersenne’s Harmonicorum Libri (1635–36), the volumes in which he describes a keyboard as an abacus, makes this point explicit: although ostensibly about harmony, these books will, Mersenne claims, be “useful for grammarians, orators, philosophers, legal advisors, physicians, mathematicians and theologians.” Quoted and translated in Knobloch, Musurgia Universalis, 263; see also Dear, Marin Mersenne.


183. On the labyrinthine genealogy of Doom, see Ndalianis, Neo-Baroque Aesthetics, 96–107. Developed and published in 1993 by Id Software, Doom became a highly influential first-person shooter (FPS). Throughout its long heyday, multiplayer Doom relied on the transmission of data packets over the internet by modems that operated according to Baudot’s multiplexing principles and whose performance was often measured in the units named in his honor.

184. On the keyboard’s relationship to sound synthesis as constructed by Robert Moog and Don Buchla, see Pinch and Trocco, Analog Days, 42–45, 58–62, and Théberge, Any Sound You Can Imagine, 52. From the most basic MIDI controller to the ondes Martenot, digital interfaces have typically been supplemented by analog modulators, whether they take the form of a pitch-bend wheel, swell pedal, ring, or ribbon controller.
In computational as well as musical terms, however, the keyboard has not exclusively operated as a binary digital interface. On the one hand, the keyboard can facilitate analog computation that, like a slide rule, models the very phenomena it seeks to measure, as demonstrated by the fifteenth-century keyed monochords of Johannes Keck, Conrad of Zabern, and Johannes Gallicus; on the other, the fine detail of such analogical mappings can be reflected by the topography of the keyboard itself. This arcane tendency was most evident in the sixteenth and seventeenth centuries, when instruments such as the archicembalo of Nicola Vicentino, the cembalo triarmonico of Giovanni Battista Doni, and the clavemusicum omnitonum of Vito Trasuntino rendered the keyboard’s interface more temperamentally granular in the service of transposition, modulation, and historical experimentation.185 Such attempts are documented in Athanasius Kircher’s

Figure 9  *Doom* piano (2013), made for the Arcade Jam at the Virgin Media Game Space by George Buckenham, Sos Sosowski, David Hayward, et al. Photograph reproduced courtesy of Sam Hughes (www.thesoundarchitect.co.uk). This figure appears in color in the online version of the *Journal*, where Video Example 1 provides a demonstration of the device in use.

185. See Barbieri, *Enharmonic*. From Doni’s revival of ancient Greek *genera* and *tonoi* to attempts to preserve the purity of Handelian sonorities in Victorian Britain, Barbieri’s comprehensive survey of enharmonic phenomena reveals that the same principles were deployed in the service of the historical imagination before they were turned to revolutionary causes by figures
Musurgia Universalis (1650), which illustrates seven “abacuses” ranging from the familiar “Halberstadt” layout putatively established by Nicholas Faber in 1361 to enharmonic architectures distributing up to thirty-two keys across four planes over the compass of an octave (see Fig. 10). Aside from the Tetris-like tessellation of the keys on Kircher’s abacuses, enharmonic keyboard designs that invoke the isomorphic properties of Gerson’s allegorical chessboard are of particular ludomusical interest. At isomorphic keyboards, the spatial relationship between any two pitches is topographically equivalent regardless of transposition. Early gestures toward isomorphism include Francesco Nigetti’s modifications to the design of Vicentino’s archicembalo and the enharmonic Hammerklavier built in Vienna by Johann Jakob Könnicke to Johann Georg Roser’s specifications (ca. 1796; see Fig. 11). On this six-manual instrument, reputedly played by Haydn and Beethoven, the thirty-one equally tempered pitches per octave are symmetrically distributed over forty-two keys in a six-by-seven grid redolent of the QWERTY keyboard (an interface that would emerge from the comparable scale of the task of alphanumerical representation). The eleven “redundant” keys per octave facilitate substitutions that render seven different fingering patterns sufficient to account for all thirty-one of the instrument’s tonalities.

Going even further, each of the fifty-three equally tempered keys per octave of James Paul White’s fully isomorphic “harmon” (1883) is labeled with a color or ludic symbol a knight’s remove from its nearest counterpart, which sounds its diatonic neighbor in Pythagorean terms (see Fig. 12). In various aspects, White’s “harmon,” based on fifty-three-note equal temperament, reflects Robert Holford Macdowall Bosanquet’s “enharmonium” (1872–73) and Paul von Jankó’s isomorphic piano keyboard (1882), as well as Charles Wheatstone’s early designs for the interface of the English concertina; see Gawboy, “Wheatstone Concertina.” In consultation with Bosanquet, Hermann von Helmholtz identified the harmonium as particularly suitable for enharmonic experimentation, comparing it favorably with the “false and disturbing” sound of the piano: Helmholtz, Sensations of Tone, 323; see also Hui, Psychophysical Ear, 55–87, and Steege, Helmholtz, 206–14.

186. The keys of the Halberstadt organ’s “ manuals,” illustrated in the appendix to the second volume of Michael Praetorius’s Syntagma Musicum (Theatrum Instrumentorum seu Scigraphia, 25), were two inches wide, a carillon-style spacing that indicates they were to be played with fists rather than fingers. Since the organ was rebuilt in the fifteenth century it is possible that this layout does not in fact date as far back as 1361.

187. See Barbieri, Enharmonic, 441–505.

188. Ibid., 463–66.

189. Ibid., 100–102, 345–51. In various aspects, White’s “harmon,” based on fifty-three-note equal temperament, reflects Robert Holford Macdowall Bosanquet’s “enharmonium” (1872–73) and Paul von Jankó’s isomorphic piano keyboard (1882), as well as Charles Wheatstone’s early designs for the interface of the English concertina; see Gawboy, “Wheatstone Concertina.” In consultation with Bosanquet, Hermann von Helmholtz identified the harmonium as particularly suitable for enharmonic experimentation, comparing it favorably with the “false and disturbing” sound of the piano: Helmholtz, Sensations of Tone, 323; see also Hui, Psychophysical Ear, 55–87, and Steege, Helmholtz, 206–14.
Figure 10  Athanasius Kircher, *Musurgia Universalis, sive Ars Magna Consoni et Dissoni* (Rome: Francesco Corbelletti, 1650), 1: plate following p. 486. This figure appears in color in the online version of the *Journal*.
Figure 11  Johann Jakob Könnicke, enharmonic *Hammerklavier* (ca. 1796). Photograph reproduced by permission of the Kunsthistorisches Museum, Vienna. This figure appears in color in the online version of the *Journal*.

Figure 12  James Paul White, “Harmon no. 3” (1883). Photograph by Andrew Hurlbut, reproduced courtesy of the New England Conservatory. This figure appears in color in the online version of the *Journal*.
of chess.190 Such grids are ubiquitous today in games of strategy and role-play played on boards and computers alike, and they continue to inform the design of musical interfaces such as Erv Wilson’s and Siemen Terpstra’s honeycomb-like isomorphic keyboards.191

As with the diverse motivations and effects associated with the operation of Baudot’s five-bit keyboard interface, the relations between these multiple iterations of analogous topographical features are better understood in terms of media operations—combinations, loops, recursions—than they are as symptoms or outcomes of linear historical processes. Independent of their revolutionary or reactionary motivations, materializations of microtonality via keyboard interfaces can be understood from a media-archaeological perspective to perform the Democritan function of increasing digital granularity, thereby bringing symbol and signal into closer alignment and minimizing the distortion associated with quantization. Media-archaeological evidence can thus help clarify how divergent ideas have been channeled by the same means and materials as well as how similar concepts have been susceptible to different representational strategies.

Accordingly, we should be wary of attributing overarching motives or functions to the persistence of the “Halberstadt” layout, which has often been correlated with the hegemony of twelve-note equal temperament and, more recently, the tyranny of MIDI.192 It is true, of course, that the gradual equalization of keyboard temperament moved to resolve irregularities and nuances into a pattern composed of discretely fungible steps, an epistemological gradus ad Parnassum. Operating along permutational rather than proportional principles, moreover, the keyboard facilitated the quantization, assimilation, manipulation, transcription, and dissemination—which could be said to amount to the colonization—of all kinds of music. Invoking Hector Berlioz’s description of the orchestra as “subordinate to the action of an immense keyboard played on by the conductor following the directions of the composer,” Dolan shows that digital operations have forced the music and bodies of others to conform to the keyboard’s grid.193 Yet the ubiquity of twelve-note equal temperament should not render us insensitive to the fact that, from slendro to the Bohlen-Pierce scale, every tuning system makes an ideology audible, however justly or unjustly it might strike our ears. Clearly, the equality of temperament by no means correlates with the equality of the people whose musical actions it has systematized.

190. The Kriegsspiel was developed by Georg Leopold von Reiswitz in order to train Prussian military commanders: on its history, see Perla, Art of Wargaming, and Peterson, Playing at the World.

191. See Keislar, “Microtonal Keyboard Design.”


By eschewing any pretensions to Pythagorean purity, however, the keyboard served as a test-bed for the development and application of commutative transpositional permutations and transformational enharmonic modulations that offered unprecedented opportunities for musical innovation and exchange.

Conceiving of the keyboard as a cultural as well as a digital interface allows us to register how its means and ends have varied drastically over space and time. The historical pursuit of its ramifications takes us far beyond European borders: long before its industrial heyday, the keyboard was a site of technological exchange that staged the encounter of Islamic model-making traditions, the Chinese invention of the escapement mechanism, and the application of other insights gained from the engineering of astronomical instruments and mechanical clocks as well as the manufacture of psalteries and dulcimers. Moreover, the establishment of twelve-note equal temperament might itself be attributed in part to the Chinese scholar Zhu Zaiyu, who articulated its principles in 1584, a year before the Flemish polymath Simon Stevin’s first published pronouncements on the matter provided mathematical clarification of its fundamental irrationality. As Stevin observed in 1605, the frequency ratio of a semitone can be expressed as the twelfth root of two; as Turing demonstrated, such numbers are computable despite their irrationality. Yet the processes by which such computation is materialized always involve negotiation and compromise as well as approximation: in practice, the acoustic effects of the piano’s inharmonicity and the consequent stretching of its octaves mean that some of its equally tempered intervals are more equal than others.

The predominant configurations of keyboards today at once mask and expose this complex genealogy. Outwardly, the straight lines and hard surfaces of the grand piano are supplemented by the curve that indexes the ratios

194. For a toe-curling demonstration of the keyboard’s colonial implications, see William Watson’s Victorian poem “The Key-Board”: “Five-and-thirty black slaves, / Half-a-hundred white, / All their duty but to sing / For their Queen’s delight, / Now with throats of thunder, / Now with dulcet lips, / While she rules them royally / With her finger-tips!”. Poems of William Watson, 1:72. I ruefully thank Carmel Raz for bringing this poem to my attention.

195. Bowles, “Origin of the Keyboard Mechanism.” For Bowles, all these elements are reflected in the earliest extant treatise on the construction of keyboard instruments, written by the physician and astronomer Henri Arnaut de Zwolle between ca. 1438 and 1446 (160–62). On the influential Islamic legacy of “fine technologies” associated with mechanization, automation, calculation, and decoration, see Nadarajan, “Islamic Automation.”

196. See Cho, Musical Equal Temperament, 147–226; on the establishment of twelve-note equal temperament in Europe, see also Barbieri, Enharmonic, 279–98.

197. In the interim, as detailed in Siegert’s Passage des Digitalen, Leonhard Euler and Jean-Baptiste Joseph Fourier represented the nonrepresentability of irrational numbers and thereby enabled their incalculability to factor into calculations, making relationships of time and frequency available for manipulation and technological transfer via digital means (207–67). I am grateful to Melle Kromhout and Peter McMurray for bringing this aspect of Siegert’s work to my attention.
of Apollo’s kithara. At the matrix of the keyboard, the digitality of finger, key, note, and Boolean logic intersects with the analogicity of embodiment, signal, and irrational number; behind the fallboard, the keyboard’s arithmetic mapping of frequency is made geometrically audible. The keyboard is at once material and ideal, manipulable and manipulative, obfuscatory and revelatory. It both constitutes and represents a field of play on which systematized actions and reactions unfold according to certain rules, but the stakes, the means of regulation, and the interpretation of outcomes are all contingent and contestable. In short, the matter of the keyboard is not black and white—except, of course, that it is.

Tristan’s Chord, Schoenberg’s Voice

The keyboard’s capacity to encode and decode the content not only of musical notation but of literary, numerical, and other informational systems via transcription, transduction, and computation helps explain its position as the default interface in historical terms as well as in our own multimedia age. Unlike typewriters, player pianos, and even La Musicienne, however, Turing’s machine and modern digital computers are capable of recursion, of inspecting and remembering their own states and altering their programs correspondingly. How might a harpsichord, clavichord, or piano compare on these terms?

A discursive strand running from the eighteenth century to the present day suggests that such keyboard instruments could indeed be imagined to operate recursively insofar as they were deemed capable of representing their own representational functions. Purportedly in conversation with Jean le Rond d’Alembert, Diderot wondered what the consequences would be if harpsichords were endowed with the ability to perceive and remember:

Imagine a harpsichord with sensation and memory, and then tell me whether it will not repeat by itself the tunes you play on its keyboard. We are instruments endowed with sensation and memory. Our senses are merely keys that are struck by the natural world surrounding us, keys that often strike themselves.198

198. Diderot, “Entretien,” 114: “Supposez au clavecin de la sensibilité et de la mémoire, et dites-moi s’il ne se répétera pas de lui-même les airs que vous aurez exécutés sur ses touches. Nous sommes des instruments doués de sensibilité et de mémoire. Nos sens sont autant de touches qui sont pincées par la nature qui nous environne, et qui se pincent souvent elles-mêmes.” On this passage, see Abbate, “Outside Ravel’s Tomb,” 475–82; Rex, Diderot’s Counterpoints, 173–75; Christensen, “Bemetzrieder’s Dream,” 45–46; and Erlmann, Reason and Resonance, 118. On the lineage of the keyboard instrument as a metaphor for sensation, advanced by Cartaud de La Vilate, the Abbé Jacquin, Montesquieu, and Julien Offray de La Mettrie, among others, see Erlmann, Reason and Resonance, 116–20, and Thomas, “Competing Models of Sensibility,” 161n16.
In Diderot’s thought experiment, the harpsichord’s capacity to read and repeat gives rise to an awareness of its own state and a power to act accordingly—a degree of recursive autonomy usually reserved for human consciousness or digital computation.\(^{199}\) By imagining the harpsichord to be alive, self-aware, and even capable of generating offspring, he was treating it as a media system capable of transmission (via play), reception (sensation), storage (memory), and reproduction.

On the one hand, Diderot was drawing attention to the mechanistic principles and properties that animate humans and other life-forms. On the other, he was performing a boldly vitalistic maneuver vis-à-vis the vibrant matter of the harpsichord: life is not grafted onto it from the biological realm, but is to be found in the sympathetic resonance of the strings its keys activate, as Condillac, Jean Gerson, and Aristides Quintilianus had previously intimated.\(^{200}\) Johann Gottfried Herder was also struck by the keyboard’s recursive properties, its materialization of natural law (alongside the alphabet, the rainbow, and calculus), its ordering of knowledge, and its capacity for play and calculation: “Music plays a clavichord within us, which is our own most intimate nature. . . . It is not we who count and measure, but rather nature; the clavichord within us plays and counts.”\(^{201}\) Herder located the source of music not in the rational mind, nor even in Leibniz’s unconscious soul, but in the common nature that he held to define humanity from both within and without.

Although the prominence of the keyboard in Diderot’s and Herder’s discourses seems to strengthen its claim as a means of testing and demonstrating the harmony of the universe, each author’s metaphorical strategy betrays a degree of anxiety.\(^{202}\) As Dolan points out, Herder was deeply suspicious of claims that equated mathematical or acoustical elegance with aesthetic value, and considered instrumental music to be particularly susceptible to the charge of scientism.\(^{203}\) For his part, Diderot was acutely aware of the

\(^{199}\) While Erlmann reads this recursion as articulating “an inexorable totality and completeness of organization that lends a hermetic closure to both the subject and the discourse about the subject” (\textit{Reason and Resonance}, 118), it could also be understood as a radical expansion of both, especially in light of Diderot’s observations on the unlikely imaginative leaps that constitute analogical thought, modeled on the sympathetic resonance of neighboring strings.

\(^{200}\) Condillac, \textit{La logique}, 85: “[Nous] éprouvons des sensations à peu-près comme un clavecin rend des sons.” See also the insightful commentary by Thomas (“Competing Models of Sensibility,” 155–58) and Christensen (“Bemetzrieder’s Dream,” 45–51), who stress the ludic and chiastic elements of the analogy and its intertwining of the sensible and the material chez Condillac and Diderot respectively.


\(^{202}\) On the conflict between German vitalists and mechanists as played out musically in the eighteenth century, see Yearsley, \textit{Bach}, 173–208.

\(^{203}\) Dolan, \textit{Orchestral Revolution}, 73–79.
solipsistic delusions that attended the mapping of sensory data onto cosmic ontology. Even for harpsichords, that way madness lay: "There is a moment of delirium when a sensitive harpsichord thinks it is the only harpsichord in the world, and that it alone is responsible for all the harmonies of the universe." Alongside Burney’s descriptions of Bach inspired and possessed at the clavichord, Herder’s evocation of nature and Diderot’s description of the delirium induced by keys and resonating strings anticipate the Hoffmannian lettering of Romantic consciousness, made and unmade through music by way of—and yet despite—its instrumental materialization.

As the processes of calculation, writing, logical reasoning, making music, and playing games were automated over the course of the nineteenth and twentieth centuries, the complaints of humanists such as Hoffmann, Edmund Husserl, Martin Heidegger, and William Gaddis grew ever louder. Correspondingly, the shifting locations of technological power and agency in relation to the human can be traced via the roles assigned to the keyboard and its players. For Berlioz, as we have seen, the keyboard instrumentalized musical hierarchy, serving as the conductor’s metaphorical conduit between composer and orchestra. For the biologist Jakob von Uexküll, it rather represented the organizing principles behind the ecological networks (Umwelten) that surround and sustain living beings:

> Countless Umwelten compose . . . the keyboard on which Nature plays her symphony of meaning, beyond time and space. In our lifetimes, in our Umwelten, we are given the task of forming a key in the gigantic keyboard, over which an invisible hand glides, playing.

Souls are no longer analogized by a keyboard’s broad compass, as they were for Diderot and Herder. For Uexküll, the task of fashioning a single key was more in keeping with humans’ place in the order of things; the luxury of play was reserved for Nature, at once anthropomorphized and disembodied.


205. See, for instance, Bernard Stiegler on Husserl’s dismissal of algebra as “a mere art of achieving results, through a calculating technique according to technical rules”: *Technics and Time*, 1:3; Heidegger, *Question concerning Technology*, and Gaddis’s sparsely punctuated novel *Agape Agape*, which rails against mechanization, reserving particular virtil for the player piano, its epistemological and technological lineage, and its dehumanizing effects.

206. Uexküll, *Bedeutungslehre*, 159: “All die zahllosen Umwelten liefern . . . die Klaviatur, auf der die Natur ihre überzeitliche und überräumliche Bedeutungssymphonie spielt. Uns ist während unseres Lebens die Aufgabe zugewiesen, mit unserer Umwelt eine Taste in der riesenhaften Klaviatur zu bilden, über die eine unsichtbare Hand spielfeld hinausvergleitet.” For Uexküll, the keyboard served as a multilayered metaphor capable of representing an organism’s genetic program as well as cosmic order.
As the keyboard’s analogical scope narrowed, the reach of Turing’s universal digitality expanded. By the later decades of the twentieth century, fewer retained faith in the wisdom—or even the existence—of the hands, invisible or otherwise, charged with ensuring the harmonious cooperation of society and the self. Thus Flusser undertook his own thought experiment centered on the “new human being” of the future, who no longer possesses hands but uses the tips of his fingers to tap on keys so as to play with symbols. The new human being is not a man of action anymore but a player: *homo ludens* as opposed to *homo faber*. Life is no longer a drama for him but a performance. It is no longer a question of action but of sensation.207

What kind of logic governs the performance of this *homo ludens*, fused with his keyboard? For Flusser, the answer lay in the function of the key itself:

Keys are devices that permutate symbols and make them perceptible: *viz.* the piano and the typewriter. Fingertips are needed to press keys. . . .

. . . I choose a key, I decide on a key. I decide on a particular letter of the alphabet in the case of a typewriter, on a particular note in the case of a piano. . . .

. . . [But] the freedom of decision of pressing a key with one’s fingertips turns out to be a programmed freedom. A choice of prescribed possibilities. I choose according to the regulations (outlined in the manual).208

As Jacques Derrida wrote of linguistic play, the field of the keyboard affords “infinite substitutions in the closure of a finite ensemble,” but such ludic infinitude is conceivable only under the digital imposition of strict limits and absolute distinctions.209 Flusser’s player was no longer played in accordance with the composer’s whims or Nature’s mysterious laws. Play itself had become a function of recursion, trapping players within the logic of the system, sardonically described by Flusser as “extremely satisfactory”—by which he meant totalitarian.210

Here Flusser, who suffered terribly at the hands of a totalitarian regime, registered the threats represented by play and the abdication of the self, however temporary, that it demands.211 In different ways, systems of

207. Flusser, *Shape of Things*, 89. Flusser’s distinction between hands and fingers, the manual and the digital, holds telling implications for the history of pianism vis-à-vis typing; see also Ingold, *Making*, 123–24.


210. Flusser, *Shape of Things*, 93. As Nicklas Luhmann observed, and as the delirium of Diderot’s harpsichord betrays, recursion can serve as a principle that conceals, in Larson Powell’s words, “the inability of systems to ground their own legitimacy”: Powell, “Excursions and Recursions,” 436.

211. Flusser’s father, mother, grandparents, and sister all died in German concentration camps during the Second World War.
twentieth-century music composition and theory defined and imposed arbitrary rules while investing them with the political or spiritual rhetoric of necessity.\textsuperscript{212} The recursion of serialism, a generative system imaginable only under the temperamental equality imposed by the keyboard, was matched by analytical methods derived from combinatorial logic and Shannon’s information theory that accounted for its operations.\textsuperscript{213} Algorithmic models and techniques also informed the automated (re)production of synthesized, aleatoric, stochastic, and minimal music; even timbre and dynamics, the oscillographic remainders of Romanticism, were not immune from quantization and systematization.\textsuperscript{214} Flusser suspected that the compelling internal logic of such processes masked the fact that their operations were divested of human significance: subjected to autotelic recursion, they canceled themselves out, leaving only the tapping of keys, the permutation of symbols, the meaningless oscillation of bits or strings. In such a scenario, the orbits of the planets represent not the rapture of cosmic *harmonia*, nor even the musicomathematical maneuvers of a *Glasperlenspiel*, but merely the playing out of events that are at once arbitrary and overdetermined.

Whether manifested as mosaic, montage, loop, remix, or mashup, the medium-agnostic principles of transcoding and recombination continue to define the dominant aesthetic protocol of our times. Despite Flusser’s anxieties, however, even the most avowedly mechanical play can still surprise, touch, and unsettle when its digital elements are charged with analogical power. Composer and artist Tristan Perich has based much of his work on binary principles, deploying traditional instruments such as the harpsichord and piano alongside “1-bit electronics” whose musical signals are transmitted with maximal informational economy.\textsuperscript{215} Performances of these works invite listeners to contemplate points of contact between human and machine while compelling them to confront the keyboard’s digital lineage and the technological means that connect soundboard and circuit board, score and code, traveling key and vibrating speaker cone.

Perich’s work is thoroughly Leibnizian, and not only to the extent that it bears out Leibniz’s motto (“omnibus ex nihilo ducendis sufficit unum”) across both sonic and visual media. The development of Leibniz’s binary

\begin{itemize}
\item[212.] See, for instance, Babbitt, “Twelve-Tone Invariants.”
\item[213.] See, for instance, Lewin, “Some Applications”; on the intellectual context of this discourse, see Grant, *Serial Music, Serial Aesthetics*.
\item[214.] See Meyer-Eppler, “Statistische und psychologische Klangprobleme.” Meyer-Eppler’s blending of acoustics, synthesis, and information theory had a considerable impact on postwar European music in general and on Karlheinz Stockhausen’s compositional technique in particular. The overtly ludic implications of Josef Hauer’s *Zwölftonspiele*, many of which draw as much on the principles of indeterminacy as on “serial” techniques, reveal how the same principles and procedures could freely cross aesthetic battle lines.
\item[215.] Tristan Perich’s keyboard works include *Dual Synthesis* for harpsichord and 4-channel 1-bit electronics (2009) and *Surface Image* for piano and 40-channel 1-bit electronics (2013).
\end{itemize}
thought was dialectically entwined with his principle of continuity, founded on the premise that noticeable perceptions arise by degrees from phenomena too minute to be registered, but that can nonetheless be divided into innumerable monadic constituents.\footnote{See Leibniz, \textit{Nouveaux essais}, 17, and Leibniz, \textit{La monadologie}. Erlmann offers an illuminating perspective on this aspect of Leibniz’s thought in relation to Helmholtz and nineteenth-century otology: Erlmann, \textit{Reason and Resonance}, 242–46.} Perich’s \textit{Microtonal Wall} (2011) consists of 1,500 speakers arrayed like pixels in a grid analogous to White’s isomorphic keyboard (see Fig. 13). Across the range of four octaves, each speaker plays a discrete frequency, precisely interpolated with those of its nearest neighbors, that can be aurally resolved only at close quarters. At a distance, the microtones coalesce into a mighty chord of white noise, bearing out Leibniz’s famous observation that the tiny sounds made by individual waves collectively compose the roar of the sea.\footnote{Leibniz, \textit{Die philosophischen Schriften}, 5:48; see also Cox, “Sound Art,” which shows that Leibniz’s sonic observations have provided epistemological foundations for contemporary sound art as a distinct category of aesthetic experience.} By digitizing Leibniz’s thought, Perich has achieved a new kind of sound field.
analogy, Perich’s wall draws our attention to its individual components, the process of their aggregation, the technological means that realize both, and the overarching epistemological principles that sustain our awareness of all three. The wall tests the limits of perceptual resolution, encouraging us to discover the threshold at which organized sound gives way to noise, multitudes to magnitudes, the lyricism of Apollonian order to the oceanic scope of the poetry favored by insatiable Phthonos.  

Whereas Perich’s wall materializes a Leibnizian thought experiment via signals and speakers, A Letter from Schoenberg (2008), created by Peter Ablinger with Winfried Ritsch and Thomas Musil, derives its analogous effect from the interface of the keyboard. Although it might be understood as a distant descendant of La Musicienne, Ablinger’s work makes no attempt to simulate the outer form of a human; instead, it outsources the eighteenth-century android’s digital functions to a Vorsetzer that covers the keyboard of a conventional piano (see Fig. 14). In accordance with the principles of the player piano, the “digit” for each key takes the form of a computer-controlled actuator endowed with the ability to play with superhuman velocity: collectively, they can trigger as many as sixteen distinct events every second (the temporal threshold that, Ablinger claims, marks the perceptual boundary between the discrete and the continuous tested by the frequencies of Perich’s wall).

The “text” of A Letter from Schoenberg consists of a sound recording made by an angry Arnold Schoenberg in 1951, in which he dictates a letter to record company executive Ross Russell berating and threatening him for “publish[ing René] Leibowitz’[s] performance of my Ode to Napoleon with a woman [sic] voice.” Instead of transcribing Schoenberg’s words at a typewriter, as the composer presumably intended, Ablinger and his collaborators recreated them at the piano’s keyboard. After being subjected to spectral analysis, the recording was vocoded into a detailed stream of MIDI data used to program the Vorsetzer. The resulting approximation of the sound and sense of Schoenberg’s voice is uncannily lifelike, even as its conspicuous

218. See Callimachus, Hymn 2 (to Apollo), line 106: “οὐκ ἄγαμα τὸν ἀνθιὼν ὃς οἶνό ὃσα πάντως ἀκιώ” (I do not admire the singer who sings less than the sea; translated in Cheshire, “Kicking ΦΘΟΝΟΣ,” 354).


220. G. Douglas Barrett places Ablinger’s work in the context of automata as well as that of Michel Chion’s notion of the acoumière: Barrett, “Between Noise and Language.” The original design of Ablinger’s Vorsetzer was developed by Trimpin in collaboration with Conlon Nancarrow. Such devices can be traced at least as far back as the “antiphonel” of Alexandre Debain, which captured Berlioz’s attention; see Berlioz, Orchestration Treatise, 314.


reliance on technological resources—which, in Hoffmannian terms, “attempt nothing but to be mechanical”—ironizes Schoenberg’s outrage at another instance of irreverent reproduction via an unratified medium.

Like Perich’s *Microtonal Wall*, *A Letter from Schoenberg* problematizes both analogies and distinctions between form and content, signal and noise. It can also be set alongside Cory Arcangel’s *Drei Klavierstücke op. 11*, a video montage that algorithmically reconstructs the pitches and durations of Schoenberg’s landmark opus via approximately commensurable interactions between cats’ paws and keyboards found on YouTube. Both works are supremely digital to the extent that they interpret “Schoenberg” through the grid of the keyboard, subjecting the composer to a caricature of his own combinatorial method. The differences between the two can be explained in terms of medial and agential shifts: instead of Arcangel’s feline simulacrum

![Figure 14](image.png)

*Figure 14* Peter Ablinger, *A Letter from Schoenberg* (2008). Photograph reproduced courtesy of Zeitvertrieb Wien Berlin. This figure appears in color in the online version of the *Journal*, where Video Example 3 shows the work in performance.

223. As well as demonstrating play’s extra-human dimensions, Arcangel’s feline “rendition” of Schoenberg’s op. 11 evokes Michel de Montaigne’s proto-Gadamerian thoughts on ludic reciprocity: “Quand je me joue à ma chatte, qui sçait, si elle passe son temps de moy plus que je ne fay d’elle?”: Montaigne, *Les essais*, 474. It also reverses the sadistic dynamics of the apocryphal *Katzenklavier*, in which the keyboard “plays” a clowder of cats ordered according to the relative pitches of their yowls of protest; see Schott, *Magia Universalis*, 2: plate following p. 372.
of Schoenberg’s piano music, Ablinger’s work features the piano itself as medium, as decipherer and transmitter of the dead composer’s voice. As such, its dissonance distantly echoes Bach’s “cry of complaint” at the clavichord as well as the febrile outpourings of such literary characters as Honoré de Balzac’s Paolo Gambara and Thomas Mann’s Adrian Leverkühn, both of whom are driven into delirium by the task of transcoding sound via digital activity.  

A Letter from Schoenberg goes further, mediating between the living and the dead by exploiting the fact that computation can inform and transform the fine-grained mechanical manipulation of the keyboard’s discrete interface via the plotting of temporal and spatial clusters. Dithering the keyboard’s normatively crude quantization of pitch and rhythm, these clusters approximate the analog fluctuations of Schoenberg’s voice. Ablinger’s work thus makes the past present by combining the reproductive technologies of de Caus’s barrel and oscillographic media, fusing the epistemologies of Leibniz and Turing, and thereby effecting an imaginary reconciliation between the Lacanian registers of the Symbolic and the Real. By way of the piano’s acoustic properties as well as its digital input mechanism, the poet’s roar is rendered with Apollonian clarity, its semantic sense and seismic force simultaneously enciphered and unlocked by the play of the keys.

For Roland Barthes, play was the means by which text mobilizes and propagates in the face of potential ossification into a work fit only for philological or hermeneutic exhumation. Barthes—an amateur pianist as well as a lover of games—invoked music as a paradigm for the collaborative process of “play[ing] a text, of mak[ing] it go.” For Huizinga, the performance of music was indispensable to the very notion of artistic play; for Laurence Dreyfus, the simple pleasures of play offer reciprocal access to “music’s greatest joy.” In their different ways, all three divert attention away from what texts, games, and music can be said to be and toward how they (enable people to) play, indicating that human actions can still invest play with

224. The impassioned, intoxicated Gambara plays his compositions on the Panharmonicon, a keyboard instrument modeled after Johann Nepomuk Maelzel’s famous mechanical organ of the same name designed to simulate an entire orchestra: Balzac, Gambara, 108, 125. Thomas Mann described Leverkühn’s abortive performance of The Lamentation of Dr. Faustus in analogous terms, Leverkühn’s tears wetting the keys as he “attacked [them with] a strongly dissonant chord” before emitting a loud wail and falling unconscious: Mann, Doctor Faustus, 503.

225. In this sense, unlike Arcangel’s absurdist montage, Ablinger’s work resonates with Schoenberg’s own exploration of the piano’s acoustic attributes via silently depressed notes in op. 11 no. 1 and elsewhere. As Joseph Auner observes, such techniques demonstrate how integral the resonance of individual sonic phenomena was to Schoenberg’s expressionistic aesthetic: Auner, “Weighing, Measuring, Embalming Tonality,” 33–36. On the broader history of the way composers have taken advantage of the piano’s oscillographic qualities, see Nonken, Spectral Piano.


transformative power.\footnote{In this regard, it is telling that the drastic force of play has served as a touchstone within performance studies writ large: see, for example, Schechner and Schuman, \textit{Ritual, Play, and Performance}.} As a field of play, the keyboard offers access to a wide range of ludomusical experiences, whether performed as recreations of prior events, conceived as simulative praxis under a particular set of historical and cultural conditions, or configured in the infinitely finite terms of an emergent improvisatory process. Equally significant are the ways in which the interactive dynamics of musical play at the keyboard trace the complex formations of historical and media-archaeological discourse. From Shakespeare to Ablinger, the keyboard has sustained technological fantasies both predicated on and made parsable by digital analogies, and it will doubtless continue to do so in ways that are yet to become conceivable. The keyboard’s persistence as an interface, its patterning of fixity and flexibility that has at once resisted and accommodated change, forms a shifting boundary that connects and separates worlds, cleaving human and machine, player and played, \textit{Bebung} and \textit{Doom}, the analog and the digital. The play of the keys demonstrates how a system operates, but also probes its limits: whether we choose to play along or to rewrite the rules of ludomusical engagement remains up to us.

\textbf{Works Cited}


Freke, John. “A Letter from Mr. John Freke F. R. S., Surgeon to St. Bartholomew’s Hospital, to the President of the Royal Society, Inclosing a Paper of the Late Rev. Mr. Creed, concerning a Machine to Write Down Extempore Voluntaries, or Other Pieces of Music.” *Philosophical Transactions* 44 (1746–47): 445–50.


vr01&Itemid=716&lang=en.


Abstract

Relating evidence from the mythological to the contemporary in both historical and media-archaeological registers, this article explores how techniques of sonic generation and representation shuttled between what might be defined as digital and analog domains long before the terms acquired their present meanings—and became locked in a binary opposition—over the latter half of the twentieth century. It proposes that such techniques be conceptualized via the “digital analogy,” a critical strategy that accounts for the nesting of techno-musical configurations. While the scope of digital analogies is expansive, the focus here falls on a particular interface and mode of engagement. The interface is the keyboard; the mode of engagement is the play, both ludic and musical, that the keyboard affords. Operations at the keyboard have been integral to ludic communication and computation as well as to the practices of composition, performance, and improvisation. To map out this genealogy and to show how it continues to inform loci of musical play from sound art to digital games, the article draws on an array of critical and theoretical texts including Friedrich Kittler’s media analyses, Vilém Flusser’s writings on technology, and post-Foucauldian discourses on cultural techniques.

Keywords: digital, analog, keyboard, play, media archaeology