

Zen and the Art of Software Performance

John Cage and Lejaren A. Hiller Jr.'s *HPSCHD* (1967-1969)

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THESIS

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SUMMARY

This dissertation examines John Cage and Lejaren A. Hiller Jr.'s computer-assisted music event *HPSCHD* (1967-69), constituting a crucial moment in the history of software in artistic practice. Engaging both Cage's interest in indeterminacy as well as Hiller's creative application of information theory in composition, the two collaborators programmed an event juxtaposing the mechanical simplicity of the harpsichord with the complex capabilities of a supercomputer to investigate procedural and ontological notions of chance operations.

HPSCHD remains a difficult performance to describe much less analyze, even among other early computer artworks from its era. As an attempt to provide a model for future early computer art analysis, this dissertation demonstrates how computer artworks such as *HPSCHD* necessitate non-traditional, interdisciplinary methods for analysis. As such, Chapter 1 investigates *HPSCHD* as coming from a deeply networked history, necessitating an understanding of the nexus of the histories of prosthetics, information theory/cybernetics, prognostication and its relationship to computation and Zen Buddhism. Chapter 2 describes the challenges Hiller faced in programming *HPSCHD*, ultimately demonstrating how programming constitutes a performance, its dematerialization of both information and art placing it within the larger movement of conceptual performance practices of the 1960s and 70s. Chapter 3 explores the *HPSCHD* visuals, and how these methods revealed the slippages between the more material, process-based discipline of system theory and popular readings of cybernetics; these misunderstandings—alongside fundamental anxieties of the autonomous, “creative” computer—helped fuel the fear and distrust some critics felt towards a performance they found largely impenetrable due to the treatment of its technological elements.

I. Introduction

I. 1. General Introduction

This is a lecture on composition which is indeterminate with respect to its performance. That composition is necessarily experimental. An experimental action is one the outcome of which is not foreseen. Being unforeseen, this action is not concerned with its excuse. Like the land, like the air, it needs none. A performance of a composition which is indeterminate of its performance is necessarily unique. It cannot be repeated. When performed for a second time, the outcome is other than it was. Nothing therefore is accomplished by such a performance, since that performance cannot be grasped as an object in time. A recording of such a work has no more value than a postcard; it provides a knowledge of something that happened, whereas the action was a non-knowledge of something that had not yet happened.

—John Cage¹

Writing compositional algorithms forces me to scrutinize composition as process. I have to be aware of how compositional logic really works and how compositional priorities arrange themselves. In working with computers, musical ideas come to me that I probably would not otherwise have imagined.

—Lejaren Hiller²

... the self is not something ready-made, but something in continuous formation through choice of action.

—John Dewey³

This dissertation examines John Cage and Lejaren A. Hiller Jr.'s ambitious, computer-assisted music event *HPSCHD* (1967-69), foregrounding a crucial moment in the history of software in artistic practice. Engaging both Cage's interest in chance operations as well as Hiller's research in the creative application of information theory, the two collaborators programmed an event juxtaposing the mechanical simplicity of the harpsichord with the complex capabilities of a supercomputer to explore chance operations to their fullest. Pronounced

¹ John Cage, "Indeterminacy: pt. 2 of 'Composition as Process,'" in *Silence: Lectures and Writings* (Middletown, CT: Wesleyan University Press, 1961), 35.

² Lejaren Hiller, "Composing with Computers: A Progress Report," *Computer Music Journal*, Vol. 5, No. 4 (Winter, 1981): 7.

³ John Dewey, *Democracy and Education: An Introduction to the Philosophy of Education* (New York: Courier Dover Publications, 2004), 336.

“harpsichord” as per its FORTRAN computer handle equivalent, the performance was composed of seven solo pieces for harpsichord derived from processed pieces by Mozart, Beethoven, Chopin, Schumann, Gottschalk, Busoni, Schoenberg, Cage, and Hiller, 52 microtonal, computer-generated magnetic tapes, and over 8,000 slides and 40 motion picture films.⁴

On the evening of May 16th, 1969, spectators entering Assembly Hall—the flying-saucer-like arena constructed at the University of Illinois campus—found themselves bathed in what initially seemed complete auditory chaos.⁵ These fluctuations eventually gave way to momentary snatches of classical harpsichord coming from the seven instrumentalists on raised platforms in the center of the sports arena, punctuated by the more subtle tones of the computer-generated microtonal tapes amplified from loudspeakers placed about the perimeter. Around the soloists hung several parallel sheets of semi-transparent material, as well as a continuous 340-foot screen hung on the interior walls, onto which were projected the many slides of space flight, classical music scores, and bursts of abstract blotches. From 7pm to just before midnight, nearly 6,000 people arrived, met friends, danced, or simply sat and meditated on the experience. As

⁴ Each solo was transcribed with the following description: “twenty-minute solos for 1-7 amplified harpsichords and tapes for 1-51 amplified monaural machines to be used in whole or in part in any combination with or without interruptions, etc. to make an indeterminate concert of any agreed-upon length having 2-58 separate channels with loudspeakers spaced around the audience.” Though the description indicates “1-51” tapes, by all accounts the *HPSCHD* premiere involved the full 52 produced through the “HPSCHD” program and manual editing/transcribing process. *HPSCHD for Antoinette Vischer*, Solos I-VII, JPB 95-3 Folders 352-358, John Cage Collection, Special Collections and Archives, New York Public Library, New York.

⁵ Throughout this text, the institution will be referred to as “The University of Illinois,” its official name from 1885 until 1982. This encompasses not only Cage’s appointment, but also Lejaren Hiller’s career at the university (he joined the Music Department faculty at the University at Buffalo in 1968). The university reorganized under the present title, “The University of Illinois at Urbana-Champaign,” in 1982 when the Illinois state university system merged the Chicago Circle and Medical Center (Chicago) campuses into the University of Illinois at Chicago. Maynard Brichford, “A Brief History of the University of Illinois,” from the University of Illinois at Urbana-Champaign Archives (1970, revised June 1, 1983), accessed April 24, 2016: <http://archives.library.illinois.edu/features/history.php>.

reported by Kostelanetz in his *New York Times* review, “Just after midnight, the mix ran down into silence, the house lights turned on, and the elated audience drifted out. At parties that night and the following day, people contrasted perceptions; and while everyone saw the same things in general, each one registered a specific experience particularly his own.”⁶

In a 2007 lecture, James Elkins described what he interpreted as a trend toward privileging experience through analyzing material presence in recent art literature:

Clement Greenberg’s high-modernist trust in eyesight is no longer viable, now that works of visual art are so often also textual, olfactory, tactile, or auditory. Synesthesia, *Einfühlung*, empathy and sympathy, immersion, performance, and embodied encounters are now central to the art experience. Art history is no longer an archivist’s or iconographer’s paradise, driven by textual sources: it has become attentive to the physical stuff, the presence, the material of the artwork, its bulk, its human scale, and even its “base materiality.”⁷

If Elkin’s (somewhat hyperbolic) claim that a predominant movement in art literature emphasizing materiality is necessary after such a pronounced high-modernist focus on vision, then it is crucial that *computation* appear alongside his foci of “art experience.” It might seem that *HPSCHD* constitutes a poor choice to represent the importance of materiality to computer art within this paradigm: most photographic documentation of the performance was destroyed during a plague of arsons at the University of Illinois in the 1970s [Fig. 1.1].⁸ Ronald Nameth’s

⁶ Richard Kostelanetz, “They All Came to Cages ‘Circus,’” *New York Times*, May 25, 1969.

⁷ James Elkins, “On Some Limits of Materiality in Art History,” accessed March 21, 2016, https://www.academia.edu/168260/On_Some_Limits_of_Materiality_in_Art_History; originally published as “On Some Limits of Materiality in Art History,” 31: *Das Magazin des Instituts für Theorie* [Zürich] 12 (2008): 25–30.

⁸ In his 2013 Eyebeam *HPSCHD* performance blog, Nick Hallett addressed the lack of documentation of the original 1969 performance: “For anyone wondering why there isn’t a great amount of photography or moving image of *HPSCHD*’s 1969 premiere on this blog, the reason is that not much still exists. Most of the official documentation was destroyed in a fire, which—as evidenced by the accompanying news clip from *The Daily Illini*—seems to have been a sign of the times.” G. Robert Hillman, “Arson plagues UI, cities,” *The Daily Illini*, August 1970; Nick Hallett, “*HPSCHD*: A blog about John Cage and Lejaren Hiller’s 1969 multimedia Gesamtkunstwerk *HPSCHD*, presented by Nick Hallett for Darmstadt Essential Repertoire on

film of the 1969 *HPSCHD* performance was destroyed in a fire in the New York sound studio where they were matching the audio and visual film tracks.⁹ In addition, John Cage's popularity deflects discussion regarding the computer-assisted elements of *HPSCHD*, drawing focus from the importance of the research and programming ephemeris that hold clues to processes that so fundamentally embodied the work of his co-composer, Lejaren Hiller. This one-sidedness only serves to further reinforce the misrepresentation, or relative invisibility, of computer art in the larger context of art history, theory, and practice.

Regarding Cage and Hiller's *HPSCHD* as a deeply collaborative process, both in terms of Cage and Hiller's co-authorship as well as the intensive trial-and-error nature of early programming, allows a unique opportunity to interrogate the history and context of the computer's potential as an artistic tool.¹⁰ An examination of *HPSCHD* through the programming of the uniquely designed ILLIAC (Illinois Automatic Computer) series of supercomputers, as well as the large-scale research mainframe IBM-7094 computing model, reveals the networked histories of the quickly expanding field of information theory, the popularization of cybernetics, and that of 1960s and 70s conceptual art practice. Critically analyzing the often anxious

May 3 & 4, 2013 at Eyebeam Art + Technology Center, produced by ISSUE Project Room in collaboration with Electronic Music Foundation, and NYU-Poly," accessed April 30, 2016, <http://johncagehpschd.tumblr.com/post/49435431774/for-anyone-wondering-why-there-isnt-a-great>.

⁹ Stephen Husarik, "John Cage and Lejaren Hiller: *HPSCHD*, 1969," *American Music*, Vol. 1, No. 2 (Summer, 1983): 20.

¹⁰ Both Cage and Hiller insisted on the collaborative process involved in creating *HPSCHD*. Cage remembered, "So, Jerry Hiller did the programming for me, and, since he's had so much experience in the field and is himself a composer, the piece has become a collaboration between us." Likewise, Hiller reflected, "Every single note was a mutual decision. It was a rather unique instance that two composers' endeavors were so intertwined that you can't tell them apart." Larry Austin, "John Cage and Lejaren Hiller, *HPSCHD*," in *Source: Music of the Avant-garde, 1966–1973*, ed. Larry Austin, Douglas Kahn, and Nilendra Gurusinghe (Berkeley: University of California Press, 2011), 11; Kostelanetz, "They All Came to Cage's 'Circus'."

relationship between early digital computers, their users, and the general public cultivates a better understanding of how *HPSCHD* and other early computational performances fit into the greater history of dematerialization transforming both art and information in the latter half of the 20th century.

I. 2. A Methodological Approach to *HPSCHD* through Four Interrelated Narrative Themes

Cage and Hiller's *HPSCHD*, like the majority of early experiments in computer art, has received little recognition within an art historical context. In his text *When the Machine Made Art*, Grant D. Taylor reasoned that "... computer art resists the linearity of art history. To research computer art is to probe several disciplines and their histories at once."¹¹ In taking up the challenge of this deeply interdisciplinary, frustratingly non-linear task, an analysis of *HPSCHD* necessitates an elucidation of four distinct, but interrelated narrative themes: 1) the history and theory of prosthetic relationships and media, 2) the dematerialization of information as it relates to the development and popularization of information theory, cybernetics, and conceptual art, 3) prognostication as *a priori* ritual and its relationship to chance operations, and 4) Zen Buddhism and its de-ritualization/dematerialization upon translation from East to West. These themes are constructed into a loose chronology guiding the second and third chapters of this dissertation, proceeding from the conceptual planning and programming of the *HPSCHD* audio content (Chapter 2), the collection, creation, and curation of its varied visuals, and the

¹¹ Most art historians and media theorists focusing on the digital arts recognize difficulties in prescribing methodologies for incorporating computer art into a larger art historical narrative. Similar to Taylor's concerns, Edward Shanken, in his essay in Oliver Grau's edited volume *Mediaarthistories*, regards computer art as a deeply interdisciplinary field; see Grant D. Taylor, *When the Machine Made Art: The Troubled History of Computer Art* (New York: Bloomsbury, 2014), 10; Edward Shanken, "Historicizing Art and Technology: Forging a Method and Firing a Canon," in *Mediaarthistories*, ed. Oliver Grau (Cambridge MA: MIT Press, 2007), 44.

reception and legacy of the performance regarding its unique historical/cultural context as a critical moment in the development of digital computing (Chapter 3). Each of the theorists and definitions outlined within these thematic sections guides the methodology with which this dissertation investigates *HPSCHD* as a deeply performative work, dependent on the equally crucial interactions between its creators, computational tools, and participants.

I. 2. i. Extensions and/or Symbionts: Media and Prosthetics

In 1923, jaw cancer forced the removal of a large part of Sigmund Freud's palate, requiring him to wear a fitted prosthesis for the remainder of his life. Ernest Jones, Freud's biographer, recounted:

The huge prosthesis... designed to shut off the mouth from the nasal cavity, was a horror; it was labeled "the monster." In the first place it was very difficult to take out or replace because it was impossible for him to open his mouth at all widely. On one occasion, for instance, the combined efforts of Freud and his daughter failed to insert it after struggling for half an hour, and the surgeon had to be fetched for the purpose. Then for the instrument to fulfill its purpose of shutting off the yawning cavity above, and so make speaking and eating possible, it had to fit fairly tightly. This, however, produced constant irritation and sore places until its presence was unbearable. But if it were left out for more than a few hours the tissues would shrink, and the denture could no longer be replaced without being altered.¹²

Enduring this excruciating pain, Freud wrote his 1929 essay "Civilization and its Discontents," widely considered one of the first foundational media theory texts. In its most famous passage, Freud pronounced, "Man has, as it were, become a kind of prosthetic God. When he puts on all his auxiliary organs he is truly magnificent; but those organs have not grown on him and they still give him much trouble at times." Like the division between the conscious and subconscious,

¹² This was only the first of 33 surgeries to his jaw and palate over the last 16 years of Freud's life. Jones detailed the surgery itself and Freud's convalescence in his 1957 text *Sigmund Freud: Life and Work. Vol 3: The Last Phase 1919-1939* (London: Hogarth Press, 1957); Sigmund Freud, *Civilization and Its Discontents*, in *The Freud Reader*, ed. Peter Gay (New York: W. W. Norton & Company, 1995), 738.

Freud regarded these “auxiliary organs,” or *prostheses*, as possessing sentience and autonomy at war with our own.

The term *prosthetic* suffers wildly varied usage in psychoanalytical, medical, and media theories.¹³ The *October* theorists, most notably Hal Foster, use the prosthetic to illustrate certain trends in modernist and postmodernist artworks through predominantly psychoanalytical methodology, but largely ignore its common usage denoting the physicality of technological devices and cybernetic body augmentation and their social effects.¹⁴ This reading prompts enormous ramifications: it identifies the prosthetic as psychic trauma shifting from id to ego, its emergence upon phenomenal reality remaining confused.¹⁵

¹³ The term “prosthesis” originates from ancient Greek, first used in the context of linguistics; its root “pros” emphasizes the prosthetic as an extension of an existing word. In reference to the construction of language, the prosthetic is an adding, advancing, and giving power to that which it is extending. David Wills provided etymological research of prosthetics in his text *Prosthesis* (Stanford: Stanford University Press, 1995). Not until much later, during the latter half of the 19th century, did the term “prosthetic” migrate to primarily medical discourse. For more information on both early medical and Fordist models of prosthetics, see Sarah S. Jain, “The Prosthetic Imagination: Enabling and Disabling the Prosthesis Trope,” *Science, Technology, and Human Values*, Vol. 24 (Winter, 1999): 31-54.

¹⁴ Hal Foster applied psychoanalysis to *Civilization and its Discontents* in analyzing contemporary art practices with emphasis on the *uncanny* in “An Art of Missing Parts,” *October* Vol. 92 (Spring, 2000): 128-156; Foster, *Prosthetic Gods* (Cambridge: MIT Press, 1995).

¹⁵ As noted by Marquard Smith in his introduction to *The Prosthetic Impulse: From a Posthuman Present to a Biocultural Future*, the majority of contemporary writings about prosthetics define them as either fantastical or metaphorical to the detriment of the prosthetic as object. Likewise, medical and legal anthropologist Sarah S. Jain worried this elision continues to widen the fundamental split between the medical and engineering disciplines, ultimately marginalizing disability discourse and the populations that might benefit. Instead of focusing on individuals with varied abilities, research tends toward normalization. The already unexplored contexts of the diverse realm of prosthetic users—among them, every human of varying ability and background—remains obscured despite the excitement of marketable prosthetic paradigms often heralded in engineering and computing research. Marquard Smith, “Introduction,” in *The Prosthetic Impulse: From a Posthuman Present to a Biocultural Future*, eds. Marquard Smith and Joanne Morra (Cambridge MA: MIT Press), 2; Jain, 49.

Though still deeply influenced by psychoanalysis, Marshall McLuhan's 1964 text *Understanding Media: The Extensions of Man* cast the prosthetic relationship as having the potential for both trauma and *extension*: the prosthetic simultaneously signaled a deficiency and enhancement. His material reading of media as "any extension of ourselves" defined clothing as an extension of the skin, wheels as an extension of the foot, and electric technology as an extension of the central nervous system.¹⁶ McLuhan's "electric nervous system," a poetical abstraction of the digital computer, still maintained Freud's insistence that prosthetic extensions remained largely unmanageable: the subconscious influencing these external "auxiliary organs" *extended*, but also *amputated*.¹⁷

For example, in his 1962 text *The Gutenberg Galaxy: The Making of the Typographic Man*, McLuhan's techno-utopian "global village" offers the freedom of citizenship regardless of physical location, allowing a vast expansion of social spheres and information sharing; however, the consequences of this networking sacrifices both individualism and nationalism, but also conceptual boundaries of the self. Regarding the extent to which the global village could penetrate the human body, McLuhan wrote, "It is possible now to program conditions of the senses in such a way among themselves that they come close to the condition of consciousness (...) If we expanded our central nervous system to the electromagnetic technology, it is only one step more for the transmission of our consciousness also into the world of the computers."¹⁸ Constituting the ultimate amputation—that of the entire body—the digital computer represented the final prosthetic, extending all executive functioning of the human. Though McLuhan's

¹⁶ Marshall McLuhan, *Understanding Media: The Extensions of Man* (New York: Routledge, 1964), 7-8.

¹⁷ McLuhan claimed "autoamputation" is a necessary component of media. McLuhan, *Understanding Media*, 43.

¹⁸ McLuhan, *Understanding Media*, 464.

theories are often interpreted as techno-utopian in nature, closer readings paint a far more ambiguous and uncertain technological future; as detailed in Chapter 3, the prosthetic relationship defined by the emergence of digital computing entered public consciousness during a tumultuous period of political and social unrest. The *HPSCHD* performance, though outwardly techno-utopian in its celebration of spaceflight, could not entirely allay its participants' anxieties regarding the more troubling connotations of automation, dematerialization, and alienation signaled by its enigmatic computational elements.

Following from these mounting fears, media theorist Friedrich Kittler described the rapid evolution of prosthetic technologies as disastrous, warning that these developments marked humans for eventual obsolescence. In *Gramophone, Film, Typewriter*, Kittler also identified the prosthetic as a replication and replacement of human faculties: the gramophone from his voice, the film from his image, and the typewriter from his word.¹⁹ However, he identified these machines not as “extensions of man,” but rather *a priori*, having always been a condition of being human. In agreement with the apocalyptic prognosis of Martin Heidegger's 1953 treatise “On the Question Concerning Technology,” Kittler saw the world as increasingly dominated by technology, eventually causing the obsolescence of the human subject: “World War II thus produced the first self-guided weapons systems, which have since made people, the subject of all modern philosophies, simply superfluous.”²⁰

¹⁹ Friedrich Kittler, *Gramophone, Film, Typewriter* (Stanford: Stanford University Press: 1999).

²⁰ As analyzed by Sjoukje van der Meulen in her essay “Between Benjamin and McLuhan: Vilém Flusser's Media Theory,” media theorist Vilém Flusser had similar concerns to Kittler's about the growing inequality in the relationship between humans and technology. Because these concerns are largely analyzed in Flusser's study of 20th century science fiction, particularly Stanley Kubrick's *2001: A Space Odyssey*, van der Meulen's analysis serves as a fitting conclusion to themes covered in Chapter 3. Kittler, *Optical Media* (Cambridge: Polity Press, 2010), 218; Sjoukje van der Meulen, “Between Benjamin and McLuhan: Vilém Flusser's Media Theory,” *New German Critique* 110, Vol. 37, No. 2, (Summer 2010): 181-207.

Rather than debate exactly when and how prosthetics physically or ontologically shape humanity—in other words, whether or not they constitute a primary condition of being human—the emphasis of this study lies in the investigation of our complicated *reflexive*, symbiotic relationship with the technological tools that so fundamentally transform both our environment and ourselves.²¹ The dystopian theorization of the prosthetic relationship—that our autonomy increasingly disappears into technology—may at first seem an exaggeration of our underlying fears of technology. However, the variety of early computer art reviews—especially those of both Lejaren Hiller and Leonard Isaacson’s *Illiac Suite: String Quartet No 4* (1956) and later, Cage and Hiller’s *HPSCHD*—reveal not only that these fears were commonplace, but that the rhetoric used then still proves terribly familiar today.²²

These ongoing anxieties spoke to our complicated relationship with dematerialization, and informed the subsequent appearance of discourse regarding the *virtual*.²³ More recent media theory often defines the virtual as that which is *not real* while still exhibiting the full qualities of the real; this contradictory definition is used to explain how virtual environments, including

²¹ N. Katherine Hayles, in her text *How We Became Posthuman*, explained that the original cybernetic definition of “reflexivity” described how feedback loops incorporate a subject into its own creation: “Reflexivity is the movement whereby that which has been used to generate a system is made, through a changed perspective, to become part of the system it generates.” N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature and Informatics* (Chicago: University of Chicago Press, 1999), 8.

²² The reviews for the *Illiac Suite* are discussed in Chapter 2, section II. 2., “A MUSICAL SUITE COMPOSED BY AN ELECTRONIC BRAIN”; the reviews of *HPSCHD* concern a large portion of Chapter 3, including section III. 4. “Utopia of Escape.”

²³ From the Latin *virtus*, meaning strength, the *virtual* was originally recognized as latent power rather than an extant quality. The coining of the related concept “artificial reality” is commonly credited to computer artist Myron Krueger, who from the late 1960s into the 1980s experimented with video recognition technologies. Krueger’s experiments spawned two related, but currently diverging research topics: *virtual reality* and *augmented reality*. While augmented reality (AR), does not replace reality as much as it supplements it, virtual reality (VR) constitutes seamlessly immersive, interactive environments. Myron Krueger, *Artificial Reality* (Boston: Addison-Wesley, 1983).

massively-multiplayer online role-playing games (MMORPGs) and social networks, are psychologically impactful.²⁴ This conflicting definition of virtuality has become a dominant theme in present science fiction: many texts incorporate debates regarding technological accessibility, education, class conflict, and ethics. Though fictional, these texts warn of the real inequities built into a system that privileges the wealthy few, marginalizing the very real labor creating and sustaining these virtual worlds.²⁵ Currently, virtuality is identified with the interactive fantasy realms accessed by those with the technological and economic means; this emphasis on the non-physicality of these interactions ignores the agents that comprise and complete the system, such as software engineers and developers, system administrators, hardware and web programmers, the unpaid labor of beta testers and feedback responders, and the illegal or physically dangerous labor of identity thieves, phishing scammers, gold farmers, and e-waste workers.²⁶

²⁴ Notable theorists theorizing virtuality include Brian Massumi, Sherry Turkle, and Anne Friedberg. Massumi, for example, replaces the traditional opposition of “literal and figural” with “stasis and motion”; while these concepts emphasize performance and its social, cultural, and psychological effects, the physicality of technology is ignored. See Brian Massumi’s *Parables for the Virtual: Movement, Affect, Sensation* (Duke University Press, 2002).

²⁵ Examples abound, from the proto-virtual family room of Ray Bradbury’s *Fahrenheit 451* (1953), the Internet-like immersive landscapes of Neal Stephenson’s *Snow Crash* (1992), to the Wachowski siblings’ *Matrix* trilogy (1999-2003). Many recent science-fiction works critically examine how technology further widens the gap between classes while promising accessibility and equality. Some examples include Ernest Cline’s *Ready Player One* (2012), Neal Stephenson’s *Reamde* (2012), and Cory Doctorow and Jen Wang’s graphic novel, *In Real Life* (2014). Each of these examples finds young adult protagonists struggling with virtual entertainment and work, offering new critiques of globalization.

²⁶ “Gold farming” is a practice in which players of massively multiplayer online games acquire in-game currency (often literally “mining” or “farming” online) to exchange for real-world money, often from wealthy players wanting to advance more quickly, constituting full-time employment in developing nations. The invisibility of virtual labor is a vast subject, dealing with topics ranging from virtual economics to human rights violations. Though this subject expands far beyond the subject of this dissertation, the marginalization of virtual labor can be observed early in the development of digital computing, even with the first computer researchers.

I. 2. ii. Information Theory, Cybernetics, and Dematerialization

It's no wonder, then, that early in the development of digital computing anxiety regarding the loss of autonomy in the human-technological prosthetic relationship fueled ongoing cultural prejudice toward computers. Some of these anxieties were simply due to the rapidity with which emerging disciplines gained such fervent institutional support after World War II—among them information theory, cybernetics, and the vastly expanding field of computer science, followed by the many branching hybrid disciplines within systems theory: systems biology, systems psychology, network theory, etc. Even early on, the relationship between information theory and cybernetics remained vague, with no clear consensus of whether they constituted discreet or interrelated disciplines, or if one simply enveloped the other.²⁷

The foundation of information theory is attributed to Claude Shannon, who defined this subset of mathematics as the study of transmission, processing, utilization, and extraction of information. First published in 1948 in the *Bell System Technical Journal* as “A Mathematical Theory of Communication,” Shannon proposed information be treated like a measurable physical quantity, akin to density or mass.²⁸ This fundamental abstraction governs that information is treated as quantitative, disregarding inherent meaning. It was because of this dematerialization—abstracting information from its material form—that Shannon's mathematical theory of

²⁷ One attempt to differentiate the two disciplines was August Smith's “Information Theory and Cybernetics,” *Cybernetics & Systems* Volume: 4 Issue 3 (1974); Smith focuses on the fundamental postulate that information can be treated like a measurable physical quantity, while cybernetics abstracts all forms of communication to describe progressively larger systems.

²⁸ The book adapted from “A Mathematical Theory of Communication” was re-titled *The Mathematical Theory of Communication*, emphasizing its interdisciplinarity; in anticipation of its cultural popularity, it was republished in condensed form in *Scientific American* in July, 1949 under the same title. Claude Shannon, “A Mathematical Theory of Communication,” *Bell System Technical Journal* 27 (3): 379–423; Shannon, *The Mathematical Theory of Communication* (Urbana: University of Illinois Press, 1949).

communication fundamentally transformed the landscape of any discipline concerned with sending and receiving information, and is responsible for the development of digital computing.

In contrast, cybernetics—coined from the Greek word *kubernetes*, or “steersman” by mathematician Norbert Wiener in 1948—constituted a much more deliberate attempt at interdisciplinary discourse, investigating the flow of information to predict, control, and automate the behavior of both mechanical and biological systems.²⁹ The Macy Conferences of 1943 through 1954, held in New York at the behest of Frank Fremont-Smith at the Josiah Macy Jr. Foundation, involved the analysis of how this flow of information involved or resulted in homeostasis, which extended the biological concept of maintaining steady states despite environmental changes to the functioning of machines. Even in its earliest incarnations, cybernetics vacillated between a utopian vision and one with dystopian, destructive possibilities, discussion teetering between what N. Katherine Hayles called “a vision of man as a homeostatic self-regulating mechanism whose boundaries were clearly delineated from the environment, and a more threatening, reflexive vision of a man spliced into an informational circuit that could change him in unpredictable ways.”³⁰ Despite this internal conflict, Wiener’s predominantly utopian text *The Human Use of Human Beings* (1950)—a lay version of his earlier, more technical text *Cybernetics: Or Control and Communication in the Animal and the Machine*

²⁹ What I refer to as cybernetics is often called “first-wave cybernetics” in order to distinguish its subsequent transformation/integration into “new cybernetics” and systems theory. In her text *How We Became Posthuman*, N. Katherine Hayles describes the first wave of cybernetics as taking place during first Macy Conferences, held between 1945 and 1954. Hayles, *How We Became Posthuman*, 63.

³⁰ Hayles gives an etymology of homeostasis: “The term ‘homeostasis,’ or self-regulating stability through cybernetic corrective feedback, was introduced by physiologist Walter B. Cannon in ‘Organization for Physiological Homeostasis,’ *Physiological Reviews* 9 (1929): 399-431. Cannon’s work influenced Norbert Wiener, and homeostasis became an important concept in the initial phase of cybernetics from 1946-1953.” Hayles, “Virtual Bodies and Flickering Signifiers,” accessed February 7, 2015, <http://www.english.ucla.edu/faculty/hayles/Flick.html>.

(1948)—introduced the similarities between the internal organization of both biological and mechanical systems to a popular audience, proposing the potential for creativity once machines freed humans from the alienation of repetitive work.³¹

As *The Human Use of Human Beings* penetrated popular culture, the term “cybernetics” found lasting traction with writers, artists, and musicians especially interested in its proposals involving space travel, robotics, and computing.³² Because of its widespread influence, many media theorists and historians of technology make claims that often characterize experimental art of the 1950s and 60s as necessarily incorporating both cybernetics and information theory on a subconscious, even cellular level. For example, Edward Shanken observed that Cage’s momentous *4’33”* reflected the popularization of cybernetics in that the performance exemplified “the regulation of a system through the feedback of information”: the silence of the performer seated at the keyboard “invoked the ambient sounds of the environment (including the listener’s own breathing, a neighbor’s cough, the crumpling of a candy wrapper) as integral to its content and form.”³³ Likewise, Cage-influenced performances contemporary with *HPSCHD*—such as Fluxus and Allan Kaprow Happening-related events—are often interpreted as enacting the extremes of entropy and self-regulation, key concepts discussed in cybernetic theory.

However, simply assuming the existence of these connections in retrospect mischaracterizes cybernetics as a discrete discipline unaffected of the kinds of historical and

³¹ Norbert Wiener, *Human Use of Human Beings* (New York: Da Capo, 1950), 12.

³² For example, authors Kurt Vonnegut and Thomas Pynchon attributed works to Wiener’s *Human Use of Human Beings*; Vonnegut’s *Player Piano* (1952) imagined a future overrun by the work of machines. Pynchon attributed the themes of *The Crying of Lot 49* (1969) to Wiener as well, focusing on scientific and metaphorical entropy.

³³ Shanken, “Art in the Information Age: Cybernetics, Software, Telematics and the Conceptual Contributions of Art and Technology to Art History and Aesthetic Theory” (PhD diss., Duke University, 2001), 33.

culturally-contingent assumptions and attitudes that shape our understanding of other popular trends and movements from the latter half of the 20th century. Among media theorists in particular, the specific tenets of cybernetics often over-determine technology-related artworks, obscuring alternative interpretations through a veil of contemporary expectations. Many readings cleave to ontological models rather than the material basis that girds the history of computation. Current schools of thought gaining popularity, such as Levi Bryant, Graham Harman, and Ian Bogost's theorization of object-oriented ontology, as well as Matthew Fuller and Lev Manovich's treatment of software studies, have a tendency to choose adaptable subjects and place upon them contemporary language that denies historical contextual analysis; while object-oriented ontology provides an imbalanced method of material study by placing humans and objects on equal footing regardless of anthropological and ethical concerns, many texts that attempt an aesthetic critique of software lack a clear material understanding of the deeply physical prosthetic relationship involved in the development of computation and programming.³⁴

A more useful method for understanding this late 20th century trend toward dematerialization of information is its parallel to the dematerialization of art, commonly identified with the rise of conceptual art practices.³⁵ In her preface for *Six Years: The Dematerialization of the Art Object from 1966 to 1972* entitled "Escape Attempts," Lucy Lippard

³⁴ Particularly compelling is Rosi Braidotti's criticism that object-oriented ontology fails to recognize previous work done in this area by feminist thinkers in the 1970s, particularly theorists Donna Haraway, Simone de Beauvoir, Luce Irigaray, and Gilles Deleuze; in fact, she points out that having scoured present OOO material, many contributions made by women seem to have been intentionally "scrubbed out" of the blogosphere, where much of the conversation regarding OOO presently resides. Rosi Braidotti and Timotheus Vermeulen, "Borrowed Energy," *Frieze Magazine*, Issue 165 (September, 2014).

³⁵ To maintain agreement with the methodology of this dissertation, I will use the un-capitalized "conceptual art" or "conceptual practices" to denote an adherence to a "worldview" (as described by Fluxus artist Ken Friedman) rather than a distinct historical movement.

excused herself from nailing down a definitive definition of this “movement” (“I’m not a theoretician,” she wrote), but offered:

There has been a lot of bickering about what Conceptual art is/was; who began it; who did what when with it; what its goals, philosophy, and politics were and might have been. I was there, but I don't trust my memory. I don't trust anyone else's either... As I reconstitute the threads that drew me into the center of what came to be Conceptual art, I'll try to arm you with the necessary grain of salt, to provide a context, within the ferment of the times, for the personal prejudices and viewpoints that follow.³⁶

Most useful in understanding this relationship between information theory and conceptual art practice was Lippard’s description of the various Fluxus practices she witnessed during this period; she quoted Ken Friedman, the former head of Fluxus West in San Diego, who in 1971 claimed, “Concept art is not so much an art movement or vein as it is a position or worldview, a focus on activity.”³⁷ This description of conceptual art overlaps with the compelling assertion that Fluxus itself is not a movement, but a continually adapting network of artists and actions; as stated by Hannah Higgins in *Fluxus Experience*, Fluxus was at its most vulnerable during “those moments when zealous members tried to pin it down. Still a living creature, it resists being impaled.”³⁸ Though conceptual practices became increasingly popular in the 60s and 70s, readings of artworks influenced by conceptual practice and information theory mustn’t be confined to a certain era, but rather interpreted as part of much longer historical networks informing a “worldview” privileging action.

For example, Lejaren Hiller maintained that his and Leonard Isaacson’s *Illiac Suite* existed as an introductory exploration of information theory as applied to music composition. Citing previous forays into compositional analysis, Hiller emphasized the importance of

³⁶ Lucy Lippard, “Escape Attempts,” in *Six Years: The Dematerialization of the Art Object from 1966 to 1972* (Berkeley: University of California Press, 1973), vii-viii.

³⁷ *Ibid.*, x.

³⁸ Hannah B Higgins, *Fluxus Experience* (Berkeley: University of California Press, 2002), 66-67.

establishing a relationship between the material content of the information, classical and experimental music composition from the 17th to 20th centuries, and its subsequent transformation through computational methods of generating musical scores. While performances of the *Suite* remained traditional in format—they featured a string quartet performing transcribed compositions on stage—the compositions played on any occasion were only one of many possible versions; the ILLIAC I program had the potential to produce an infinite number of compositions, all of which would constitute an iteration of the *Illiac Suite*.³⁹

This emphasis on dematerialization dominates the writings and exhibitions by technologically-minded artist and curator contemporaries Roy Ascott, Jack Burnham, and Jasia Reichardt, all of whom shared Lejaren Hiller’s interest in exploring information theory as aesthetic practice. Roy Ascott, foundational telematics artist and theorist, famously emphasized *software*—the programmed instructions encoded to be understood by the computer and executed—as a *behavior* (concepts investigated more fully in Chapter 2). In his 1964 essay “The Construction of Change,” Roy Ascott renounced the idea of art simply as object, and instead proposed the increasingly popular idea of art as behavioral process by which subsequent action and transformation may be generated. Software constituted an intervention in knowledge, whereas hardware provided corporeal experiences of objects.⁴⁰ Behavior thus consists of relationships between artwork, artist, and audience. Because the nature of the *Illiac Suite*—and,

³⁹ Hiller’s methods and ongoing experiments in information theory and aesthetics are detailed at length in Chapter 2. Hiller, “Computer Music,” *Scientific American* 201, No. 6 (December 1959): 109-121. This article was partially reprinted in Jasia Reichardt’s catalogue for *Cybernetic Serendipity: The Computer and the Arts, a Studio International special issue* (London: Studio International, 2nd edition, Set. 1968), 21-23, as well as the compilation *Readings from Scientific American: Computer and Computation* (San Francisco: W. H. Freeman, 1971), 113-122.

⁴⁰ Roy Ascott, “The Construction of Change,” and “Behaviourables and Futuribles,” in *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness by Roy Ascott*, ed. Edward Shanken (Berkeley: University of California Press, 2003), 158.

subsequently, *HPSCHD*—made it possible for infinite performances without exact repetition, its programming process provides a virtual model, a paradigm in which prospective futures may be tested prior to approval for more general applications; this coincided with what *Software* curator Jack Burnham poetically called “a psychic dress rehearsal.”⁴¹

I. 2. iii. The History of Prognostication

Ironically, as these conceptually-focused artworks privileged action and performance, they also elevated the entire network of actors and materials involved in the process of artmaking; by shedding Modernist notions that privilege traditional materials and genres, conceptual practices highlighted the relationships between artists, participants, as well as non-traditional materials, including technological tools like digital computers. In addition, this interpretation of conceptual practices provides a more ontological reading of artmaking that relates to other branches of inquiry, making a case for performance and conceptual practice constituting a condition of being human.

While comparisons between such historically and culturally embedded practices and performances such as 17th century counterpoint compositions, the *I Ching*, ILLIAC/IBM punch cards, Schoenbergian 12-tone experimental music, and Markov chains should not assume a direct material relationship, the fundamental similarities between predominantly binary systems of any era or region indicates a historical, socio-cultural connection that correlates many early predictive, or *prognostication* systems with both algorithmic processes and performance. Many of the known ancient and classical prognostication methods were performed with systematic

⁴¹ Jack Burnham, *Software: Information Technology: Its New Meaning for Art* (New York: Jewish Museum N.Y., 1970), 44.

precision, learned through experience and patience; for example, despite its strange imagery in modern contexts, the ancient Etruscan prognostication ritual of *extispicy*, reading entrails, was performed in such a scientific manner that it might be thought of as an early mode of autopsy, making use of inductive reasoning. Extispicy constituted one of the first prognostication systems deriving meaning from elements outside of the human body and not simply from the whims of a designated group member.⁴² In similar fashion, *augury*, reading the flight patterns of birds for divination purposes, depended on systematic methods of inquiry involving the generation of binaries creating a complex algorithmic system, a stream of questions combined to form a procedural schema advancing in complexity as conditions were met.⁴³ In a more enduring example, ethno-mathematician Ron Eglash examined fractal patterns underpinning architecture, art, and design across the continent of Africa. By looking at aerial-view photos and detailed ground research, Eglash discovered many far-flung villages purposely form fractals, with self-similar shapes repeated in the layout of houses in the village, the designs of the homes, and even within the rooms of the house in mathematically predictable patterns.⁴⁴

While recent studies regarding ancient forms of prognostication upend longstanding assumptions regarding ritual and religion, they also provide a fascinating historical connection between more recent performative art processes, such as chance operations, and algorithmic

⁴² Derek Collins, “Mapping the Entrails: The Practice of Greek Hepatoscopy,” *American Journal of Philology* 129 (2008): 319-345; more information about the early cross-cultural influence of Eastern prognostication methods across ancient Europe is explored in Walter Burkert, *The Orientalizing Revolution: Near Eastern Influence on Greek Culture in the Early Archaic Age* (New York: Thames and Hudson, 1992), 46–51.

⁴³ Burkert’s text relates the divination method of augury with extispicy and other Eastern-influenced methods: *ibid.*, 49.

⁴⁴ Ron Eglash, *African Fractals: Modern Computing and Indigenous Design* (New Brunswick: Rutgers University Press, 1999); Eglash, *Appropriating Technology: Vernacular Science and Social Power*, ed. Eglash, R., Croissant, J., Di Chiro, G., and Fouché, R. (Minneapolis: University of Minnesota Press, 2004).

computation. Though Stephan Mallarme's *Un coup de dés jamais n'abolira le hasard* (*A roll of the dice will never abolish chance*, 1897) is an often-cited Modernist example of chance methods in the visual and language arts, the tradition of musical dice games existed even before Wolfgang Amadeus Mozart famously used it in his *Musikalisches Würfelspiel* (*K. 294d/K. Anh. C 30.01*) of 1787; the game existed in many forms in Germanic households for centuries.⁴⁵ As will be discussed in Chapter 2, these historical examples of compositional chance operations, alongside a number of recent computational experiments, guided Lejaren Hiller's suggestion to convert Mozart's dice game into one of the many *HPSCHD* programs. This idea eventually became research assistant, Laetitia Snow's, FORTRAN program "DICEGAME," used to generate each of *HPSCHD*'s seven harpsichord solos.

In contrast, John Cage's dedication to chance operations began with translating the *I Ching* to compositional methods through more ritualistic, interpretive means.⁴⁶ Though he had experimented with chance operations early in his career, evidenced by the third movement of *Concerto for Prepared Piano and Chamber Orchestra* (1950–51), it was through the *I Ching* that Cage found a consistent chance operations tool, using it in nearly every work he composed after 1951.⁴⁷ Cage interpreted the *I Ching*'s method as "imitating nature in its manner of operation":

⁴⁵ Musicologist Lawrence Zbikowski, in *Conceptualizing Music: Cognitive Structure, Theory, and Analysis*, outlines the conceptual reasons for the development of such a musical dice game, using Mozart's version of the dice game as an example of how musical structures maintain a close relationship to human cognition more generally. Lawrence Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (New York: Oxford University Press, 2005), 142-143; Wolfgang Amadeus Mozart, *Musikalisches Würfelspiel*, *K³.Anh.294d ; K⁶.516f* (Bonn, Germany: N. Simrock, 1787).

⁴⁶ In an interview with Cole Gagne and Tracy Caras, Cage remembered how in 1951, Christian Wolff, a former pupil, presented Cage with a copy of the *I Ching*: this first complete English translation had been published by Wolff's father by Pantheon Books just the year previous. Kostelanetz, *Conversing with John Cage* (New York: Routledge, 2003), 68.

⁴⁷ James Pritchett, *The Music of John Cage* (Cambridge: Cambridge University Press, 1993), 71.

his subsequent compositions, *Imaginary Landscape No. 4 for 12 radio receivers* and *Music of Changes* (both from 1951), involved the compositional method of asking the *I Ching* a series of questions, then interpreting the book's often nature-inspired poetical passage.⁴⁸ In a conversation with Richard Kostelanetz in 1977, Cage explained, "That's why I have used chance operations. I use them in a way involving a multiplicity of questions which I ask rather than choices that I make. So that if I have the opportunity to continue working, I think the work will resemble more and more, not the work of a person, but something that might have happened, even if the person weren't there. Something like that."⁴⁹

I. 2. iv. Zen Buddhism and Systems of Control

Though the importance of the *I Ching* oracle to Cage's oeuvre is undeniable, it over-determines his devotion to Zen Buddhism as a ritualistic practice in everyday life.⁵⁰ Even Cage often excused himself from any strict adherence to Zen Buddhist ideas, openly admitting that his interpretations were his, and his alone:

Critics frequently cry "Dada" after attending one of my concerts or hearing one of my lectures. Others bemoan my interest in Zen... It is possible to make a connection between the two, but neither Dada nor Zen is a fixed tangible. They change; and in quite different ways in different places and times, they invigorate action. What was Dada in the 1920's is now, with the exception of the work of Marcel Duchamp, just art. What I do, I do not wish blamed on Zen, though without my engagement with Zen (attendance at lectures by Alan Watts and D. T. Suzuki, reading of the literature) I doubt whether I would have

⁴⁸ *Ibid.*, 53.

⁴⁹ Kostelanetz, *Conversing with John Cage*, 55.

⁵⁰ In his article "'In order to thicken the plot:' toward a critical reception of Cage's music," David Bernstein pointed out that the methodology of Cage's *Music of Changes* was an "idiosyncratic use of the book's process," in that his hexagram chart was clearly manipulated to more closely resemble Schoenberg's 12-tone system. Marc Jensen further posited that Cage actually used the *I Ching* as a method of exploring current trends in chaos theory. David Bernstein, "'In order to thicken the plot:' toward a critical reception of Cage's music," in *Writings through John Cage's Music, Poetry, and Art*, ed. David W. Bernstein and Christopher Hatch (Chicago: University of Chicago Press, 2001); Marc G. Jensen, "John Cage, Chance Operations, and the Chaos Game: Cage and the 'I Ching'," *The Musical Times*, Vol. 150, No. 1907 (Summer, 2009): 97-102.

done what I have done. I am told that Alan Watts has questioned the relation between my work and Zen. I mention this in order to free Zen of any responsibility for my actions.⁵¹

Even though Cage links Zen and Dada in this particular quote, tellingly describing Dada's transformation from its 1920s zealotry to "just art," Zen in the 1960s was, and still is, a living religion, fundamentally shaping history, culture, and politics in Japan. A form of Mahayana Buddhism which developed in China during the 6th century, Zen derived from the Japanese pronunciation of the Chinese *Chán*, which in turn is derived from the Sanskrit word *dhyāna*, roughly translated as "absorption" or "meditation." Unlike other forms of Buddhism, Zen Buddhism emphasizes a teacher-pupil relationship, where enlightenment teachings transmit directly from master to disciple, through action and experience. In this way, Zen concentrates on what is described as "suchness," or "reality just-as-it-is," constituting an attempt to teach through actions in daily life and not simply through the spoken or written word.⁵²

Since the Meiji-restoration in 1868, Zen Buddhism maintained a troubled relationship between the ruling and underclasses in Japan. Its close association with the totalitarian and feudal *shogunate* caused many Japanese to identify Buddhism with decadence and archaism. As Buddhism became increasingly synonymous with superstitious and xenophobic practices at the turn of the 20th century, modernization efforts resulted in the bureaucratization of Zen Buddhist institutions; subsequent institutional involvement with politics further polarized public opinion. In addition, Japanese Buddhism historically received state support. Copious political materials

⁵¹ Cage, *Silence*, xi.

⁵² Heinrich Dumoulin's *A History of Zen Buddhism*, as well as Peter Harvey's *An introduction to Buddhism* provide thorough historical analysis of Zen's development throughout its early history and subsequent changes in modern contexts, with special attention paid to orientalist/post-colonial interpretations. Heinrich Dumoulin, *A History of Zen Buddhism* (New Delhi: Munshiram Manoharlal Publishers Pvt. Ltd., 2000); Peter Harvey, *An introduction to Buddhism: Teachings, history and practices* (Cambridge University Press, 1995).

document official World War II sanctions by Zen Buddhist institutions: for example, The Zen Soto priest Brian Daizen Victoria documented in his book *Zen at War* how Buddhist institutions justified Japanese militarism in official publications and cooperated with the Japanese Army directly on the battlefield. In addition, Victoria detailed how the Japanese military bureaucracy intentionally modelled military life upon Zen monastic practices, from the organization of units down to infantry mess kits; military training based its philosophy on Zen practices aimed to emphasize extreme asceticism and create indifference to death.⁵³

As postwar Japan suffered long-lasting tumult during and after the renewal of the USA-Japan Security Treaty, the new conservative ruling party promoted vast de-politicization of everyday life and emphasized capitalist modes of growth and consumption to both pacify the public and co-opt the newly defeated opposition.⁵⁴ Many young artists protested this political

⁵³ Victoria's texts included material relating to political assassination, suicide attacks, and atrocities against civilians, such as the Nanking massacre, occurring before and during WWII. His subsequent *Zen War Stories* follows the personalities illustrating Zen Buddhism's support of the totalitarian military regime of Imperial Japan through translations from period wartime texts and interviews, including critical commentary. In response to these books, several sects issued an apology for their wartime support of the government. Brian Daizen Victoria, *Zen at War*, 2nd ed. (London: Rowman and Littlefield, 2006); Victoria, *Zen War Stories* (London: Routledge Curzon, 2003).

⁵⁴ The USA-Japan Security Treaty, officially titled *The Treaty of Mutual Cooperation and Security between the United States and Japan*, was colloquially referred to as *anpo joyaku* or *ANPO* in Japan. It was signed in 1952, renewed and amended in 1960. The 2015 College Art Association panel "The Turbulent Decade: East Asian Art and the Global 1960s," specifically Nick Kapur's presentation of "Art in Japan after the 1960 US-Japan Security Treaty Crisis," provided invaluable historical context in understanding both Zen religious practice and artmaking in postwar Japan. This investigation was further supported by William Marotti's texts about art and revolution in Japan during the 1960s, focusing upon the Yumiuri Independent and the formation and participation of the activist art groups that made the exhibitions infamous—Gutai, Neo-Dada, Hi-Red-Center, and Group Kyushu; Nick Kapur, "Art in Japan after the 1960 US-Japan Security Treaty Crisis," College Art Association Conference, February 2015; Kapur, "Japanese Literature and Art after ANPO," Asian Studies Conference Japan (ASCJ), June 2010; William Marotti, "Political aesthetics: activism, everyday life, and art's object in 1960s' Japan," *Inter-asia Cultural Studies*, Volume 7, Number 4 (2006): 606; Marotti, *Money, Trains, and Guillotines: Art and Revolution in 1960s Japan* (Durham, NC: Duke University Press, 2013).

agenda by further divorcing themselves from the complacency they identified with the militarization of Zen traditions during WWII. These artist-activists practiced anarchic methods, their provocations regularly receiving the ire of the Japanese government throughout the 1960s.⁵⁵ Their artworks emphasized performance and practice rather than object, eschewing both the traditional patronage system and the commodity capitalism encouraged by the dominant political party.⁵⁶ Though activist artworks bore certain similarities to the counter-cultural, experimental artworks and performances happening in the West, their radical politics diverged significantly on account of specific historical cultural context; while activist Japanese artists attempted to distance themselves from the methods and ideologies that made WWII and its aftermath possible, the 1960s version of Zen in Western popular culture tended toward an emphasis on spiritual enlightenment as an *alternative* to Western ideologies and religious practices. This approach to Zen Buddhist practices, including the usage of the *I Ching*, was largely influenced by the works of Daisetz Teitaro Suzuki, whose translations are usually credited with the popularization of Zen Buddhism in the West.

⁵⁵ Marotti, "Political aesthetics: activism, everyday life, and art's object in 1960s' Japan," 607.

⁵⁶ Because the annual Yomiuri Indépendent Exhibitions maintained a democratic system of allowing anyone, regardless of experience and skill, to show work, this new generation of activist artists, many of whom had no formal training, took advantage of this alternative to the traditional patronage system to create increasingly provocative artworks. Protesting against the smokescreen of government-endorsed commodity culture and the complacency identified with Zen and Shinto traditions, these artists constructed increasingly radical ephemeral waste landscapes: for example, Toyoshima Sôroku, a member of the group Neo-Dada, created *Junk Put on the Wall* (*Kabe ohino janbu*), a series of frenzied collages of old painted tatami mats and broken glass. Other associated radical art groups, such as Group Kyushu, were banned altogether from the Yomiuri Indépendent for submitting urine and excrement-covered "anti-art." Marotti detailed this installation and others by both Tagoshima and fellow Neo-Dadaists during these many embattled Yomiuri Indépendent shows; *ibid.*, 610-611; *Kyushu-ha ten (Group Kyushu Exhibition)*, exhibition catalog (Fukuoka: Fukuaka Museum of Art, 1988).

Cage was not a newcomer to Zen when he first encountered Suzuki, already having encountered the works of Alan Watts, writer of *Spirit of Zen* (1939). As early as 1949, those who frequented “The Club”—a community of abstract expressionists and avant-garde artists, including Cage, who met at a loft on 39 East Eighth Street in Greenwich Village—discussed Zen and its relationship with art more than any other topic.⁵⁷ Having attended Watts’ lectures and spoken to him on many occasions, Cage’s growing interest in the subject lead him to seek out Suzuki. Cage once commented, “I didn’t study music with just anybody; I studied with Schoenberg,” likewise, “I didn’t study Zen with just anybody; I studied with Suzuki. I’ve always gone, insofar as I could, to the president of the company.”⁵⁸ In October 1962, John Cage and David Tudor visited Japan at the invitation of the Sogetsu Art Center (SAC). Though they met with many Japanese musicians and sound engineers, there is no indication from Cage’s accounts that they invested any time in the contemporary Japanese art scene; rather, he recalled that most of their free time was spent visiting various historic Zen temples.⁵⁹

Cage’s experience of a historical, rather than a contemporary Japan wasn’t unique. Buddhism was treated as a novel approach to living during the 1950s and 60s through a

⁵⁷ Victoria Holstein describes at length how the discussions that took place at The Club reflect how Abstract Expressionism “provided a model for a new way of seeing, a model of a human-scaled project that recognized that mutuality of individuals and society,” thus indicating their commitment to the leftist, anti-repressive politics of the 1960s. It makes sense, then, that Cage’s own political interests aligned with theirs, using Watts and Suzuki’s teachings of Zen as a method for further understanding this sensibility. Victoria Holstein, “Abstract Expressionism’s Counterculture: The Club, the Cold War, and the New Sensibility,” lecture, Museum of Modern Art, New York, February 25, 2011.

⁵⁸ Richard Fleming and William Duckworth, eds., *John Cage at Seventy-Five* (Lewisburg: Bucknell University Press, 1989), 25.

⁵⁹ Cage, “How to Pass, Kick, Fall, and Run,” in *A Year from Monday: New Lectures and Writings* (Middletown, CT: Wesleyan University Press, 1967), 137; John Cage, Michael Kirby and Richard Schechner, *Tulane Drama Review* 10, No. 2 (Winter 1965), repr. in *Happenings and Other Acts*, ed. Mariellen R. Sanford (New York: Routledge, 1995), 64.

mythology promoting a spiritual alternative to modern Western militarization and suppression. In particular, “Suzuki Zen” welcomed Westerners to a “modernized” Zen Buddhist practice compatible with counter-cultural interests, excising militaristic/conservative historical narratives to achieve what was interpreted as an “academic” treatment of the “philosophy.”⁶⁰ In fact, in both the U.S. and Japan, Suzuki’s teachings were commonly promoted as an “intellectually, reformed” version of Zen Buddhism.⁶¹ For the Westerner, the East provided mental escape, an Other for everything forbidden in the West while providing what they interpreted as an ancient touchstone, as opposed to their own rapidly shifting Western historical and cultural moment.

Jørn Borup, religion and theology scholar and author of *Japanese Rinzai Zen Buddhism:*

Myoshinji, a Living Religion, advocates for an updated, postcolonial reading of Zen in the West:

Perhaps the most important quality of Buddhism was its status as ‘dead’: Actual living Buddhism was looked upon as a false folk-religion, degenerated from pure and only existing ‘real’ textual Buddhism. Living Buddhists were not true Buddhists... Buddhism became an invented tradition, and a projected battlefield, reflecting the mind and culture of the “discoverer.”⁶²

⁶⁰ As explained by Wilhelm Schiffer in a review of Daisetz T. Suzuki’s text, “As [Suzuki] is trained in the Zen way of life, he can explain this way in the language of the Westerner.”

Wilhelm Schiffer, “Review: *Zen and Japanese Buddhism* by Daisetz T. Suzuki; Charles E. Tuttle,” *Monumenta Nipponica*, Vol. 14, No. 1/2 (Apr.-Jul., 1958): 228-229.

⁶¹ Jørn Borup, “New Approaches to the Study of Religion,” in *Volume 1, Regional, Critical, and Historical Approaches*, eds. Peter Antes, Armin W. Geertz, and Randi R. Warne (Berlin: Verlag de Gruyter, 2004), 460.

⁶² As pointed out by his critics, Suzuki’s explanation of Zen and Buddhism closely followed the 19th century Western trend of “empiricizing” a predominantly religious tradition, even featuring a thorough bibliography. Edward Said pointed out this tendency in Western academia toward citation in order to render Eastern culture academic: “the ‘determining imprint of individual writers upon the otherwise anonymous collective body of texts constituting a discursive formation like Orientalism,’ because ‘Orientalism is after all a system for citing works and authors.’” Even though Said’s seminal text *Orientalism* focused on the colonized Islamic Middle East, un-colonized countries such as Japan still felt the effects of colonialism. Edward Said, *Orientalism* (New York: Vintage, 1978), 23; Borup, 461.

One can interpret the transformation of Zen from East to West as a *de-cultification* of ritualistic practices; this de-cultified version becomes more *philosophy* than religion, with a historical and cultural vacuum acting as a mirror for the “discoverer” rather than dogma to be followed.⁶³

Though not bearing a direct material relation, Cage’s use of Zen Buddhism, particularly the *I Ching*, as a methodology rather than an embedded ritualistic practice bears similarities to the larger trend toward dematerialization of information and the growing popularity of conceptual art. For Cage, the de-centering of subjectivity, the ability to shift perspective between sentient and non-sentient objects both pertained to Zen Buddhist principles and a more networked understanding of materials existing in the universe:

You know, in Zen Buddhism everything causes everything else; one doesn’t speak about causes and effects since one is in a network of causes and effects. In a situation where that’s the case, and where also every being—whether sentient or nonsentient—is the “Buddha,” we are completely free of hierarchy, of one being more important than another. So this makes possible many things. The octave, then, has no more reason being divided into 5, 6, 7, 8, or 9 equal intervals than it has to be divided into 34, 43, or 56 parts, and it’s just a question of establishing limits. I can’t see the idea of superimposing all those various divisions of the octave [as I did in *HPSCHD*] arising in a structure influenced by our [Western] way of thinking. I can’t find a reason for that in conventional European or Christian thinking—where it would have been much more natural to find out what would be the “right” division of the octave, and then put the rest of them in Hell.⁶⁴

Cage’s shift from ritualistic to methodological description of the use of Zen Buddhism in *HPSCHD* shares a commonality with his misreading of stochastic and philosophical-ontological chance. As discussed in Chapter 2, Cage’s compositional methods were largely guided by his own unique interpretations of information theory. Furthermore, these methods were again

⁶³ “Zen Orientalism,” defined by Japanese Religions scholar Bernard Faure, can be detected in the writings of Suzuki: Faure comments, “Suzuki relied heavily on the categories of nineteenth-century Orientalism. He simply inverted the old schemas to serve his own purposes.” A more thorough investigation of Suzuki’s tendency toward 19th century religion-as-science methods can be found in Bernard Faure’s *Chan Insights and Oversights: An Epistemological Critique of the Chan Tradition* (Princeton: Princeton University Press, 1993), 5, 52-64.

⁶⁴ Husarik, 2.

transformed as his dedication to anarchy waned, a subject concerning Chapter 3. Hiller, however, used programming to mimic the embedded performative practices method of the *I Ching*. Though still far from executing traditional, ritualistic Zen Buddhist practice, Hiller's "ICHING" subroutine was an experiment in translating a highly performance-based prognostication ritual into programming, further emphasizing the performative basis of computer software.

I. 3. Literature Review

In the case of *HPSCHD*, John Cage's popularity undeniably deflects discussions regarding its computer-assisted properties. Because of Cage's reputation and well-known philosophies, it has been difficult to divorce his individual works from the prevailing Happening/Fluxus-based paradigm, much less his meditations on indeterminacy and chance operations. However, considering *HPSCHD* through the four themes surveyed above offers an interdisciplinary alternative to the well-worn Cage-centric narrative with which we are so familiar; through these "lenses," we have a unique opportunity to re-examine these early years of aesthetic software practice.

William Fetterman's description of *HPSCHD* as a "large-scale *Musicircus*" remains one such example of the consequences to the prevailing Cage-centric paradigm; while some important comparisons can be made between *Musicircus* and *HPSCHD*, such as Cage's interaction with university administration and the work's development while holding a research position at the University of Illinois, Fetterman ignores obvious differences in scale and approach, as well as the importance of Cage's close collaboration with Lejaren Hiller.⁶⁵ This comparison, and references to other technologically experimental works by Cage, ignores the

⁶⁵ William Fetterman, *John Cage's Theatre Pieces* (London: Harwood Academic Publishers, 1996), 139.

significance of software. Other Cage texts concentrate on more biographical details, *HPSCHD* only appearing as a side note to his more recognized and more undeniably “Cage-ian” works. James Pritchett’s well-known text *The Music of John Cage* includes an accurate, but brief two-and-a-half pages on *HPSCHD*. Despite the necessary biographical details, much of the theoretical, cultural, or historical importance of *HPSCHD* in Pritchett’s text is rejected in service of a neater biographical narrative. In contrast, David Revill’s biography *The Roaring Silence* provides an abundance of information regarding the context of *HPSCHD* within events in Cage’s life.⁶⁶ Revill describes the circumstances of *HPSCHD*’s conception as growing out of Cage’s interests in electronic sounds, as evidenced by his earlier involvement with Billy Klüver’s Experiments in Art and Technology (E.A.T.), and his relationship with Hiller.⁶⁷

More specific to Cage’s time at the University of Illinois is Johanne Rivest’s research into Cage’s various visits and subsequent appointment on the campus from the years 1952 to 1969.⁶⁸ Though brief, Rivest’s information about the development of *HPSCHD* offers insight into the workings of the university in relationship to Cage. As previously mentioned, Brandon Joseph’s article “*HPSCHD*—Ghost or Monster?” provides invaluable analysis of the trajectory of Cage’s political ideas during the 60s and early 70s. While Rivest’s work explains *HPSCHD* in

⁶⁶ David Revill, *The Roaring Silence: John Cage: A Life* (New York: Arcade Publishing, 1992), 223-230.

⁶⁷ Bell Labs engineers Billy Klüver and Fred Waldhauer, and artists Robert Rauschenberg and Robert Whitman, founded Experiments in Art and Technology (E.A.T.) in 1966, bringing together 40 engineers and 10 artists to create performances using new technologies. These experiments resulted in 9 Evenings: Theatre and Engineering, held in October 1966 at the 69th Regiment Armory in New York City. Cage performed *Variations VII*, incorporating electrically amplified sound with reactive photocells that controlled the electronic sources.

⁶⁸ Rivest presented her research for a musicology colloquium in Urbana on April 22, 1999, and the essay has since been included in the liner notes to EMF’s 2003 recording of *HPSCHD* and previously published on the EMF website. Johanne Rivest, “In Advance of the Avant Garde: John Cage at the University of Illinois, 1952-69,” *EMF Institute* (1999) accessed May 11, 2014, <http://emfinstitute.emf.org/articles/rivest99/rivestoncage991.html>.

the context of its presence on the University of Illinois campus, Joseph considers the work as it lives within Cage's changing political interests and how these impacted the work and its subsequent reception.⁶⁹ Journalist accounts and reviews from the premiere also provide useful contextual information regarding the *zeitgeist* of late 1960s Cage performances. Richard Kostelanetz's various accounts of *HPSCHD* come the closest to realizing its significance, mostly in terms of its scale and the conceptually loaded aspect of its content. Kostelanetz, himself deeply embedded in the avant-garde of the 60s and 70s through personal relationships and arts journalism, serves as a valuable eyewitness to the event.⁷⁰ Also of great importance is Stephen Husarik's "John Cage and Lejaren Hiller: *HPSCHD*, 1969," published in *American Music* in 1983. Husarik includes interviews with Cage, composer and frequent Cage collaborator Ben Johnston, *HPSCHD* coordinator and University of Illinois Dean of the College of Fine and Applied Arts Jack McKenzie, and correspondence with Hiller and filmmaker and *HPSCHD* moving-image collaborator Ronald Nameth.⁷¹ Husarik's article tempers Kostelanetz's hyperbole with a descriptive overview of *HPSCHD*'s construction and its subsequent reception.

Dissertations on *HPSCHD* largely focus upon a musicological or music education perspective, arguing for its significance specifically within John Cage's oeuvre. Two significant works by William Duckworth and Sara Heimbecker, both completed at the University of Illinois, provided helpful models for approaching *HPSCHD* research. Duckworth's dissertation

⁶⁹ Brandon Joseph, "HPSCHD—Ghost or Monster?" in *Mainframe Experimentalism: Early Computing and the Foundation of the Digital Arts*, ed. Hannah B. Higgins and Douglas Kahn (Berkeley and Los Angeles: University of California Press), 147-169.

⁷⁰ Kostelanetz, "Environmental Abundance," in *John Cage* (New York: Da Capo Press, 1970), 177; Kostelanetz, "John Cage as a *Hörspielmacher*," in *Writings About John Cage*, ed. Richard Kostelanetz (Ann Arbor: University of Michigan Press, 1989), 217; Kostelanetz, "The Keystone of the Cagean Canon," in *Innovative Music(Ian)S* (New York: Limelight Editions, 1989), 43.

⁷¹ Husarik, 1-21.

“Expanding Notational Parameters in the Works of John Cage,” the first study to include *HPSCHD*, surveys Cage's works by tracking notational developments in his music to determine their relationship to stylistic changes. Having completed his doctoral work in 1971, Duckworth attended the premiere of *HPSCHD* during his studies and consulting various computational research assistants from the performance.⁷² Though extremely brief in its descriptions, Duckworth's documentation was the best secondary source from which to further ascertain the function of individual programs and subroutines involved in programming *HPSCHD*. Sara J. Heimbecker's 2011 dissertation, “John Cage's *HPSCHD*,” focuses on how musicality and event collided to culminate in *HPSCHD* as a utopian spectacle. Though from a musicological perspective, Heimbecker provides a model for the kind a comprehensive treatment of a single important Cage work by challenging assumptions through contextual critical analysis. Her documentation and commentary on an abundance of primary source material was especially helpful in my research into the processes and performance model *HPSCHD* follows.⁷³

While all of these texts share insights into Cage's enthusiasm for experimental methods grounded in his concept of indeterminacy, nearly all succumb to vagaries when faced with the technical aspects of his electronic and computation-centric performances; with *HPSCHD* in particular, most mention the use of a computer with little to no additional information regarding the materials and labor necessary to produce the computer-generated microtonal tapes. Much of this is due to the disconcerting lack of recognition afforded Lejaren Hiller as co-composer.

Hiller's absence excises the theoretical groundwork for software in art, leaving a unique project

⁷² William Duckworth, *Expanding Notational Parameters in the Works of John Cage* (PhD diss., University of Illinois, 1971).

⁷³ Sara J. Heimbecker, “John Cage's *HPSCHD*” (PhD diss., University of Illinois at Urbana-Champaign, 2011).

such as *HPSCHD* unmoored from its historical context and unrecognized as an important progenitor of current computational art practices. The abundance of texts by Lejaren Hiller Jr. serve the important role of grounding this large-scale work within the larger context of not only the history of electronic music composition, but also the more contemporary study of software aesthetics. Hiller, though undoubtedly lesser known than Cage, was both an accomplished writer and composer of electronic compositions and music. Though primarily published in trade journals and not in art publications, his articles and essays detail his ideas about how computer music could be theorized, performed, written, and enjoyed. These articles and others co-authored by various students and collaborators prove invaluable in discovering Hiller's legacy in electronic music as well as the fundamental importance of his pedagogy regarding the mechanical functioning and programming of his technological tools. Especially helpful in understanding the *HPSCHD* programming process are Hiller's published trade journal essays describing the programming processes for the *Illiac Suite* and his "HPSCHD" subroutine "ICHING."⁷⁴ In his article "Programming the *I-Ching* Oracle," Hiller details his method for translating the *I Ching* into a subroutine capable of supplementing each of the main *HPSCHD* computer programs. His account of the process includes both a description of the *I Ching* as a historically significant ritual for a performance, and how its resulting computer program, "ICHING," provided a flexible randomization algorithm that could be used even beyond the *HPSCHD* performance for generating random numbers in a conceptually meaningful way.

Despite the loss of film and photographic documentation of the premiere *HPSCHD* performance, a substantial amount of material from the programming process resides at The John

⁷⁴ Hiller, "Computer Music," 109-121; Hiller, "Programming the *I-Ching* Oracle," *Computer Studies in the Humanities and Verbal Behavior* 3 (1970): 130-143.

Cage Manuscript archive at the New York Public Library of the Performing Arts. This archive contains a wealth of material from the *HPSCHD* programming process, annotated by Cage, Hiller, and programmers within the computing department, including research assistant Laetitia Snow, and others.⁷⁵ As noted within the description of the development of information theory, the content of these printouts—mostly strings of integers meant solely for manual transcription—are valuable in quantitative measure rather than qualitative study. The original documentation produced by the ILLIAC II and IBM-7094 remaining from this transcription process remains valuable in comprehending the sheer abundance and the extremely labor-intensive process of programming *HPSCHD*. In addition, a number of original flowcharts from Hiller’s collection, many of which were from planning the *HPSCHD* programming architecture, were found and restored for a 2007 exhibition at SUNY Buffalo, co-curated by Judy Jungels and John Bewley. After their restoration and subsequent exhibition, each of these charts have been added to the Lejaren Hiller Archive, Music Library, University at Buffalo, The State University of New York, Buffalo, New York. They now reside in the Lejaren Hiller Collection of Compositional Flow Charts, circa 1968-1987, Music Library, The State University of New York at Buffalo.⁷⁶

Unfortunately, many general historical accounts regarding the history of computing leave out information about the ILLIAC supercomputer series, opting to outline the modifications and advances made by IBM (the International Business Machines Corporation) in creating a more business-oriented and commercially-viable computer.⁷⁷ However, existing operating system

⁷⁵ New York Public Library Music Division Archives, John Cage Music Manuscript Collection.

⁷⁶ The Lejaren Hiller Collection of Compositional Flow Charts, circa 1968-1987, Music Library, The State University of New York at Buffalo.

⁷⁷ Though he attempted to construct a thorough history of “modern” computing, Paul Ceruzzi’s *History of Modern Computing* leaves out computing research in academic institutions. Paul E. Ceruzzi, *The History of Modern Computing* (Cambridge MA: MIT Press, 2003).

manuals for both the EDVAC and ILLIAC series, as well as the Institute of Electrical and Electronics Engineers (IEEE) Computer Society reports updating professionals in the expanding field as to their research and advancements provide invaluable insight into the functioning of these early computers.⁷⁸ Each report provides system standards regarding the rapidly evolving hardware architecture and the materials used to both program and transcribe information so fundamental to the transformation and evolution of the growing computer science discipline.

Because of the interdisciplinary nature of information theory, much of the literature that provides a historical basis for understanding the context of programming *HPSCHD* lies in texts outside of the art historical domain, and instead in interdisciplinary fields such as the history of science and technology and in media theory. Writings by pioneer telematics artist Roy Ascott, as well as Gene Youngblood's 1970 text *Expanded Cinema*, serve as prescient examples explaining the zeitgeist in which *HPSCHD* was conceived and the process-based, performance context in which programming was understood. More recent secondary historical texts, such as Grant D. Taylor's *When the Machine Made Art: The Troubling History of Computer Art*, Edward Shanken's encyclopedic *Art and Electronic Media*, a variety of works by media archaeologists Erkki Huhtamo and Siegfried Zielinski, as well as collections such as *Mediaarthistories* edited by historian Oliver Grau, and Hannah B Higgins and Douglas Kahn's indispensable *Mainframe Experimentalism: Early Computing and the Foundations of the Digital Arts*, attempt to reconcile

⁷⁸ Jon Von Neumann, *First Draft of a Report on the EDVAC*, Moore School of Engineering University of Pennsylvania, Philadelphia (June 30, 1945); *Report No. 80: On the Design of a Very High-Speed Computer. October 1957, second edition, revised in part April 1958* (The University of Illinois Graduate College Digital Computer Laboratory, 1958); H. C. Brearley, H. C. C, "ILLIAC II—A Short Description and Annotated Bibliography," *IEEE Transaction on Electronic Computer*, Volume EC-14, Number 3 (June 1965); Daniel Slotnick et al., *Illiack IV system manual*, accessed December 16, 2015: <http://archive.computerhistory.org/resources/text/Burroughs/Burroughs.ILLIAC%20IV.1974.102624911.pdf>.

the often disparate histories of art and computation. It is my hope that this text will be added to this ever-increasing list of texts that elucidate the history of radical aesthetic experimentation through the mediums of hardware and software engineering.

Though John Cage's interest in the writings of—and friendship with—Marshall McLuhan clearly influenced some of the themes driving *HPSCHD*, casting McLuhan's writings as overwhelmingly techno-utopian over-determines much of the deeper historical significance and connections of his work. As demonstrated in the extended prosthetic relationship description, it is essential to return to Marshall McLuhan's relevant texts for a greater understanding of the media zeitgeist surrounding a work such as *HPSCHD*: McLuhan's widely influential 1962 text *Gutenberg Galaxy: The Making of Typographic Man* undeniably made its mark upon the ultimate form of *HPSCHD* as a celebration of humanity's ascendance into the Digital Age, but also touched upon the psychoanalytical tug-of-war over autonomy and agency that the prosthetic relationship played with our technological extensions. In addition, some of McLuhan's lesser-known works, especially his 1963 essay "The Agenbite of Outwit," provided an uneasy warning regarding our lack of control over these prosthetic extensions; in describing "the agenbite of outwit," a play upon James Joyce's "agenbite of inwit," McLuhan remarks, "The point of the Narcissus myth is not that people are prone to fall in love with their own images but that people fall in love with extensions of themselves which they are convinced are not extensions of themselves."⁷⁹ Though providing a much darker view of the prosthetic relationship, McLuhan

⁷⁹ A play on the Old English phrase "the agenbite of inwit," in which "agenbite" refers to remorse, or being "bitten again," functions as a reference to the circular plight of James Joyce's *Ulysses*. "Agen" stands for the Old English for "again," which references both the return of remorse, but also the reflexive nature of the prosthetic relationship. This was one of John Cage's favorite of McLuhan's texts, having used it as a major source for his mesostics; McLuhan, "The Agenbite of Outwit," *Location*, 1:1 (1963): 41-44.

suggested that through our technological extensions, we have the opportunity to remake ourselves—that is, if we are able to see through the deceptions constructed by our subconscious.

Here again I return to John Dewey, his pronouncement with which I opened this introduction, "...the self is not something ready-made, but something in continuous formation through choice of action."⁸⁰ The ongoing relationships that characterize the circumstances around *HPSCHD* extend not only back as far as human history in its description of prosthetic (human-technological) relationships, but into a future of new technologies and their subsequent impact and transformation in relation to their human partners. Dewey explains, "We are not sufficiently alive to feel the tang of sense nor yet to be moved by thought. We are oppressed by our surroundings or are callous to them. Acceptance of this sort of experience as normal is the chief cause of acceptance of the idea that art cancels separations that inhere in the structure of ordinary experience."⁸¹ In this way, Dewey casts a long shadow over any interdisciplinary research, but also proves a helpful guide to any art historian troubled by this callousness in the face of such rich, experience-based projects as *HPSCHD*. It only seems proper that Dewey come to the rescue of Cage, a professed acolyte, and Hiller, an interdisciplinary scion whose pedagogical practices greatly ally with the pragmatists' methods. While *HPSCHD* is neither simply a disappointment nor a triumph, it is a deeply radical, experimental performance that is still, through its many re-stagings and renewed historical interest, in continuous formation.

⁸⁰ Dewey, *Democracy and Education*, 336.

⁸¹ Dewey, *Art as Experience*, 271.

II. *I Ching* to “ICHING”: Programming as Performance

II. 1. Turning on/into Artists, Turning on/into Machines

I must admit I’ve never particularly liked the [harpsichord]. It sounded to me like a sewing machine. The fact that it had so little change in dynamics, and the quality of sound seemed to obscure the—I don’t know—life of the sound, the pitch of the sound, or what you wish.

—John Cage⁸²

My music tends to proceed from disorder to order. It starts with random generation of musical elements and proceeds with the imposition of more and more constraints on the elements' acceptability. I have done this consistently since the original *Illiac Suite*. To be sure, I was much influenced by readings I had done in information theory. Not only does this procedure work, but it seems philosophically satisfying. The trap in writing a completely deterministic set of algorithms is that they reduce the whole process to mere data transformation.

—Lejaren A. Hiller Jr.⁸³

When art is a form of behavior, software predominates over hardware in the creative sphere. Process replaces product in importance, just as system supersedes structure. Consider the art object in its total process: a behaviourable in its history, a futurible in its structure, a trigger in its effect.

—Roy Ascott⁸⁴

In 1937, John Cage delivered a lecture to a Seattle arts society on the future of music.⁸⁵

He explained how new technological methods in music composition fundamentally reconfigured the role of composer: with the advent of “synthetic” music production, a composer could have direct access to the tools for organizing sound without the mediation of performers. No longer confined to the flavors of the orchestra, new technologies could create music from any recorded, stored, replayed, and manipulated sound. Tones freed from whole and half steps could occupy an

⁸² Austin, “John Cage and Lejaren Hiller, *HPSCHD*,” 11.

⁸³ Hiller, “Composing with Computers: A Progress Report,” 8.

⁸⁴ Ascott, “Behaviourables and Futuribles,” 158.

⁸⁵ Cage’s Seattle lecture was reprinted in *Silence* with this introductory note: “The following text was delivered as a talk at a meeting of a Seattle arts society organized by Bonnie Bird in 1937. It was printed in the brochure accompanying George Avakian’s recording of my twenty-five-year retrospective concert at Town Hall, New York, in 1958.” Cage, *Silence*, 6.

infinite range of frequency, and fractions of a second could be manipulated to become infinitely divisible. Cage concluded with a description of a future music laboratory, listing the tools necessary for an environment commensurate with the scientific method:

Before this happens, centers of experimental music must be established. In these centers, the new materials, oscillators, turntables, generators, means for amplifying small sounds, film phonographs, etc., available for use. Composers at work using twentieth century means for making music. Performances of results. Organization of sound for extra-musical purposes (theatre, dance, radio, film).

THROUGH

THE PRINCIPLE OF ORGANIZATION OR MAN'S COMMON ABILITY TO
THINK.⁸⁶

As indicated by a 1966 diary entry, Cage's enthusiasm for technology was only heightened by the capability of the computer to increase art's audience: in a critical play on Timothy Leary's motto of "Turn on, tune in, drop out," Cage imagined the computer as a crucial component in new, inclusive methods of art participation:

Are we an audience for computer art? The answer's not No; it's Yes. What we need is a computer that isn't labor-saving but which increases the work for us to do, that puns (this is McLuhan's idea) as well as Joyce revealing bridges (this is [Norman O.] Brown's idea) where we thought there weren't any, turns us (my idea) not "on" but into artists.⁸⁷

So when his friend, professor of experimental music and computation Lejaren A. Hiller Jr., found him an appointment at the University of Illinois, Cage jumped at the chance.⁸⁸ The contract named him an Associate Member of the Center for Advanced Studies and Visiting Professor of Music, giving him the benefit of a salary without teaching duties for the academic

⁸⁶ The text is reprinted here using the format of Cage's 1957 brochure. Ibid.

⁸⁷ Cage, "Diary: Audience 1966," in *A Year from Monday*, 50.

⁸⁸ The details of Cage's research position at the University of Illinois can be found in Daniel Alpert's official appointment letter: Daniel Alpert, Dean of the Graduate School, to John Cage, April 5, 1968, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

year of 1967-68 with an opportunity for renewal.⁸⁹ He gained unrestricted access to the University of Illinois Experimental Music Studios (EMS), a setting similar to the one he had imagined in 1937: Hiller had founded the lab in 1958, and it rapidly gained distinction for incubating major contributions in electro-acoustic music, including the development of the Harmonic Tone Generator by his EMS colleague James Beauchamp, and extensive research in expanded gestural computer synthesis by electronic music composer Herbert Brün.⁹⁰ In addition, Cage was given access to the relatively new Graduate Department of Computer Science (previously the Digital Computer Laboratory), granting him the assistance of researchers in experimenting with the university's supercomputer, the ILLIAC II.⁹¹

Douglas Kahn, in his exploration of Cage's discrimination of sound, observed:

...when questioned from the vantage point of sound instead of music, Cage's ideas become less an occasion for uncritical celebration (as is too often the case among commentators on Cage) and his work as a whole becomes open to an entirely different set of representations. What becomes apparent in general is that while venturing to the sounds outside music, his ideas did not adequately make the trip; the world he wanted for music was a select one, where most of the social and ecological noise was muted and where other more proximal noises were suppressed.⁹²

⁸⁹ Hiller claimed Cage called him, stating, "I'd like to do some computer music with you," while Cage recalled Hiller calling with an offer to use his institution's computer facilities for art. John Cage to Peter Yates, 10 March 1967, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois; Cole Gagne and Tracy Caras, "Interview with John Cage," *New York Arts Journal* 1, No. 1 (May 1976): 235.

⁹⁰ The Experimental Music Studios, located within the College of Music at the University of Illinois at Urbana-Champaign, continues to house a variety of experimental, electronic music pursuits. The University of Illinois at Urbana-Champaign, "The Experimental Music Studios," accessed June 11, 2015, <http://ems.music.illinois.edu/>.

⁹¹ The University of Illinois provides an in-depth timeline of the history of computer science, covering the development of its computational systems and the foundation of the graduate computer science degree in 1966. The University of Illinois at Urbana-Champaign, "CS History Timeline," accessed April 12, 2016, <https://cs.illinois.edu/about-us/cs-history/cs-history-timeline>.

⁹² Douglas Kahn, "Silence and Silencing," *The Musical Quarterly*, Vol. 81, No. 4 (Winter, 1997): 556.

Cage was largely deaf to what Kahn calls “a sociology of sounds,” as his performances so often downplayed the social and political aspects of sound despite their increasing relevance in the socio-cultural climate of the late 60s.⁹³ Similarly, Cage’s approach to the computer as an artistic tool suffered the same double-standard: despite espousing such enthusiastic proclamations regarding the burgeoning discipline of computer science, those who knew and worked with Cage reported a startling timidity toward technology. Computer-sound synthesis pioneer Frances White, having worked with Cage on his *Essay* pieces, later remembered:

I always picked up from him a certain shyness around the technology. The equipment was intimidating; it was not user-friendly. He was eager for us to tell him what we were doing with the signal processing and such. He wanted to know what was behind the speech synthesis work we were doing. He never seemed to have an interest in a hands-on approach to the equipment. I observed a sort of reserve from him about technology. We think of him as focusing on the future of music, and yet didn’t get involved in the technology directly and personally.⁹⁴

Frequent Cage collaborator James Tenney corroborated her claim: “Cage’s relationship with the computer was rather tenuous in the beginning... aside from his connection with Lejaren Hiller and the development of *HPSCHD*, I don’t know of any direct involvement than he’s had.”⁹⁵

Though White observed that Cage’s timidity regarding the material equipment of computing was understandable due to its demanding learning curve, his disinterest in “a hands-

⁹³ Kahn also briefly mentions Yvonne Rainer’s criticism of Cage’s “goofy naiveté” toward politics. However, like Kahn in his analysis of Cage’s reduction of sound to his own selfhood, I argue that this judgment seems far too simplistic a dismissal of Cage’s engagement with current sociological and political trends. Kahn, 557; Yvonne Rainer, “Looking Myself in the Mouth,” *October*, No. 17 (Summer 1981): 65-76.

⁹⁴ This conversation came from a panel discussion between James Pritchett (acting as chair), James Tenney, Andrew Culver, and Frances White. The panel was featured at a conference entitled “Here Comes Everybody: The Music, Poetry, and Art of John Cage,” which took place at Mills College in Oakland, California from November 15 to 19, 1995. The transcript was eventually included in a compilation as “Cage and the Computer: A Panel Discussion,” in *Writings through John Cage’s Music, Poetry, and Art*, 198-199.

⁹⁵ *Ibid.*, 190-191.

on approach” indicated a troubling indifference to the physical act of programming; even though he had unfettered access to the ILLIAC II during his time at the university, Cage admitted he learned very little about programming beyond assisting punching FORTRAN cards and learning some longhand computer notation. In correspondence with friends Van Meter and Betty Ames, Cage joked, “[Hiller] does all the programming for me, but I sit by and try to learn (I can now multiply 5 x 5 and get 25 in binary numbers).”⁹⁶ Though the note is likely facetious—by all accounts, Cage remained devoted to watching the programming process, enthusiastically annotating printouts and discussing progress—there is little evidence that Cage adapted his ideas regarding computing and chance operations after his experiences with the ILLIAC II.

Furthermore, from a computer programming perspective, Cage’s interpretation of chance operations seems incomplete, even pedestrian. For example, Florian Cramer, art and technology historian specializing in the digital and analog divide, stated:

It seems paradoxical that Cage sought to create indeterminacy through algorithms. While this contradiction superficially resembles the link of algorithms and the imaginary in psychogeographical computing, it in fact is more naive since it relies on a dubious understanding of “chance.” Algorithms can be used for chance operations as Tzara’s Dadaist poem shows, and—with much older origins probably in ancient India—the dice as a random computing device. But such random operations create stochastic chance, not philosophical-ontological chance. Throwing a die is a stochastic chance operation with the possible outcome of 1, 2, 3, 4, 5, 6. Since these results are foreseeable as the set of potential results, they represent not an ontological, but a deterministic chance... With pieces like *Atlas Eclipticalis*, *Variations I/II* and all *I Ching*-based compositions, it seems as if Cage misreads stochastic chance for ontological chance. The mere fact that a musical piece sounds “like John Cage” or “Cagean” because of its atonality and lack of development for example, disproves Cage’s claim of “indeterminacy.” If his music were really, ontologically indeterminate, it should—for example—be able to sound like a Britney Spears song, too.⁹⁷

⁹⁶ John Cage to Van Meter and Betty Ames, 12 January, 1968, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

⁹⁷ Florian Cramer, *Words Made Flesh: Code, Culture, Imagination* (Rotterdam: Piet Zwart Institute, 2005), 78-79.

Cramer’s observation regarding Cage’s misreading of stochastic and philosophical-ontological chance indicates a much greater, crucial rupture in the theorization of computing in the arts: interpretations of many important principles of information theory, including stochastic chance, often transform into metaphorical or philosophical concepts to the detriment of their procedural, algorithmic significance in computer programming. Though many of Cage’s works appear amenable to cybernetic or systems theory-based readings—for example, Edward Shanken’s cybernetic interpretation of *4’33’’*—Cage’s intentions were guided more by his own interpretations of indeterminacy, chance operation, and Zen Buddhist principles.⁹⁸ As suggested in Chapter 1, Cage’s use of the *I Ching* demonstrates how his unique readings of Zen often altered to suit current interests and projects.

Because present art historical interpretations of *HPSCHD* tend to overemphasize Cage’s involvement, its lack of “Cagean” style—what Cramer identified as evidence of Cage’s misinterpretation of “philosophical-ontological” models of stochastic chance—casts this experiment as a misstep, often citing Cage’s disappointment with the resulting computer-generated sounds as proof.⁹⁹ However, *HPSCHD* was, by all accounts, a truly collaborative process, and disregarding Hiller’s conceptually rich programming methodology also ignores the vital contributions of early computer artists to conceptual art practices of the 1960s and 70s.¹⁰⁰ Though Hiller and Cage shared an interest in the exploration of chance operations, Hiller’s stochastic approach to composition greatly contrasted with Cage’s more philosophical,

⁹⁸ See footnote #33 for Shanken’s interpretation of Cage’s *4’33’’* as a cybernetic artwork. His explanation of Cage’s work and its relationship to Jack Burnham’s concept of systems aesthetics is explored more fully in his article “Art in the Information Age: Technology and Conceptual Art,” *Leonardo* Vol. 35, No. 4 (2002): 433-438; Shanken, “Art in the Information Age,” 33.

⁹⁹ Cage’s various disappointments with the *HPSCHD* audio programs are explained more fully in section II. 4. “Conclusion: Expectations vs. Results.”

¹⁰⁰ See footnote #10.

metaphorical methodology. As explained in his opening quote, Hiller's method of proceeding from the computation of random musical elements to programming "more and more constraints on the elements' acceptability" demonstrates an emphasis on rigid stochastic structures, but also a deeply performative practice involving intense human-computer interaction.¹⁰¹ By examining the research methodologies Hiller and his research assistants employed while programming the audio components of *HPSCHD*, we can better understand how programming constitutes a *performance*: as declared by Roy Ascott in his quote opening the chapter, "When art is a form of behaviour, software predominates over hardware in the creative sphere," emphasizing the importance of process and concept in computational art practice by equating the procedural nature of software with conceptual art practice and performance.¹⁰² An exploration of Hiller's process of experimenting with computational compositions, uniquely influenced by a dogged pursuit of aesthetics as interpreted through information theory, not only reveals remarkable achievements in experimental computational music, but also places *HPSCHD* within a the larger art historical context of conceptual art practice. Ultimately, focusing on *HPSCHD* as a deeply conceptual performance allows us to observe a shift from an art of objects to an art of processes and information.

II. 2. "A MUSICAL SUITE COMPOSED BY AN ELECTRONIC BRAIN": The ILLIAC I and the *Illiatic Suite: String Quartet No 4* (1956)¹⁰³

For many problems, the speed of a computer depends, in a rather complicated way, on the speed of its main random-access memory. A large core memory lends itself to more

¹⁰¹ Hiller, "Composing with Computers: A Progress Report," 7-8. See footnote #82.

¹⁰² Ascott, "Behaviourables and Futuribles," 157.

¹⁰³ The phrase "A MUSICAL SUITE COMPOSED BY AN ELECTRONIC BRAIN" dominated the headline of The United Press news release about premiere of *Illiatic Suite* on August 10, 1956. John Bewley, "Lejaren A. Hiller: Computer Music Pioneer," exhibition notes for *Lejaren A. Hiller: Computer Music Pioneer*, exhibited at the University at Buffalo, SUNY Music Library (Buffalo, NY, 2004), 11.

complicated numerical methods and table look-up procedures, whose use can result in a faster program. Furthermore, for problems whose temporary storage requirements exceed the capacity of the core memory, data must be held on the drum or on magnetic tapes, and be sent to or from the core memory in blocks. Unless the core memory is large, an inordinate amount of time may be consumed in transferring data to and from these auxiliary memories.

— *Report No. 80: On the Design of a Very High-Speed Computer*¹⁰⁴

To understand how Hiller's interest in both information theory and music composition lead to *HPSCHD*, one need look no further than his and Leonard Isaacson's earliest experiments with the ILLIAC I supercomputer, resulting in their seminal 1957 composition *The Illiac Suite: String Quartet No. 4*.¹⁰⁵ Their primary tool, The ILLIAC I at the University of Illinois, was the first computer built and owned by a university. Originally housed in The University of Illinois Graduate College Digital Computer Laboratory, the institutional supercomputer was built as a twin to the ORDVAC (Ordnance Discrete Variable Automatic Computer) computer stationed at the U.S. Army's Aberdeen Proving Grounds in Maryland, performing ballistic trajectory calculations. The ILLIAC weighed approximately 5 tons, and measured 10 feet long and 8½ feet high, and upon its completion contained more computing power than held by all of Bell Laboratories.

As the first high-speed, institutionally-owned supercomputer of its kind, the ILLIAC serves as a prime example of the rapid standardization of modern digital computing components.

The *hardware* of the ILLIAC was based on the computing architecture mathematician Jon von

¹⁰⁴ *Report No. 80: On the Design of a Very High-Speed Computer*, 34.

¹⁰⁵ Though initially titled *Illiatic Suite*, later recordings and performances use its second, more formal title, *String Quartet No. 4*. Today, the work is most commonly referred to by its first title, most likely to highlight its importance as the first computer music composition. In addition, the *Suite* is usually said to have been completed in 1957, even though its premiere was on August 29th, 1956; the most likely reason for this discrepancy is because the *Suite* debuted before the fourth experiment was fully finished, and only the first three movements were performed. The full *Suite* was officially completed and performed again in 1957.

Neumann developed at the Institute for Advanced Study at Princeton, New Jersey in 1945.¹⁰⁶ Like all digital computers after it, the structure of the ILLIAC consisted of a central processing unit (the CPU, which determined its processing “speed”) containing an arithmetic logic unit (ALU) and processor registers, as well as a control unit containing an instruction register and program counter; these elements communicated with an internal memory unit (capable of storing up to 1024 “words,” 40-bit groups of digits, binary or decimal), and input and output mechanisms. In the case of the ILLIAC, auxiliary memory components consisted of drum memory (capable of storing up to 12,800 words) or external magnetic tapes. From the outset, these hardware elements necessitated constant upkeep from the university’s engineering faculty and staff, many of whom dedicated much of their careers to the ILLIAC series’ functioning. Maintenance of the computer was a particularly onerous task; while later computers in the ILLIAC series converted to more robust processing electronic components, the ILLIAC I contained 2,800 vacuum tubes, each lasting for only one year, making daily “preventive maintenance”—that is, tube replacement—necessary for the machine to function reliably.¹⁰⁷

Unlike hardware, the term *software* did not enter common usage in engineering and the computer sciences until well into the 1970s. In his 2000 investigative essay “Origin of the Term Software: Evidence from the JSTOR Electronic Journal Archive,” librarian Fred Shapiro claimed

¹⁰⁶ The Von Neumann architecture is first described in his “First Draft of a Report on the EDVAC,” repr. in *IEEE Annals of the History of Computing*, Vol. 15, No. 4 (1993): 27; Von Neumann, *First Draft of a Report on the EDVAC*.

¹⁰⁷ The ILLIAC II, completed in 1963, was approximately 125 times faster than the ILLIAC I, and contained more than 4 times (53K) its memory. Its most important innovations were the replacement of vacuum tubes with transistors, greatly reducing maintenance time, and the introduction of the pipeline technique: rather than needing to process each instruction one at a time, instructions could be divided into sequences of steps executed concurrently and in parallel. Not only did this automate many repetitive processes, but greatly decreased processing time. This information, as well as more in-depth technical specifications, can be found in H.C. Brearley’s “ILLIAC II—A Short Description and Annotated Bibliography,” 399-403.

that mathematician and engineer John W. Tukey was the first to coin the term “software” in a 1958 published essay regarding the pedagogy of mathematics.¹⁰⁸ Though the etymology of the term still remains unclear, Tukey’s definition of software still proves startlingly apt:

Today the “software” comprising the carefully planned interpretive routines, compilers, and other aspects of automative programming are at least as important to the modern electronic calculator as its “hardware” of tubes, transistors, wires, tapes, and the like.¹⁰⁹

Software can be loosely understood as incorporating input, the programmed instructions encoded to be understood by the computer, and output, the resulting stored or executed data. In the case of the ILLIAC and other early digital computers, the process of programming involved constant interactions between programmer and computer, mediated by a variety of transferable materials, or “units.” The ILLIAC design instructions described the input-output process as contingent on the speed of newly-developed commercial units necessary to the transcription process:

For balance only the fastest possible types of input-output would be appropriate. This includes only magnetic drums and the fastest magnetic tape units. These units are greatly affected by commercial developments and no specific items are listed.

Equipment for Off-Line Operation

Punched card equipment
Punched paper tape equipment
Card and paper tape to magnetic tape converters
Fast printer

Equipment for On-Line Operation

Magnetic tape units with 30 or more channels per tape
Magnetic drum, 50,000 words
Cathode ray tube display equipment
Switching elements need not have an operation time shorter than 1 [use].¹¹⁰

¹⁰⁸ Fred Shapiro, “Origin of the Term Software: Evidence from the JSTOR Electronic Journal Archive,” *IEEE Annals of the History of Computing*, 22 (2000): 69–71.

¹⁰⁹ John W. Tukey, “The Teaching of Concrete Mathematics,” *American Mathematical Monthly*, Vol. 65 (1958): 1–9.

¹¹⁰ *Report No. 80: On the Design of a Very High-Speed Computer*, xv.

As early digital computers had extremely limited core memory, programming depended upon coding by punching out numbers printed onto stock paper cards or paper tape, corresponding to algorithms calculated in advance by the programmer [Fig. 2.1]. The punched cards or tape were then transcribed onto magnetic tape, which would then be loaded or fed into the computer.

Though the mechanical and electronic components have drastically evolved over time, the digital computer still conforms to von Neumann's basic design: hardware forms the material component of digital computing, and software the execution of instructions involved in the programming process. Both the ILLIAC design manual as well as Tukey's definition make clear that software and hardware perform symbiotically; though hardware forms the material aspect of the digital computer, its abilities and limitations fundamentally determine the depth and functionality of the software. In addition, the earliest instantiations of software did not clearly delineate a programming and execution phase; while much of the programming for the ILLIAC involved "Off-Line Operations"—for example, devising algorithms by hand, then translated into punched cards or tape—the adaptations upon running these programs proved frequent and arduous.¹¹¹ Programs consisted largely of defining limits through devising algorithms and converting these sequences into binary notation. Once fed into the computer and executed, magnetic or paper ticker-tape had to be transcribed by hand into decimal notation for human intelligibility.

¹¹¹ I've spoken with a few now-retired scientists who "cut their teeth" on early IBM computer models while students in the 1970s and early 80s. Their anecdotes almost unanimously involved complaints about the weeks, and even months of continuously walking stacks of FORTRAN punch cards from computing facilities to various workspaces around campuses. Some particularly fascinating (and often amusing) anecdotes regarding early computing and its various frustrations are recorded in the IEEE Computing Society journal *IEEE Annals of the History of Computing*.

Regardless of the work involved in this largely trial-and-error process, many researchers from diverse scientific disciplines at the University of Illinois used the ILLIAC I for a variety of purposes previously impossible or too time-consuming to realize: examples included calculating an ephemeris of the Sputnik satellite's orbit, to chemical analysis involving calculating boundary conditions of tetrahedral carbon bonds.¹¹²

However, Lejaren Hiller was the first to express interest in its potential in music composition. This was unsurprising, as much of his childhood background included music study: Hiller's photographer and illustrator father, Lejaren Hiller Sr., encouraged lessons in a variety of instruments, including the piano, saxophone, oboe, and clarinet, as well as composition and harmony.¹¹³ Hiller continued his education in music composition while a chemistry student at Princeton, studying under Milton Babbitt, the noted serialist and electronic composer. He remembered:

The first person I met at Princeton in the Music Department was Milton Babbitt. I still very clearly remember going in and being interviewed by Milton. At that point he was, of course, just a beginning instructor there, he was a young man himself, and he was stuck with handling all the freshman theory classes. So I showed him things like that march I mentioned, and a few other odds and ends, those old pieces, I don't remember what I showed him, but he moved me out of the first-year course and put me into strict counterpoint, which he himself taught, the sophomore course.¹¹⁴

Hiller first began using the ILLIAC as a tool for automating chemical analyses while employed as a research associate at the University of Illinois. After learning how to operate the

¹¹² One of the more storied of the ILLIAC I's functions was its usage in early astrophysical research, running various simulations of artificial Earth satellite orbits. The later task was one of those assigned to Lejaren Hiller while still a researcher in the University of Illinois Department of Chemistry. Bewley, "Lejaren A. Hiller: Computer Music Pioneer," 7.

¹¹³ Born John Hiller, the elder Lejaren studied painting and illustration at the Art Institute of Chicago, becoming mostly known for his staged photographs, used to illustrate fictional and historical scenes. His most well-known series of photographs were his dramatic tableaux illustrations for *Sutures in Ancient Surgery* (New York: Davis and Geck Inc., 1950).

¹¹⁴ Bewley, "Lejaren A. Hiller: Computer Music Pioneer," 5.

computer on a government-supported contract on synthetic rubber research, Hiller began to experiment with adapting these computational methods to music composition. Assisted by fellow chemist Leonard Isaacson, Hiller worked on the *Illiatic Suite* while still a full-time researcher in the chemistry department. He recalled:

While I was in the Chemistry Department I wrote the *Illiatic Suite*, the computer piece, and of course, being not in the field, I was in a state of total frustration about music... Leonard Isaacson and I did this *Illiatic Suite* completely as a bootleg job at night on the Illiac I. The programming came about because I actually adapted some of the rubber molecule programming to the writing of counterpoint. In other words, I had an idea one day when I was hanging around the chemistry lab just doing I don't know what, when I thought, 'Well, you know, if I change the geometrical design of this random flight program I've written,' which had gotten quite complicated, 'Change the parameters – the boundary conditions, so to speak—I can make the boundary conditions strict counterpoint instead of tetrahedral carbon bonds.' And that's how it all started... And then again, after many years, Milton Babbitt enters into my life again. I was down in New York one day, and went over to his house, just on a social occasion, as far as I can remember, and I mentioned what I was doing. I can still remember him taking a sort of double take. He said, 'My God, that is an interesting idea.' And, 'Why don't you pursue the idea?' That made me begin to take it a little more seriously, and I, in fact, then launched the *Illiatic Suite* in earnest. We did this all on our own. Well, we got three movements of it done. Don't forget, I was still teaching chemistry.¹¹⁵

Hiller and Isaacson's *Illiatic Suite* (later, *String Quartet No. 4*) was the first score composed with an electronic computer. In his 1959 *Scientific American* article "Computer Music," Hiller outlined the philosophy and process behind the construction of the *Illiatic Suite* as an introductory exploration of information theory as applied to music composition.¹¹⁶ Citing previous forays into compositional analysis, Hiller emphasized the importance of establishing a relationship between the *content* of the information and the overall *method* of generating musical scores in the service of exploring aesthetic possibilities.¹¹⁷ Hiller explained:

¹¹⁵ *Ibid.*, 7.

¹¹⁶ Hiller, "Computer Music," 109-121.

¹¹⁷ Hiller described a recent example project—a "tune maker" created by Richard C. Pinkerton of the University of Florida—that generated simple melodies through the construction of probability tables derived from nursery tunes. He observed that "this method produces only banal

Information theory relates the “information content” of a sequence of symbols (be they letters of the alphabet or musical notes) to the number of possible choices among the symbols. Information content thus resembles entropy or the degree of disorder in a physical system. The most random sequence has the highest information content; the least random (or most redundant) has the lowest. The apparent paradox in this statement derives from the definition given the term ‘information’ in the theory. As Warren Weaver has observed, the term ‘relates not so much to what you *do* say as to what you *could* say’ [see “The Mathematics of Communication,” by Warren Weaver; *Scientific American*, July, 1949].¹¹⁸

Quoting foundational information theorist Warren Weaver, Hiller emphasized that information theory “throws light on musical structure and on the methods of human composers” in service of generating musical *possibilities* of various compositional methods.¹¹⁹ Through the analysis of structural data on the oscillation between “randomness” (he equates this with “chance”) and “highly organized” or “redundant” music, a researcher might unlock information about the illusive *aesthetic* methods of composers rather than the more quantitative data describing *acoustics*:

The composer, employing what [Igor] Stravinsky has called ‘the great technique of selection,’ introduces redundancy into his relatively random materials in order to organize them into a ‘meaningful’ pattern... But musical sounds are not, as words are, primarily symbols of something else; the meaning of music is peculiarly dependent upon its own structures as such. The study of musical structures by information theory should open the way to a deeper understanding of the aesthetic basis of composition. We may be able to respond to Stravinsky’s injunction and cease ‘tormenting (the composer) with the why instead of seeking for itself the how and thus establish the reasons for his failure or success.’ From the analytical standpoint, the aesthetic content of music can be treated in

tunes. If more interesting music is desired, criteria other than simple averages must determine the probabilities.” Though classical and modern composers provided more complex data, and therefore more complex probability tables, additional analysis of the fluctuation between randomness and redundancy were necessary to elevate the project from mere banal mimicry to useful aesthetic analysis. *Ibid.*, 112.

¹¹⁸ *Ibid.*

¹¹⁹ Scientist and mathematician Warren Weaver holds special importance in Hiller’s theories regarding the use of information theory in music composition due to his pioneering efforts in machine translation; his publications are considered the most influential in popularizing the use of computers for a wide variety of interdisciplinary research subjects, including linguistics, cryptography, and systems theory.

terms of fluctuations between the two extremes of total randomness and total redundancy.¹²⁰

Hiller continued by explaining how a computer could collect information describing the oscillation of randomness and redundancy in certain musical compositions, as well as data across entire artistic oeuvres and eras; a reversal of this analysis could generate probability tables that mimicked both specific composers' styles, or emulated entire musical genres.

Each of the four movements of the *Illiad Suite* corresponded to four experiments: the first generated polyphonic melodies, the second produced four-voice segments within the confines of changing rules, the third experimented with rhythm, dynamics, and instruction, and the fourth developed models and probabilities for generative grammars or Markov chains.¹²¹ Each subsequent experiment required a new program, incorporating increasingly complex methods of generating compositions in service of exploring historical styles and aesthetics.

The first experiment involved programming the computer to compose "simple melodies":

To this end we programmed the machine to generate random integers by a technique borrowed from the "Monte Carlo" method... Random integers from 0 to 14 represented the tones ("white notes" only; no sharps or flats) in a two octave range of the C-major scale. To introduce redundancy we screened the integers by feeding in additional programming instructions; these embodied arithmetical analogues of rules of composition governing 'permissible' sequences of notes. We selected the rules from the elaborate injunctions for 'strict first-species counterpoint,' a formalized musical idiom based on the methods of such 16th-century composers as Palestrina.¹²²

¹²⁰ Hiller, "Computer Music," 109-110.

¹²¹ Lejaren A. Hiller and Leonard M. Isaacson, *Experimental Music: Composition with an Electronic Computer* (New York: McGraw-Hill, 1959): 5-7.

¹²² Giovanni Pierluigi da Palestrina (1525-1594) developed some of the earliest theories of polyphony in sacred Renaissance compositions. The basic "Palestrina style" still serves as a basis for much of the study of counterpoint. "Palestrina, Giovanni Pierluigi da," *The New Grove Dictionary of Music and Musicians*, ed. Stanley Sadie. (London: Macmillan Publishers Ltd., 1980). Hiller, "Computer Music," 113.

Though Hiller referred to integer selection as “random” without further explanation, in information theory, a *random*, or *stochastic process* defines a specific methodology for generating integers. Stochastic processes, as a means of generating random integers, are used to represent the evolution of a system of random values over time. Providing a *probabilistic* alternative to previously *deterministic* processes, stochastic processes were developed to allow a pre-determined amount of indeterminacy: even when the initial starting point is determined, there are many, often infinite, ways the process might evolve. A *Markov chain* (or a “discrete time Markov chain”) is a stochastic process that acts as a mathematical method to chain together a series of randomly generated variables representing the present state in order to model how current changes affect future states. In short, Markov chains base future predictions off of the present, disregarding any other superfluous states, called “memorylessness” in probability theory. In particular, Markov chain Monte Carlo (MCMC) methods, those borrowed by Hiller and Isaacson for the *Illiad Suite*, constitute a class of algorithms most commonly used to sample from a probability distribution. In the case of the *Illiad Suite*, generated integers sampled from a calculated probability distribution were stored in the computer's memory until the machine saved a “melody,” designated as “complete” after a predetermined numeric length was reached. The completed melody was then printed on perforated tape and then transcribed by hand into conventional musical notation [Fig. 2.2].

While the first experiment depended upon a screening procedure based on the key of C and a limited set of agreed-upon Renaissance counterpoint rules, the second and third experiments were produced using a *random chromatic method*, expanding possible tonal values to represent the chromatic scale. These experiments were programmed with the intent of exploiting randomness and redundancy to explore the aesthetic differences between 17th and 20th

century musical styles.¹²³ Specific rhythmic passages were assigned corresponding binary and digital numbers, each integer once again generated using the Monte Carlo method, saved in memory, printed, and transcribed [Fig. 2.3]. The new screening instructions for the second experiment introduced each of the “14 rules of strict first-species counterpoint” one by one, describing how they the increasingly introduced redundancy into the generated compositions; the program first was instructed to avoid random “white-note” music in four voices until “randomness was then made to yield to redundancy in small increments by feeding in the screening instructions one by one. The complete set of instructions yielded counterpoint of fair quality, strongly reminiscent, if one ignores a certain monotony in rhythm, of passages from Palestrina.”¹²⁴

By using four or fewer of the screening instructions, the third experiment ultimately mimicked contemporary experimental methods; Hiller explained by eliminating probability that favored certain tones, programming equality of the chromatic scale served to automate experimental composer Arnold Schoenberg’s influential 12-tone technique through computation:

Since the object was to produce a type of music less imitative than strict counterpoint, the machine was first permitted to write entirely random chromatic music (including all sharps and flats). The result was music of the highest possible entropy content in terms of note selection on the chromatic scale, and thus it was strongly dissonant. With the minimal redundancy imposed by feeding in only four of the 14 screening instructions, the character of the composition changed drastically [from Experiment II]. While the wholly random sections resembled the more extreme efforts of avant garde modern composers, the later, more redundant portions recalled passages from, say, a Bartok string quartet... The experiment concluded with some exploratory studies in Schonberg's 12-tone technique and similar compositional devices.¹²⁵

¹²³ Ibid., 117.

¹²⁴ Ibid.

¹²⁵ Ibid.

Schoenberg's 12-tone technique, a widely influential 20th century compositional method, prevents precedence of any of the 12 notes of the chromatic scale over any other, ensuring that each are sounded as often as one another in a piece of music. The method makes use of tone rows, a means of ordering the 12 pitch classes: all 12 notes are meant to be given equal importance, and the music avoids being in a key.¹²⁶

The fourth experiment involved an even more dedicated stochastic methodology, depending on the computational construction of a series of probability tables generated using the Markov chain Monte Carlo method. This program dictated the frequency of occurrences of all 12-tone values. One of the fourth experiment's probability tables was provided as an example alongside a brief citation describing its notational method [Fig. 2.4]:

SHIFTING PROBABILITIES governing one species of Markoff [sic] chain music are shown in part here; colored letters key the columns of the table to sections of the music shown on page 118 [Fig. 2.5]. The probabilities (P) of the intervals are defined by their "weights" (W), which shift according to a simple arithmetical formula. Markoff music has been composed by several similar schemes.¹²⁷

For example, section "a" on the example probability table indicates that there is a probably of 1.00 (100%) chance of composition section "a" consisting of all four string parts composed in unison, its weight being 1. For section "b," probabilities are shifted; there is now only a probably

¹²⁶ Serialism is recognized to have begun with Arnold Schoenberg's twelve-tone technique in 1921, and many of his contemporaries employed these methods. Schoenberg, influenced by his study of non-Western musical forms and the Hindu raga in particular, approached microtones as experimentation through method, not through sound similarity. The 12-tone technique was an attempt at realizing the destruction of hierarchical components in music; if atonality meant that any pitch could combine with another—that is, forgoing the strictures of harmony—then any traditional compositional rule could be eliminated. For a more in-depth explanation of the technique and its method, see: Arnold Schoenberg, 218; George Perle, *Serial Composition and Atonality: An Introduction to the Music of Schoenberg, Berg, and Webern* (Berkeley, Los Angeles, and London: University of California Press, 1977); Cage, "The East in the West," *Asian Music*, Vol. 1, No. 1 (Winter, 1968-1969), 16; Arnold Schoenberg, *Style and Idea*, ed. Leonard Stein, trans. Leo Black (Berkeley & Los Angeles: University of California Press, 1975), 213.

¹²⁷ Hiller, "Computer Music," 118.

of .67 (67%, roughly 2/3) of the four lines being in unison, and .33 (33%, 1/3) of each of the four sections displaying notes that are octaves of one another. Each subsequent section increases in complexity as fifths, fourths, major thirds, etc. are included with diminishing weights.

The premiere performance of the first three movements of the *Illiatic Suite* took place in the Wedgwood Lounge of the Illini Union at 8:00 in the evening of August 9th, 1956 [Fig. 2.6]. The United Press news release from August 10th indicated a mixed response, mostly negative:

(ILLIAC)
CHAMPAIGN, ILL., AUG 10-(UP)—A MUSICAL SUITE COMPOSED BY AN ELECTRONIC BRAIN WAS INTRODUCED BY A STRING QUARTET LAST NIGHT, BUT SOME LISTENERS DIDN'T DIG THE BEAT.
“WHY, IT DOES AWAY WITH THE NEED FOR HUMAN COMPOSERS,” ONE WOMAN MUSIC LOVER REMARKED GLUMLY,
ANOTHER LISTENER SAID THE FINAL MOVEMENT OF THE COMPOSITION SOUNDED LIKE A “BARNYARD.”
OTHERS AMONG THE AUDIENCE AT THE UNIVERSITY OF ILLINOIS APPEARED RESENTFUL THROUGHOUT THE 15-MINUTE RENDITION.¹²⁸

Surprised by this popular reaction, Hiller dismissed the most negative publicity as “rather silly.”¹²⁹ Despite grounding the *Illiatic Suite* as a demonstration of how computation had the ability to bring greater meaning to the composing process, the press release—as well as its report of audience members’ interpretations—insisted that the entire suite was composed by an “ELECTRONIC BRAIN,” having only been “SPONSORED BY L.A. HILLER, A CHEMIST-COMPOSER, AND L. M. ISAACSON, A RESEARCH ASSOCIATE.”¹³⁰ In their more recent re-evaluation of the *Illiatic Suite*, noted by musicologists Örjan Sandred, Mikael Laurson, and Mike Kuuskankare identified how the increasingly unrestrained, experimental sections of the

¹²⁸ Bewley, “Lejaren A. Hiller: Computer Music Pioneer,” 11.

¹²⁹ Hiller, “Composing with Computers: A Progress Report,” 10.

¹³⁰ Especially telling of the negative spin provided by this news release is calling Hiller a “CHEMIST-COMPOSER,” rather than granting him full-fledged composer status. Bewley, “Lejaren A. Hiller: Computer Music Pioneer,” 11.

composition (particularly movements three and four) may have caused the most alarm: the use of probability tables became a focal point precisely because the generated compositions explored an extreme statistical complexity that often strayed from the kind of melodic and harmonic restraint usually employed by human composers:

The lack of harmonic control is soon obvious; already when the third probability table is used (that includes repeated pitches, octaves and fifths as possible melodic intervals) in measure 5 – 6 it becomes clear that the harmonies are there as a side-effect of melodic movements. After another few measures the four voices walk over the full chromatic spectrum... the melodic intervals are distributed independently of each other. This allows the melodies to ‘walk away’ to form very complex profiles. Hiller and Isaacson are conscious of this situation, and they experiment with different approaches where choices partly depend on the opening note of the passage, or on the preceding interval. It is not clear how this was done in detail, and judging from the aural result and the score, the impact is not always obvious.¹³¹

In other words, though they believed Hiller and Isaacson did intervene in some of the compositional processes by changing tactics in certain sections to modulate repetition and complexity, the “aural result” was ambiguous to an audience unable to discern these interventions.¹³² In the *Scientific American* article, Hiller observed that “tonal” Markov music audibly resembled “atonal” Markov music, despite its different mathematical basis; Experiment III *sounded* very similar to Experiment IV, even though the process of computation between the two greatly differed. Hiller supposed this was due to the work exceeding human perceptual capacity, stating, “These correspondences suggest that if the structure of a composition exceeds a

¹³¹ Örjan Sandred, Mikael Laurson, and Mike Kuuskankare’s article “Revisiting the *Illiac Suite*—a rule based approach to stochastic processes,” accessed July 22, 2015, http://www.sandred.com/texts/Revisiting_the_Illiac_Suite.pdf.

¹³² Although much of his subsequent work after the *Illiac Suite*, with the exception of *Cartridge Cantata* and *HPSCHD*, remained tied to many varying non-computational methods, his role as persona non-grata in musicological circles, due to his supposed denigration of the human composer, remained steadfast; in fact, the *New Grove Dictionary of Music and Musicians*, long held to be an indispensable tome in music studies, only added him shortly before his death in 1994; Andrew Stiller, “Hiller, Lejaren (Arthur),” *Grove Music Online*, reviewed December 10, 2010, accessed July 22, 2015.

certain degree of complexity, it may overstep the perceptual capacities of the human ear and mind.”¹³³

Regarding the future of conceptual art, Lucy Lippard ended her text *Six Years* with a challenge:

Conceptual art has not however, as yet, broken down the real barriers between the art context and those external disciplines—social, scientific, academic—from which it draws sustenance. While it has become feasible for artists to deal with technical concepts in their own imaginations, rather than having to struggle with constructive techniques beyond their capacities and their financial means, interactions between mathematics and art, philosophy and art, literature and art, are still at a very primitive level.¹³⁴

Though Lippard does not name specific technologies among these “external disciplines,” she could easily have been addressing the Hiller’s experiments in computation and art. In contrast to works that operated on “primitive level(s),” the *Illiac Suite* catapulted Lejaren Hiller to the forefront of conceptual computer art practice without the benefit of historical precedent to slow his ascent: as the first musical score completed with the aid of a computer, the public reaction to its premiere becomes more understandable in light of its historical context. Without the requisite knowledge of the experimental, stochastic process by which each movement was produced—or even a basic knowledge of computation—the *Illiac Suite* remained obscure for some years after its premiere in the U.S. despite a growing reputation in Europe.¹³⁵ Perhaps as a counter-reaction

¹³³ Hiller, “Computer Music,” 120.

¹³⁴ Lippard, 263.

¹³⁵ In contrast to the popular reaction to the *Illiac Suite* in Urbana-Champaign, Europe had already greatly outpaced the U.S. in acceptance of creative digital practices. A particularly popular subset of digital experimentation in Europe unfolded in the realm of computer music. In 1946, the Internationales Musikinstitut Darmstadt (IMD) New Music courses were founded as a nexus for documentation, performance, and experimentation. Darmstadt dictated the direction of the European musical avant-garde, having been visited by many of the significant international experimental composers. Lejaren Hiller had been invited to Darmstadt in 1963 to lecture and perform the *Illiac Suite*. Amy C. Beal, *New Music, New Allies: American Experimental Music in West Germany from the Zero Hour to Reunification* (Berkeley: University of California Press, 2006), 141-142.

to its controversy, Hiller and Isaacson continued their investigations, even initially planning a more elaborate follow-up to the *Suite*:

Since completing the “Illiatic Suite,” our efforts have been devoted to more complicated problems of musical structure, the solutions to which may yield a “Second Illiatic Suite.” As against the rather fragmentary music thus far obtained, the objective is to produce compositions in relatively lengthy conventional forms, such as theme and variation and four-part fugue. The computer will also be put to work on “totally organized” music as well as more complex Markoff [sic] chains...

A far more elaborate project is suggested by the question that began this discussion: Can a computer be used to compose a symphony? In principle, there seems to be no reason why it cannot... With a program of reasonable length, the machine could be made to produce, say, a 42nd Mozart symphony, which would prove to be a representative but almost certainly undistinguished work. So long as the human programmer collaborates in the undertaking, the computer cannot be regarded as a truly independent composer.¹³⁶

II. 3. Programming as Performance

Unsurprisingly, Hiller and Isaacson’s *Illiatic Suite* excited John Cage, both because of its notorious reputation and novelty, as well as for its fascinating conceptual premise. Having met on an invitation to the Darmstadt International Summer Courses for New Music, Cage and Hiller maintained a friendly correspondence, much of it regarding the usage of technology in composition. After a brief visit to the University of Illinois campus during the yearly Festival of Contemporary Arts in the mid-60s, Cage made computational composition a priority research topic, despite his playful claims to the contrary (on March 10th, 1967, Cage wrote to his close friend Peter Yates, “Have been appointed to U. of Illinois for next academic year—no obligations, assistant and access to computer! What in Heavens Name will I do with it?”)¹³⁷

¹³⁶ Hiller, “Computer Music,” 120.

¹³⁷ John Cage to Peter Yates, 10 March 1967, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

In a letter to Hiller dated June 12th, 1967, Cage discussed a project using the computer involving “parameasurements”:

2nd idea. A piece for harpsichord following a parameasurement of Mozart, then this measurement applied to a multiplicity of octave divisions (e.g. 5-43 or whatever division it was that Partch settled on), all overtone structures to be harpsichord-like. Piece to be playable on harpsichord with or without tapes, or on tapes with or without harpsichord: many tapes—at least one for each octave division.¹³⁸

Cage’s brief mention of “parameasurement” resembled Hiller’s analytical breakdown of music aesthetics to the fluctuations between randomness and redundancy he described in his 1959 *Scientific American* essay: Hiller conceived the two poles of chaos and monotony as the definition of music, and that the information theorist could take advantage of this fluctuating “ordered disorder” to analyze music aesthetics rather than acoustics.¹³⁹ However, instead of progressing from redundancy to randomness while using counterpoint rules adapted from those established by Palestrina during the Renaissance, Cage proposed to generate compositions from acoustical analysis of Mozart—a proposition Hiller casually mentioned in his article. In addition, Cage’s reference to experimental composer and theorist Harry Partch indicated he was interested in using the computer to exploit *microtones*, interval divisions of semitones of the scale.¹⁴⁰

Though Cage’s “2nd idea” could be interpreted as a natural extension of Hiller’s proposal for a Second *Illiac Suite*, plans for *HPSCHD* continued to expand greatly in scale and theatrical

¹³⁸ John Cage to Lejaren Hiller, 12 June 1967, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

¹³⁹ Hiller, “Computer Music,” 110.

¹⁴⁰ Cage continued his scholarship on computer music, as indicated by the bibliographic notes he kept during the programming process. Some texts included Lejaren Hiller and Leonard Isaacson’s, *Experimental Music: Composition with an Electronic Computer*; Abraham Moles’ *Les Musiques expérimentales* (Paris: Editions du Cercle d’Art Contemporain, 1960); Fred K. Prieberg’s *Musica Ex Machina* (Berlin, 1960), and Heinz Von Foerster and James W. Beauchamp’s edited collection *Music by Computers* (New York: John Wiley and Sons, Inc., 1969). John Cage Collection, New York Public Library, New York, New York.

form, beyond any previously proposed performance. Cage recalled the harpsichord commission he had received from Antoinette Vischer (the Basel, Switzerland-based harpsichordist), and proposed it to Hiller as a project suitable for collaboration.¹⁴¹ He suggested that by situating the limited timbre of the harpsichord in the complexity of a mixed-media event, they could demonstrate computational complexity through harpsichord solos, computer-generated tones, and a variety of visual elements.¹⁴² With the assistance of the University of Illinois' ILLIAC II, the work could be performed on gigantic scale, larger than any composition or performance ever attempted. Of its concept, Cage remembered (author's emphasis):

The original idea, I thought, was more or less tailor-made for a computer: that is to say, an enormous project—enormous in the sense of having so many details in it that, were one to sit down with pen, ink, and paper, it would be a project exceeding the time one could spend at a desk—one that would be suitable for a computer. The original idea came from a notion I had about Mozart's music and how it differed from Bach's music... I thought to extend this 'moving-away-from-unity' and 'moving-toward-multiplicity' and, taking advantage of the computer facility, to multiply the details of the tones and durations of a piece of music.¹⁴³

Neither Cage nor Hiller explained what prompted the combination of harpsichord and computer, though it remains likely that, once confronting the reality of the physical appearance of the ILLIAC II, Cage was either consciously or subconsciously struck by the mechanical resemblance between the harpsichord and the supercomputer. Despite Cage's expressed dislike of the instrument, the harpsichord retains significance as one of a handful of instruments representative of the mechanized, technological turn in music-making, its popularity coinciding

¹⁴¹ Accounts about the beginnings of *HPSCHD* slightly differ; Cage recounted a relaxing evening discussing future projects in the Hillers' backyard garden, but correspondence between Hiller and Cage indicates an ongoing conversation regarding developing "a piece about Mozart"; Cage and Daniel Charles, *For the Birds: John Cage in Conversation with Daniel Charles* (London: Marion Boyers Publishers Ltd., 2010), 141.

¹⁴² Austin, "John Cage and Lejaren Hiller, *HPSCHD*," 11.

¹⁴³ *Ibid.*

with the industrial printing of sheet music. Coming into fashion during periods of pitch, phrasing, and scale standardization in the late 17th and early 18th centuries, it was one of the first complex percussive instruments, necessitating continued access for maintenance, whether for tuning or string and plectrum replacement.¹⁴⁴ In addition, because of innovations in metallurgy, parts such as soundboards, wrest-plates, bridges, nuts, and plectrums could be accurately duplicated to maintain standardization and allow for professional upkeep and maintenance.¹⁴⁵

Because the ILLIAC II constituted a room-sized array of magnetic drum storage units and circuit board modules, all manipulated by one human-sized control panel, it retained aspects of an industrial-era machine in its open mechanics, and—reminiscent of the harpsichord—need of constant human intervention for maintenance and adaptation [Fig. 2.7]. Though this resemblance might not have actively influenced Cage and Hiller’s conceptual plan for *HPSCHD*, the intriguing functional parallel between these machines coincides with their interest in creating a performance reflecting the entwined meta-histories of both music and technology. Cage imagined *HPSCHD* as a vehicle for exploring the increasing complexity of Classical, Romantic, and Modern music composition traditions—represented by Mozart, Beethoven, Chopin, Schumann, Gottschalk, Busoni, and his mentor, Arnold Schoenberg—with the complexity made possible by computing. This meta-narrative of musical composition would ultimately serve to illustrate the evolution of humankind through technology.

For Hiller, *HPSCHD* was an opportunity to expand upon his own related research into the intersection of music composition, information theory, and aesthetics, investigations he had

¹⁴⁴ Neville Horner Fletcher and Thomas D. Rossing, *The Physics of Musical Instruments*, 2nd edition (Berlin: Springer Science and Business Media, 1998), 331.

¹⁴⁵ Edward L. Kottick, *History of the Harpsichord*, Vol. 1 (Bloomington: Indiana University Press, 2003), 14-15.

initiated with Leonard Isaacson and the *Illiatic Suite*. As he explained in a letter to Stephen Husarik, “John wanted the piece to be a homage to Mozart and to quote his music on the harpsichord. I suggested the Dicegame and he went along enthusiastically with the idea.”¹⁴⁶ As noted in Chapter 1, Mozart’s *Musikalisches Würfelspiel* held particular relevance to both a longer history of chance operations in composition, but also recent computational experimentation. In a later article surveying the state of composition with computers, Hiller expressed familiarity with earlier computer composition experiments employing the dice game, remarking upon the programming method his colleague, D. A. Caplin, used to generate a computer dice game in the 1950s.¹⁴⁷ While usage of Palestrina’s counterpoint rules for the *Illiatic Suite* provided a non-arbitrary set of limitations on which to experiment with randomness and redundancy, translating Mozart’s dice game into a *HPSCHD* program greatly emphasized the embeddedness of both prognostication and performance in the history of music and human history more generally.

While Hiller and Isaacson’s *Illiatic Suite* constituted something of a pilot program for generating multiple versions of the same composition for performance, it was during the making of *HPSCHD* that the connection between *programming* and *performance* becomes especially apparent. Hiller’s intention echoes Roy Ascott’s 1967 manifesto “Behaviourables and Futuribles,” in its pronouncement that software constitutes behavior; if a process-based pastime like Mozart’s dice game paralleled both the human action of programming as well as the instruction-based performance of software, both human and computer shared a deeply reflexive, performative prosthetic relationship that fundamentally transformed both.¹⁴⁸ Ascott, a pioneer in

¹⁴⁶ Husarik, 7.

¹⁴⁷ Hiller, “Music Composition with Computers—a Historical Survey,” in *The Computer and Music*, ed. Harry Lincoln (Ithaca: Cornell University Press, 1970), 47.

¹⁴⁸ Ascott, “Behaviourables and Futuribles,” 157.

cybernetic art and the father of telematic art (the integration of computers and telecommunications in real-time art performance), recognized the fundamental effect of media on consciousness.¹⁴⁹ Though the exact terms—“behaviourable” and “futurible”—never entered common usage even in computational art circles, the concept that software was conceived as a *process*, and its programming and usage constituted performance, remained deeply connected to both the methods of many early computer art experiments as well as Lejaren Hiller’s approach to visualizing the architecture for the various *HPSCHD* audio programs and subroutines.

The remaining analysis of this chapter focuses on the enormity of the labor involved in the nearly two-year task of programming *HPSCHD*, with emphasis on the deeply embedded conceptual and poetic performances included therein. Some of this information has been gathered through examination of surviving annotated printouts and ephemera remaining from the programming process, though the mammoth scale of the task is mostly apparent in Hiller’s own programming accounts.¹⁵⁰ The overall structure of the programming elements of *HPSCHD* are apparent through existing flow charts Hiller and his research team constructed and adapted

¹⁴⁹ Edward Shanken’s introduction to *The Telematic Embrace* provides thorough evidence of Ascott’s importance to the development and theory of media art practices, much of it through his early work, such as *Video Roget* (1962) and art objects like *Diagram Boxes & Analogue Structures*, shown at the Molton Gallery in London, February, 1963. As one of the first artists to emphasize the use of technological methods for audience interactivity, he focused on inter-responsive systems where thought and action constitute interconnected components ultimately forming consciousness. Ascott described consciousness as the necessary state in which artist, the artwork, and the spectator could not only radically transform their own physical states, but also influence the creation of social space. Ascott currently serves as the President of the Planetary Collegium, an international research platform promoting interdisciplinary research. Shanken, “Telematic Embrace: A Love Story? Roy Ascott’s Theories of Telematic Art,” last accessed November 16, 2016, http://telematic.walkerart.org/timeline/timeline_shanken.html; Shanken, “From Cybernetics to Telematics: The Art, Pedagogy, and Theory of Roy Ascott,” in *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness*, 1-96.

¹⁵⁰ These manuscripts are housed in the New York Public Library of the Performing Arts research center alongside the original seven *HPSCHD* harpsichord solos.

during the process.¹⁵¹ John Bewley, in his catalogue accompanying the State University of New York at Buffalo Music Library 2007 exhibition featuring the newly restored Hiller flowcharts, explained their fundamental significance:

If a computer program can be described as a set of instructions for carrying out a particular task (an algorithm), then the flowchart was a graphical representation of an algorithm. Programmers used flowcharts to work out their ideas, and then pored over the final flowchart they created, making sure that their logic was correct, before writing the actual computer code. For many programmers, the final code was almost an afterthought: the flowchart was where the bulk of the mental work took place.¹⁵²

As will be further detailed in the description of the programming process, this was only the first of many labor-intensive steps in producing *HPSCHD* and computing more generally.

The programs used to produce *HPSCHD* derived from the programming efforts of Lejaren Hiller and his assistants using the University of Illinois' current supercomputer, the ILLIAC II, and the IBM-7094. The basic structure of the programs constituting *HPSCHD* is mapped in a block flowchart, illustrating how each program and subroutine nested inside the main "HPSCHD" program [Fig. 2.8]. Hiller explained the basic program architecture of *HPSCHD* as follows:

HPSCHD involved three sets of computer programs, one for composing the tape parts and realizing them in sound by means of digital-to-analog conversion, the second for composing harpsichord parts derived from Mozart's Musical Dice Game, and the third for creating a performance part for the high-fidelity enthusiast sitting at home listening to the collage we prepared for a commercial phonograph recording. Contrary to what many critics thought (Will they never learn?), this was not a chaotic piece. The basic note generator was a subroutine called ICHING that recreated the Oracle of the *Book of Changes*. The results of subroutine ICHING were not haphazard, but were based on a polynomial distribution. Also, much of the programming was concerned with melodic

¹⁵¹ Lejaren Hiller Collection of Compositional Flow Charts, circa 1968-1987, Music Library, The State University of New York at Buffalo.

¹⁵² Bewley, "Preserving Lejaren A. Hiller's Flowcharts: A Case Study," co-curated by Judy Jungles and John Bewley (Lejaren Hiller Collection of Compositional Flow Charts, circa 1968-1987, Music Library, The State University of New York at Buffalo, January 2007), 6.

constructions that Cage hoped would express his admiration for the melodic writing of Mozart.¹⁵³

HPSCHD was divided into three basic programs. Two of the main programs contributed directly to the performance: the program “DICEGAME,” often described as a “subroutine” when it was, in fact, a standalone program, was completed in FORTRAN by assistant programmer, Laetitia Snow, to generate the harpsichord solos. The program “HPSCHD,” used to create the multiple microtonal tapes, included several subroutines, including Hiller’s highly involved “ICHING,” as well as “VOLUME,” “CANTO,” “MODE,” “TELEO,” “TIMBRE,” “ML3DST,” and “DIGAN5.” “HPSCHD” had several named sections, constituting steps in its process: “GAMUT,” “DEVIA,” “DURAT,” “ICTUS,” and “TICTUS.” Each of the titles constituted a poetics of the programming process, as the musical terminology of the name choices poetically paralleled the purpose of the program.¹⁵⁴ The last of the named programs, “KNOBS,” was not in preparation of the performance, but instead generated the eventual individual printouts for at-home instructions to be included in the sleeve of each of the *HPSCHD* vinyl recordings.

II. 3. i. Programming the Microtonal Tapes: “HPSCHD” and its Subroutines

Cage, like many experimental musicians before him, found inspiration in a variety of non-Western cultures. In 1946, Cage published an article in *Modern Music* musing on the subject of “Oriental” methods of music composition in the West. Like his mentor, Arnold Schoenberg, Cage described his experimentation through method, not sound similarity: through Eastern inspiration, he claimed, experimental composers could back away from classical tropes regarding

¹⁵³ Hiller, “Composing with Computers: A Progress Report,” 11.

¹⁵⁴ The interpretations of the names of each of the poetically-titled programs and subroutines, as detailed in the next section, are those of the author.

key, scale, and time signature.¹⁵⁵ Schoenberg's 12-tone series represents the most influential example of this method. In a 1968 essay regarding Eastern influence in Western music composition, Cage explained Schoenbergian theory not as a straight imitation of the raga, but rather as "an admission of presence." He concluded, "This great variety of available 'scales' [in Eastern musical traditions] obviously differs from the conventional Western adherence to only two."¹⁵⁶

Cage found the Eastern-inspired microtonal scale particularly intriguing, having already dedicated some time researching the methods of microtonal experimentalists.¹⁵⁷ For Hiller, the opportunity to program microtones was less due to the psychological or philosophical aspects of the audio, but rather presented a task uniquely fitting computational translation. The program "HPSCHD," written in SCATRE by Hiller, was used to generate the material for each of the 51 microtonal, monaural magnetic tapes. Each tape represented a division of five octaves into five to fifty-six tones per octave; each of these tones were then divided into even smaller microtones. Duckworth explained, "According to Cage, these microtonal inflections were arrived at by multiplying the *I Ching* number 'sixty-four' by the binary function implicit in the computer, 'two.' In this manner, there would be one hundred twenty-nine possible pitches for each tone, i.e., -64, ... -1, 0, +1, ... +64."¹⁵⁸

¹⁵⁵ Cage, "The East in the West," 16.

¹⁵⁶ *Ibid.*, 15-16.

¹⁵⁷ Cage explained, "Although the Hindu ragas employ generally only seven tones, these seven are chosen from some forty-odd tones in the octave." Cage frequently mentioned the musicians who experimented with microtones he admired most, among them Julián Carillo, Alois Háva, Charles Ives, and Harry Partch; *Ibid.*, 17; Cage, *Silence*, 94; Duckworth spends considerable time documenting and describing the methodology of many of these composers in his dissertation "Expanding Notational Parameters in the Music of John Cage," 29-34.

¹⁵⁸ The discrepancy in the numbers— $64 \times 2 = 128$, not 129—appears to be due to the inclusion of "0" as a pitch notation. William Duckworth, while a musicology doctoral student at UIUC during the development of *HPSCHD*, witnessed this programming process and recorded the

Tonal and microtonal pitches were generated through the following “HPSCHD” subroutines: “GAMUT” generated the pitches for each scale, as each of the fifty-one tapes contains one “gamut” of five to fifty-six tones per octave. “DEVIA” (for “deviation”) further broke down each of these tones into one hundred twenty-eight microtones. “DURAT” (or “duration”) generated time durations on the order of milliseconds. “ICTUS” and “TICTUS” (for “ictus,” a poetical rhythmic or metric stress, and “tictus,” a possible play on “ictus” as its (t)win subroutine) further dictated the character of both “DEVIA” and “DURAT” subroutines. “ICTUS,” a counter generator, indicated a DEVIA for each note of the scale. Counter generator “TICTUS” assigned DURATS for each DEVIA. “ICTUS” and “TICTUS” values had a range of from one to sixteen, assigned by subroutine “ICHING.” Due to the branching structure of this program, pitch/durational relationships never remained constant.

After calculation and temporary storage of each of the tones, the monaural melody line for each scale was generated by the subroutine “CANTO” (poetically referring to “canto” or “cantus,” both used to reference the melody in vocal music, and a principal division of a long poem) [Fig. 2.9].¹⁵⁹ “CANTO” employed three additional subroutines: “MODE” (as in “diatonic

relationship between programs and subroutines in his own dissertation, “Expanding Notation Parameters in the Music of John Cage” (1972). Though some of the annotated printouts from this number generation process are held in the New York Public Library Collection, the original SCATRE program has long since degraded or destroyed, as it was kept on temporary magnetic tape. In addition, any paper cards or tape that existed in the university’s collection after the programming process—alongside images of the *HPSCHD* performance—were lost to the fires that plagued the campus throughout the 1970s. Thankfully, each of the programs Hiller personally wrote, “HPSCHD” and the “ICHING” oracle, were thorough detailed in articles he published in computer science trade journals. New York Public Library Music Division Archives, John Cage Music Manuscript Collection; Hiller, “Programming the *I-Ching* Oracle,” 130-143; Hiller, “Composing with Computers: A Progress Report,” 7-21; Austin, “John Cage and Lejaren Hiller, *HPSCHD*,” 11; Duckworth, 133.

¹⁵⁹ Flowchart for subroutine “CANTO,” Lejaren Hiller Collection of Compositional Flow Charts, circa 1968-1987, Music Library, The State University of New York at Buffalo.

mode”) generated a diatonic scale by choosing between (through a binary process) whole-steps and half-steps. “TELEO” (as in “teleology”) stochastically “chose” goals from the diatonic scales produced by “MODE.” Duckworth explained the final “CANTO” subroutine, “CHOOSE,” through its relationship to differences in “melodic writing” (differentiating between writing chromatic or diatonic melodies, or arpeggiated motion):

The subroutine “CHOOSE” provided two different functions. First, it determined the actual pitch levels for the notes lead to each goal. Second, it distinguished three styles of melodic writing in notes leading to each goal. Hiller has indicated that it was decided to utilize three styles of melodic writing “because John said he would like to distinguish—in melodic writing—how one differentiates between stepwise chromatic motion, ordinary diatonic writing, and arpeggiated choral motion.”¹⁶⁰

The subroutine “VOLUME” was used to generate the dynamic levels for each melody. The subroutine “ICHING”—a program that will be detailed more fully below on account of Hiller’s painstaking translation of the *I Ching* oracle and *The Book of Changes*—generated integers one to sixty-four. Each of these integers were separated into dynamic ranges: one through sixteen indicated *pianissimo*, seventeen through sixty *mezzo forte*, and sixty-one through sixty-four *fortissimo*. “ORMOLU” (“ormolu,” a term for gilded decorative ornamentation) designated pitch and/or amplitude ornament [Fig. 2.10].¹⁶¹ The character of the ornament was either a “steady-state sound,” a modulation of attack and decay, or a deflection of the decay slope. Each of these ornaments were calculation by additional subroutines “ML3DST” (possibly a portmanteau of “modulate” and “adjust”) and “TIMBRE” (“timbre”).¹⁶²

The final subroutine, “DIGAN5” (likely indicating its function of converting (dig)ital to (an)alogue), translated all of the program and subroutine data from digital into an analogue

¹⁶⁰ Austin, “John Cage and Lejaren Hiller, *HPSCHD*,” 18; Duckworth, 135.

¹⁶¹ Flowchart for subroutine “ORMOLU,” Lejaren Hiller Collection of Compositional Flow Charts, circa 1968-1987, Music Library, The State University of New York at Buffalo.

¹⁶² Duckworth, 135-136.

translation compatible with the subroutine “INTRFC” (“interface”). “INTRFC” recorded the information onto magnetic tape readable by the ILLIAC II sound synthesis program, which compiled this information into three-minute “songs.” The resulting tapes were then spliced together to manually create tapes approximately 20 minutes in length.

Programming the microtonal tapes for the *HPSCHD* performance proved not only extremely time-consuming, but differed greatly from Cage’s very specific ideas as to what the tones produced should sonically resemble, as he thought the timbre should mimic the harsh strike of the harpsichord as much as possible. To this end, he and Hiller had to slavishly recreate the sound Cage so despised: the sharp, brief attack with a curved decay he associated with a typewriter. In later conversations with Daniel Charles about these tapes, Cage described the difficulties the team had in synchronizing the attack and decay elements, as related to the constructed chart of possible tones:

But the curve would only fit into a part of the chart, and when the *I Ching* gave other numbers in other parts of that chart, we had to ignore them. On the other hand, any number appearing at the bottom of the diagram would have an effect on the variations. We could thus end up with very different versions of the same attack. It was interesting.¹⁶³

They were increasingly unable to coordinate the tonal variations needed to mimic the qualities of the harpsichord’s attack and decay patterns, much to Cage’s disappointment. They eventually settled for saw tooth waveforms, producing a very flat, electronic tone with a sharp attack and immediately-following decay pattern, with no possibility of simultaneous, or overlapping sound. Additionally, because of the limitations in the processing capability of the ILLIAC II computer, they also needed to greatly limit the variety of microtones between octaves to 52 divisions.¹⁶⁴

¹⁶³ Cage, *For the Birds: John Cage in Conversation with Daniel Charles*, 142-143.

¹⁶⁴ *Ibid.*, 143.

Ultimately, falling short of the longer recordings and simultaneous tones Cage had wanted, the significantly shorter 3-minute output tapes were spliced together to make several 20-minute long tapes for the performance.

Despite Cage's disappointment with these limitations, some of the programmers, namely Laetitia Snow, were exhilarated by the resulting microtonal tapes, the accompanied performance notwithstanding. In an October 28, 1968 letter to Cage, she wrote, "it was most thrilling, as a matter of fact, to hear real sounds coming out of the end of that long process—I don't think I've ever been quite so thrilled with any of my various computer projects."¹⁶⁵ Snow, who had been involved from the beginning, had found the tapes a wonder, a privilege lost on those not privy to the programming process. Having been mostly uninterested in the details of programming, Cage focused upon the sound of the tapes rather than the systems from which they were made. Not surprisingly, he remained disappointed with the results.

II. 3. ii. *Musikalisches Würfelspiel* to "DICEGAME"

Laetitia Snow was hired in December 1967 to assist Cage for 200 hours of programming. She wrote the "DICEGAME" subroutine following Hiller's original idea of employing Mozart's *Musikalisches Würfelspiel* (K. 294d/K. Anh. C 30.01) to create five of the seven resulting harpsichord solos for the *HPSCHD* performance.¹⁶⁶ Mozart's instructions on the sheet music read: "To compose, without the least knowledge of music, so many German waltzes or ländler as one pleases, by throwing a certain number with two dice" [Fig. 2.11]. His version of the musical

¹⁶⁵ Laetitia Snow to John Cage, 28 October 1968, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

¹⁶⁶ Snow's contract was outlined in a letter from John Cage to Daniel Alpert, 13 December 1967, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

dice game necessitated one hundred seventy-six pre-composed measures of music, arranged in two charts with eight number rows and eleven number columns. The first chart contains material for an A section of music, the second for a B section. Thrown dice indicated the appropriate horizontal and vertical lines on the chart [Fig. 2.12]. As evidenced by the resulting compositions, Cage, Hiller, and Snow chose one particular variant of the game, which creates compositions of sixty-four measures without repetition of phrases, conforming to a ‘AA’ ‘BB’ ‘A’ ‘A’ ‘B’ ‘B’ form.¹⁶⁷

Though simpler than Hiller’s “ICHING” oracle, Snow’s program was meant to simulate the exact method of dice throwing: by mimicking the strict pattern of a dice roll, each measure was generated by pulling from a set of compositions, each of which is identified through numerical sequences that pertained to individual measures. Each piece, as noted above, consisted of sixty-four measures, and was meant to last approximately one minute. “DICEGAME” was then repeated 20 times—producing a total realization of 1280 measures—so that its length matched the generated tapes. Each composition was then hand-transcribed from the resulting ticker-tape onto manuscript paper with the following description:

twenty-minute solos for 1-7 amplified harpsichords and tapes for 1-51 amplified monaural machines to be used in whole or in part in any combination with or without interruptions, etc. to make an indeterminate concert of any agreed-upon length having 2-58 separate channels with loudspeakers spaced around the audience.¹⁶⁸

¹⁶⁷ While Mozart’s chart provides the basis for generating music through dice rolling and designating measures of pre-prepared melodies through providing charts and instructions, it also allows for many variations of how music can be compiled. Though Cage, Hiller, and Snow’s overall form choice seems based upon standard structures from Mozart’s era, they had many variants from which to choose. This is additional evidence of consistent human intervention in the creation of computational musical compositions.

¹⁶⁸ *HPSCHD for Antoinette Vischer*, Solos I-VII, JPB 95-3 Folders 352-358, John Cage Collection, Special Collections and Archives, New York Public Library, New York.

Solos II, III, and IV used the Mozart model as their sole source. Hiller recollected, “John went through one of the regular editions of the Mozart piano sonatas and used the *I Ching* to choose which sonata and which movement. The passages so chosen were labeled ‘Replacement Music 1,’ ‘Replacement Music 2,’ etc. ... We set a limit of seven replacements so that we would end up with a fairly complete version of the terminal piece.”¹⁶⁹ Ultimately, the chosen Mozart “replacements” included: Sonata in D Major, K. 284, second movement, first 24 mm.; Sonata in C Major, K. 330, first movement, first 32 mm.; Sonata in G Major, K. 283, first movement, first 47 mm.; Fantasy in C minor, K. 475, first movement, first 10 mm.; Sonata in B flat Major, K. 281, second movement, first 32 mm.; Sonata in D Major, K. 284, first movement, first 32 mm. Solos III and IV were constructed along the same lines, but with the replacements occurring independently in each hand.¹⁷⁰

Cage offered the first “pure” dice game solo, Solo II, to Antoinette Vischer. He wrote to her on June 3, 1968, “The ‘pure’ dice-game will be circa 40 pages, and will have, I hope, the effect of Satie’s *Musique d’Ameublement*.”¹⁷¹ This hopeful comparison indicated that Cage intended for Vischer’s solo to function as “furniture music” (the literal translation of *musique d’ameublement*), a kind of elevated background music crucial to the “cerebral backdrop” of the performance environment.¹⁷²

¹⁶⁹ Austin, “An Interview with John Cage and Lejaren A. Hiller,” 23.

¹⁷⁰ Solo III and IV’s description were the same: “transcription by John Cage (ms. by allan harlock) of computer printout (“mozart dicegame” with mozart compositions used as replacements, treble and bass linked). amplitude and registration free.” *HPSCHD for Antoinette Vischer*, Solos III and IV, JPB 95-3 Folders 354 and 355, John Cage Collection, Special Collections and Archives, New York Public Library, New York.

¹⁷¹ John Cage to Antoinette Vischer, June 3, 1968, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

¹⁷² Matthew Shlomowitz, “Cage’s Place in the Reception of Satie,” from “‘Fate’ for solo guitar, solo trombone and ensemble,” (PhD diss., Stanford University, 2003), accessed March 28, 2016, <http://www.shlom.com/?p=cagesatie>.

In another letter from March 30, 1969, in preparation for the event, he wrote:

All of the soloists are learning at least 2 solos. Since there will be such a great deal of sound (and I would like to keep the density high—at least 45 of the 59 channels in operation at any time) the soloists will be provided with headphones enabling them to hear what each one alone is playing. You will be able to rest when you plan or wish (a plan cd. be made by chance operations) but that you might play Solo II say 4 times during the evening (or more) and Solo VII an equivalent length of time. As for what Mozart, I will be delighted with your choice or choices. Philip Corner is also playing Solo VII—some Concerto of Mozart I believe, with all the preparatory exercises.¹⁷³

As all of the soloists were to learn two solos, the second offered to Vischer was Solo VII, a piece that included only a title page with the instructions “practice and/or perform any composition(s) by mozart. amplitude and registration free” [Fig. 2.13].¹⁷⁴ As noted in the instructions, Cage left it entirely up to both Vischer and Philip Corner what Mozart piece they preferred to play.

Solos V and VI, on the other hand, used “replacements” from the keyboard canon outside of Mozart. It is apparent that these musical choices were relatively arbitrary, and not necessarily subject to any kind of systematic determination, as indicated by the few dashed-off notes containing alternative pieces of music Cage considered for inclusion—many existing computer printouts contain different permutations of the replacement list, as Cage seemed unsure of how to best represent the history of composition through only a handful of selected composers. For example, one of Cage’s sketches contains an attempt to find relationships and proper timeframes between the lifetimes of each included composer [Fig. 2.14]:

Mozart 1756-1791
Beethov. 1770-1827
Chopin 1810-1849
Schumann 1810-1856
Gotteschalk 1829-1869
Schoenberg 1874-1951

¹⁷³ John Cage to Antoinette Vischer, March 30, 1969, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

¹⁷⁴ *HPSCHD for Antoinette Vischer*, Solo VII, JPB 95-3 Folder 358, John Cage Collection, Special Collections and Archives, New York Public Library, New York.

Cage 1912
Hiller 1924¹⁷⁵

The only significant change from this initial list was his attempt to include Charles Ives, and when he was unable because of copyright issues, to instead include a Ferruccio Busoni concerto.¹⁷⁶ Here, Cage had the unenviable task of securing copyright for the solos, another factor in composer choices. Cage wrote to his publisher Walter Hinrichsen, president of C. F. Peters, that he would include selections from “Beethoven, Chopin, Schumann, Gottschalk, Ives, Schoenberg, and, with binary chance operation, Lejaren Hiller/John Cage.”¹⁷⁷ Later, Cage explained his composer choices: “We divided history from Mozart to the present time—that is, to Hiller’s work and my own work—into roughly 25 year periods, making an historical shift from the Dice Game through Beethoven.”¹⁷⁸ Regardless, alongside copyright issues and historical relevance, the choices remained admittedly arbitrary and subject highly to the preferences of both Cage and Hiller.¹⁷⁹

Even apart from the openness of Solo VII, every other solo had aspects tailored for the individual harpsichord performer. For example, David Tudor was given perhaps the most

¹⁷⁵ *HPSCHD* composer note, JPB 95-3 Folder 346, John Cage Collection, Special Collections and Archives, New York Public Library, New York.

¹⁷⁶ Ives was still within copyright as the composition in question, the *Three-Page Sonata*, was first published in 1949. Busoni’s lifetime—1866-1924—made him an ideal candidate for replacement, even though he was a rather late addition and musical interest for Cage. Sara Heimbecker writes at length about the intent to include Ives, and Cage’s interest in the conceptual paradigm Ives created in his *Universe Symphony*; Heimbecker, 103-107.

¹⁷⁷ Charles Hamm, *Putting Popular Music in Its Place* (London: Cambridge University Press, 1995), 92.

¹⁷⁸ Austin, “John Cage and Lejaren Hiller, *HPSCHD*,” 18.

¹⁷⁹ In later interviews, Cage wasn’t able to recount much of the details about how composers and individual pieces were chosen. The process seemed casual in nature, Cage remembering “[Hiller and I] were probably out there in the trailer telling anecdotes or something like that and it just happened. I really don’t remember.” Cole Gagne and Tracy Caras, *Soundpieces: Interviews with American Composers* (New York: Scarecrow, 1986), 236.

irregular of the solos, Solo I, the composition consisting of a chromatic computer output.¹⁸⁰ The accompanying description indicated how greatly it differed from the other six solos:

Transcription by J.C. of computer printout for scale with 12 tones per octave. Durations are represented by staff-length (5 inches = 1 second; one page = 20 seconds; large numbers at end of every third page = elapsed time in minutes) and also given in milliseconds at beginnings and ends of notes and ornaments. Changes of amplitude facilitated by pressure-sensitive control means designed at the suggestion of david tudor by hugh le caine.¹⁸¹

As noted in the description, the pressure-sensitive amplitude control special device was made to spec by Hugh Le Caine of the National Research Council of Canada, Ottawa. Rene Farley, Tudor's assistant, constructed the pressure-sensitive amplitude control used with the Baldwin electric keyboard Tudor ultimately used for the performance.¹⁸²

Despite the computational generation of each of the harpsichord solos, Cage's correspondence, and the nature of producing the various solos, indicates much of the work involved in choosing the requisite musical scores was not only labor-intensive, but filled with opportunities for choices, errors, or interpretations unrelated to the algorithmic aspects dictated by the framework of DICEGAME. In addition, as evidenced by the sheet music used in transcribing the *HPSCHD* solos, the replacement music was also heavily edited; for example, grace notes were edited out, and publisher information footnoted [Fig. 2.15].

II. 3. iii. Coding the "ICHING" Oracle

Arguably, the most significant of the programs of *HPSCHD* was the "ICHING" oracle subroutine, the second of the two programming projects personally completed by Lejaren Hiller.

¹⁸⁰ In her investigation of *HPSCHD*, Johanne Rivest suggested that Tudor was given Solo I because he hated Mozart's music. Rivest, "In Advance of the Avant Garde."

¹⁸¹ *Ibid.*; *HPSCHD for Antoinette Vischer*, Solo I, JPB 95-3 Folder 352, John Cage Collection, Special Collections and Archives, New York Public Library, New York.

¹⁸² Rivest, "In Advance of the Avant Garde."

Though it was a subroutine inserted into both “HPSCHD” and “DICEGAME” programs, it was the first of the programs completed, meant to directly translate the Zen Buddhist *I Ching* method of coin casting to a computational process. The subsequent program produced both transcribed data that could be fed into other programs and subroutines for random number generation, as well as copious comprehensive *I Ching* charts that simply calculated the numbers that could be generated by tossing coins. In this way, the “ICHING” oracle program served as the poetical programming touchstone that was meant to form the conceptual core of *HPSCHD*: it contained a novel approach to programming chance that reflected the historical concerns of the performance, as well as both the philosophical and information theory investigations that so excited Hiller. In an interview just a month after the premiere, Cage explained how the program was to provide the iconic sound and “inflection” variations for aural effect:

This subroutine was used in order to find at which point this inflection—this change of decay, this place in the sound—changes from note to note. It ought to be, in the end—and as I told you today, we haven’t heard a single sound—not only micro-tonal and micro-durational, but micro-timbral. A micro-*Klangfarben* melody, huh? (*laughter*).¹⁸³

Despite his insistence on translating the *I Ching* for the randomization elements so integral to *HPSCHD*, Cage maintained his distance from the programming process. In a handwritten note at the bottom of a typed letter to his friend Raymond Grimaila after his arrival at the university, Cage remarked, “Am now working with computers! Will never have to toss pennies again!”¹⁸⁴ Though most likely written tongue-in-cheek—he was certainly aware of the

¹⁸³ *Klangfarbenmelodie*, a German compound noun directly translated as “sound-color melody,” is a musical technique that involves dividing a melody between several instruments, meant to add “color” and “texture” (timbre) to the melodic line. The term is thought to come from Arnold Schoenberg’s *Harmonielehre*, a method of constructing “timbre structures.” Arnold Schoenberg, *Theory of Harmony*, trans. Roy E. Carter (Berkeley: University of California Press, 1978), 421. Austin, “John Cage and Lejaren Hiller, *HPSCHD*,” 148.

¹⁸⁴ John Cage to Raymond Grimaila, October 1, 1967, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

philosophical implications of programming a divination method—Cage seemed primarily interested in using the “ICHING” program to automate the time-consuming procedure of continuously tossing coins for *HPSCHD* and for unrealized future projects and personal use.

Hiller, on the other hand, found that interpreting the *I Ching* as a computational randomization method proved a difficult, but significant, historically-charged experiment perfectly suited to his musical and programming interests. He admitted that he was at first reluctant when Cage insisted on using the *I Ching* as a method for probability instead of the preferred Markov method. Aside from its usage during Hiller’s experimentation with the *Illiac Suite*, the Monte Carlo/Markov method had long been the first choice for pseudo-random computational calculations even in conceptual art: Marcel Duchamp famously relied on the Monte Carlo method for randomization calculations in his own work, having produced works such as his series of *Monte Carlo Bonds* (1924), a parody of the financial documents used in playing roulette. One indicator that Hiller recognized the “ICHING” subroutine’s importance was its unique hardware component, set apart from the rest of the *HPSCHD* programs: as detailed in Hiller’s essay describing the development of the subroutine, he programmed it in the assembly language SCATRE for the IBM-7094. Though not explicitly stated, Hiller may have also used the IBM model due to its advanced compatibility; not only would the subroutine easily integrate with the two major programs, but it was easier to store and transfer to future computational projects.¹⁸⁵

¹⁸⁵ The most notable detail of the model IBM-7094, according to Hiller, was though it lacked the processing power of the ILLIAC II, it converted information to magnetic tape storage more easily, and was capable of using a number of subsystem and language support options, such as the assembly language SCATRE—also used in the program “HPSCHD”—as well as the institutionally popular FORTRAN and COBOL; SCATRE, FORTRAN, AND COBOL constitute some of the first *compiled languages*. A *compiler* is a computer program that transforms code written in a programming language into another computer language. A compiler

In order to translate the *I Ching* into the subroutine “ICHING,” Hiller first studied the connection between the casting method and its consultation text, *The Book of Changes*.¹⁸⁶ In constant use since its inception approximately 2600 years ago, this method of *cleromancy*—using sortation, or “the casting of lots,” to generate random number sequences—eventually spread from China across the Far East, first gaining the attention of Western scholars in the 18th century. The *I Ching* coin casting divination method, as opposed to the method of throwing yarrow sticks, proved a difficult but intriguing subject for translation into software. Traditionally, the method dictates that the caster tosses three identical coins, usually bronze. Each inscribed side of the coin, or “heads,” counts three; “tails” counts two. The added sum of the coins results in 6, 7, 8, or 9. These sums correspond to a divided or undivided line, also corresponding to *yin*

is used to convert higher-level languages into a binary form, usually to create executable software programs. An *assembly language* is a low-level programming language for a computer with a strong correspondence between the language and the architecture’s machine code instructions. Each assembly language is specific to a particular computer architecture, while modern, higher-level programming languages—compiled, data-oriented, object-oriented, etc.—are portable and can be used on a variety of machines. SCATRE, though instrumental to the programming of *HPSCHD*, was a short-lived language that proved too proprietary to older IBM and institutional computing models, and was translated to more widely-used assembly languages, such as FORTRAN. Conversely, the IBM-7094 system proved successful precisely because of its compatibility with these more universal computer languages. Its upgradable components were swiftly incorporated into the functioning of various corporations and institutions globally throughout the latter half of the 1960s and 70s; in the U.S. they were being used by MIT and Caltech, NASA, American Airlines, as well as by the U.S. Air Force and Navy; in Japan they were used by Mitsubishi and Toshiba research institutes. Hiller, “Programming the *I-Ching* Oracle,” 137; Emerson W. Pugh, Lyle R. Johnson, and John H. Palmer, *IBM's 360 and early 370 systems* (Cambridge, MA: MIT Press, 1991), 36.

¹⁸⁶ The book is alternately referred to as *The I Ching*, *The Book of Changes*, and *Classic of Changes*. Sometime after the Warring States period (475-403 BCE), the book added commentary to the readings referred to as *The Ten Wings*, once attributed to Confucius. Eventually in the 2nd century, the text was adopted as a substantial classic in Chinese literature and became increasingly spread throughout East Asia as a basis for divination. Regarding its role in literature and criticism, see: Martin Kern, “Early Chinese literature, Beginnings through Western Han,” in *The Cambridge History of Chinese Literature*, Volume 1: to 1375, ed. Stephen Owen (Cambridge: Cambridge University Press, 2010), 1-115.

or *yang*: 6 is interpreted as a “changing” broken line (old *yin*), 7 is an “unchanging” solid line (young *yang*), 8 is an “unchanging” broken line (young *yin*), and 9 is a “changing” solid line (old *yang*). The caster tosses the coins a total of six times, creating a series of six divided or undivided lines. These lines, recorded from bottom to top, create a grouping of two *trigrams*, or one *hexagram* [Fig. 2.16].

As explained by Hiller in his text “Programming the *I-Ching* Oracle,” each trigram, representing a possibility of 8 different choices, symbolizes a familial relationship: whereas trigrams containing one type of line are considered “parent” trigrams, the other “mixed” types take on characteristics of their children. For example, three divided lines characterize “Mother,” while a series of two undivided followed by a divided line (read from bottom to top) are read as “Youngest Daughter.” Likewise, divided lines, interpreted as *yin*, are associated with so-called “feminine” qualities such as “receptive” and “soul.” The undivided line, the *yang*, is associated with “masculine” identification, “firm,” and “mind.” These traits create a continuum of opposing attributes. The familial relationships of the eight trigrams also correspond to opposing elemental attributes: whereas the “Mother” trigram, three divided lines, symbolizes Earth, and each daughter corresponds to the elementals of wind, fire, and marsh, the “Father” trigram represents Heaven, with sons, thunder, water, and mountain.

As the caster tosses six times, these trigrams always come in pairs, combining to form the 64 hexagrams of the *I Ching* [Fig. 2.17]. As evidenced by the readings of the individual trigrams, a hexagram reading is deeply dependent upon the meanings of individual lines, the trigrams, and their relationship to one another. Readings are nuanced interpretations of juxtapositions and interactions. Because most readings are done while referring to *I Ching* texts and varying paraphernalia—of which there are many, though canonic authors and translations exist—

interpretations can vary widely. In addition, as these texts are poetic and philosophical in nature, the act of interpretation by the caster is of a more active and scholarly nature than a daily newspaper horoscope reading. Regardless of the number of texts, variations in caster styles, usage of apocrypha, the process, or performance, of casting and assigning *I Ching* passages from hexagrams has remained largely unchanged in its 2,600 years of practice.

Though the process of casting the *I Ching* seems especially suited to a process-based software application, Hiller resisted taking shortcuts in programming it. To underline the poetic nature of couplings and centuries of interpretation and embedded cultural meaning, he explained correspondences and relationships between certain hexagrams, and identified how earlier textual translations of the *I Ching* do little work in the way of explaining why the hexagrams are numerically assigned as they are. Hiller explained that the sequence is not merely the relatively simple act of assigning the numbers 0 and 1 to divided and undivided lines; while this is the mathematically obvious solution, the particular arrangement of hexagrams correspond to a much more intricate diagram, where lower and upper trigrams are read in an eight by eight matrix [Fig. 2.18].

For example, as the caster tosses the three coins and makes the proper notations, calculations must be made to add up the value of the coin toss. Hiller noted how it would have been mathematically obvious to assign, for instance, a coin toss of heads a “0,” and tails a “1,” corresponding to binary. However, when heads is assigned “3” and tails “2,” the mathematical probability of a toss of three coins can yield one of eight permutations. His text provides a figure outlining the possible tosses, assigned values according to this system, its “name,” written notational line symbol, behavior, and the binary representation necessary to his programming

needs.¹⁸⁷ Mathematically, and for the purposes of Hiller's programmatic methods, one must notice the values resulting from adding the coin tosses are never equal in probability, and another notational option aside from the broken and unbroken line exists. The least probable coin tosses are HHH (three heads) and TTT (three tails), in value either 9 or 6, occurring only 1/4th of the time. The other values consist of 8 or 7, the other 3/4ths of tosses.

This is where the method of programming each step of the *I Ching* casting method becomes crucial to understand why it was desired over random methods; simple random number generation would make the probability of 9 or 6 equal to that of 8 or 7. In the case of three identical coin combinations, the two HHH and TTT are designated “changing,” while the others are “unchanging.” If a hexagram contains all “unchanging” values, only one entry in the *I Ching* is to be read and contemplated. A hexagram with a “changing” line, occurring 82% of the time, requires the caster to generate an additional hexagram. The “changing” notation means that the second hexagram converts the “changing” line to its opposite—divided to undivided, and vice versa. Numerically, this means 9’s are changed to 8’s, and 6’s are changed to 7’s. This second hexagram is then used to refer back to the table to read a second text, interpreted as “possible modes of conduct that would occur in time subsequent to possibilities dealt with by means of the first hexagram,” as explained by Hiller.¹⁸⁸

Hiller’s *I Ching* methods thus emphasize the performative nature of randomization in computing. Process-based actions depend largely upon conscious action and interpretation, guided through objects—the digital hardware—that make future action possible. In describing the programming process, Hiller noted how the observation that the *I Ching*’s matrix of number

¹⁸⁷ Hiller, “Programming the *I-Ching* Oracle,” 131.

¹⁸⁸ *Ibid.*, 135.

sequences has a mathematical rationale based upon the principle of the “magic square”; he realized, however, that this complexity was highly contingent on an embedded history and cultural creation largely opaque to contemporary audiences. Instead, programming the *I Ching* demanded a subroutine that operated as if actually casting coins: it required the generation of integers in four main loops in order to replicate the probability of an actual divination session.¹⁸⁹

Subsequently, computer-generated values are never truly “random,” as computer programming is highly contingent on the algorithmic process, whether it be the *I Ching*, Monte Carlo, or other method. Furthermore, Hiller’s process required months of designing, only a bit of which is communicated through the complexity of the published “ICHING” subroutine flowchart; since programming involves many complex development activities not directly evident in the source code [Fig. 2.19].¹⁹⁰ Each of the steps in casting the *I Ching* required concentrated labor in planning and translating into machine language. Hiller described his approach to the *I Ching* as a method for meaningful experimentation in statistical and probability generation:

Moreover, investigations of techniques of music composition by means of digital computers by myself and numerous other composers and investigators have almost always been strongly oriented toward if not directly dependent upon chance procedures that in turn are implemented by random integer generating routines. This is not to say that computer music is for the most part merely random music—monkey typewriter music, if you will—far from it. The constraints, the limits and the distributions that are imposed subsequent to random integer generation are the crucial determinants that the composer finds interesting to investigate and to manipulate for his expressive purposes, whatever these may be. The ‘method of divination’ is a simple but nevertheless classic case of this.

¹⁸⁹ As indicated in Chapter 1, “The History of Prognostication,” early prognostication systems were necessarily performative and deeply procedural in methodology. In the example of the four-coin method of the *I Ching*, the caster has to either toss four coins or one coin four times in succession; regardless, the order of the tosses results in what now would be interpreted as a four-bit binary number, the order of the tosses crucial in deriving the correct hexagram. *Ibid.*, 133-134, 139.

¹⁹⁰ *Ibid.*, 138.

This process, as we have seen, does NOT produce merely random numbers; were it to do so, it would be pointless to program it.¹⁹¹

Hiller's closing thoughts regarding the programming process demonstrated the importance of procedures and conceptual choice in composition, as "methods of divination" and computation are merely methods from which a composer derives the foundational beginnings of a work. Because both divination methods and computation do not merely produce random numbers, Hiller emphasizes how constraints and limitations, like those of Schoenberg's 12-tone technique or divination procedures, color the outcomes of computation and the restrictions, prejudices, and deliberate choices which the programmer makes during the programming process. The prosthetic relationship of computer and programmer, by extension, are also subject to the prejudices of the cultural context; the failure and disappointment regarding outcomes was not so much a function of the program and its results, but the expectations placed upon it *a priori*.

II. 3. iv. "KNOBS": The At-Home *HPSCHD* Experience

Nowhere are these prejudices more apparent than in the conceptual motivations behind the remaining program "KNOBS" [Fig. 2.20]. This program was created specifically for the manufacture of a Nonesuch Records printed vinyl recording, meant to be available for purchase at the premiere performance. The program produced printouts that would be included in each of the record sleeves alongside a copy of the *HPSCHD* vinyl recording [Fig. 2.21]. The printouts instructed the listener on how to manipulate the controls of her home stereo to achieve a unique and interactive listening experience. Cage claimed each record should include a unique "KNOBS" printout "which will permit a listener to manipulate a stereo playback in twenty

¹⁹¹ Ibid., 141-142.

different ways (altering volume, tone controls, and channels)” on a home record player, providing indeterminacy for the at-home audience.¹⁹²

Each “KNOBS” printout include the following instructions:

The unique set of results given below were generated by means of a program run on the CDC-6400 computer located at the State University of New York at Buffalo in April, 1969. The values listed in the column labeled (time) represent 5 second increments in elapsed duration from the beginning of the composition. The numbers in the six other columns are randomly generated settings of the volume control and the treble and bass controls for the left and right channels, respectively, of your preamplifier, whenever 0 appears, turn the knob in question full left. Whenever 4 appears, turn the knob full right. Whenever 1, 2 or 3 appears, select the appropriate intermediate position. These three intermediate positions should be equally spaced between the extremes. If your preamplifier has only one volume control and balance control, interpret (ch. 1) as the volume control and (ch. 2) as the balance control. Good luck. — — — John Cage and Lejaren Hiller [Fig. 2.22, 2.23]

Though the experimental aspects of the *HPSCHD* record shouldn’t be dismissed, there remained certain motives behind its production commensurate with Cage’s disappointment in the programs used for the performance. Heimbecker noted that although the “KNOBS” printouts created the impression that each listening experience was unique and indeterminate, they were actually the result of the inability of the microtonal tapes to produce overlapping tones; in a later interview, Cage stated that he was pleased with the overlapping that could be achieved in the recording.¹⁹³ At the time of the record release, the interactive feature of the “KNOBS” printout was hailed as a wonderful experimental addition to the performance; one reviewer, Eric Salzman of *Stereo Review*, ecstatically reported, “Right in the safety and comfort of your own living room you can

¹⁹² Sara Heimbecker discussed the philosophy behind the at-home experience of “KNOBS” at length in her dissertation “*HPSCHD*”; Heimbecker, 155; John Cage to Daniel Alpert, 26 September 1968, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

¹⁹³ Interview with John Cage and Stephen Husarik, March 12-13, 1980. Quoted in Husarik, 11.

“perform” *HPSCHD* by altering the levels, balances, basses, and trebles of both channels... [the recording] really only makes sense as a participation piece—the first of its kind!”¹⁹⁴

However, not all of the printouts were, in fact, unique. Despite having produced 12,000 unique printouts, Cage and Hiller greatly underestimated the number that would be needed. David Eisenman, a frequent visual collaborator during Cage’s time at the University of Illinois and one of the contributors to the liner notes of its 2003 compact disc re-release, had been in close contact with Cage over the course of the programming of *HPSCHD*. According to Eisenman, Nonesuch made thousands of additional copies of printout number 10929 upon realizing that *HPSCHD* was selling far beyond what they originally had thought. Eisenman and others did not realize the discrepancy in supposed unique “KNOBS” printouts until much later, upon the debut of eBay online auctions: when original *HPSCHD* recordings began to be auctioned online, it became apparent how many of one particular printout had been copied numerous times. Eisenman and many others involved in the record release agree that this is due to Nonesuch’s scrambling to supply the unforeseen demand: in an interview with Sara Heimbecker, Eisenman reasoned, “clearly Jerry [Hiller] produced several runs of the computer printout, but on the same computer programmed the same way. Between returns and everything else they gradually ran out of original printouts and, you know, the equipment was changing and... my guess is they went ahead and xeroxed one and then stuffed it into many [records]. That’s clearly what happened.”¹⁹⁵

II. 4. Conclusion: Expectations vs. Results

¹⁹⁴ Eric Salzman, “Cage-Hiller: Hpschd,” *Stereo Review* 24, No. 1 (1970): 94.

¹⁹⁵ Heimbecker, 160; John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

Though Hiller and his research assistants found the process and individual successes of the “HPSCHD” programs extremely exciting and rewarding, Cage clearly remained disappointed at the overall results. His frustrations appeared to stem from an inability to adapt his preconceived ideas regarding musicality to the strengths of the ILLIAC II; instead of producing the overlapping complexities he imagined, the computer was only able to generate linear compositional progressions. Though he remained frustrated privately, in his later interview with Austin and Hiller, Cage explained:

Rather than having a line of sounds which would go from one sound to the next, one could have a series of sounds which could overlap in various ways. But to accomplish this means going forward in the program and then going backward and then going on, etc. This would bring about complexities in programming which, in our present circumstances in this particular piece, seem excessive.¹⁹⁶

In order to achieve the overlapping effects he had planned for, Cage ultimately used the magnetic tapes as he had in previous works, particularly his 1965 composition, *Rozart Mix*.¹⁹⁷ Later, in an interview with Larry Austin, he reasoned:

The overlapping that will take place in this piece will have to be the natural overlapping of one tape on another—of different things on one another. But the things which are overlapping one another do not themselves have overlaps within them. And yet it is this fact of sounds overlapping that was, in the case of fine harpsichord playing, productive of a musical experience. What is productive of a mechanical experience is the absence of overlapping—of a sound exiting when the next one begins etc. To being about that action of overlapping in the case if the computer is no doubt possible, but it would take a great deal more programming than we have given, and we have given a great deal.¹⁹⁸

Though he claimed that “mechanical experience” is most productive through the “absence of overlapping,” the resulting performance accentuated such overlapping of all sounds, both

¹⁹⁶ Austin, 12.

¹⁹⁷ Brandon Joseph provided this observation about the usage of magnetic tapes in *HPSCHD*, observing that both make use of “multi-tracking” effects. Joseph, 151; for more details regarding *Rozart Mix* (1965), See Fetterman, 130-133.

¹⁹⁸ Austin, 12.

“musical” and “mechanical.” Further evidence of subsequent changes to *HPSCHD* for the sake of conforming to Cage’s original auditory conceptions for the piece is in the formulation of the program “KNOBS,” the at-home *HPSCHD* listening experience. The tangentially-related project of producing a vinyl recording and providing instructions for a lone listener indicated an entirely different conceptual direction than the original *HPSCHD* project.

Cage’s disappointment regarding the limitations of programming to fulfill his conceptual goals unfortunately downplays the successes achieved by Hiller and his research assistants during the programming process. As was evident from the resulting reactions and reviews of the event (subjects covered in-depth in Chapter 3), Hiller’s underlying fascination with employing information theory in aesthetic analysis in music composition was ultimately relegated to later articles detailing the programming process, and were not apparent in the resulting *HPSCHD* performance. Some of the more interesting aspects of the programming process still remain largely misunderstood or unexplored, particularly how Hiller’s method of programming the “ICHING” oracle emphasized how constraints and limitations influence the outcomes of prognostication results more generally, and how this prosthetic relationship might inform our understanding of prognostication rituals as fundamentally shaping human history.

It’s well known that the challenge of creating experimental art forms lies in the reticence of audiences to accept art that defies the comfortable traditions of the past. By defying hundreds of years of traditional music performance, an experimental composer is asking an audience to challenge deeply embedded historical, sensory, and cultural expectations of which it might not have been aware. This was especially true of computationally-assisted performances such as Hiller and Isaacson’s *Illiac Suite*, and, as will be explored further in the next chapter, even more dramatically witnessed in the varied reception of *HPSCHD*; in addition to tasking an audience

with confronting traditions and their own varied expectations, computational performances, particularly in the context of the tumultuous late 60s and early 70s, provoked deep-seeded fears regarding the anxiety-filled prosthetic relationship between human and computer.

While this chapter attempts to serve as a corrective to current art historical misreading of early computer art, particularly in terms of understanding programming as a deeply embedded performance practice, the research provided herein can do little to completely allay anxieties so deeply entrenched in the human-computer prosthetic relationship. As will be demonstrated in the following chapter, the process of programming the *HPSCHD* audio, though constituting the main focus of Cage and Hiller's original concept for the piece, ultimately remained obscured due to a confluence of prejudices and expectations about the growing field of computing and its relationship to autonomy.

As the next chapter focuses first on the visual elements of the performance and then its subsequent mixed reception, it remains to analyze how the many complex elements of *HPSCHD* ultimately contributed—and continue to influence—subsequent cultural expectations of computation, multimedia, and participatory performance. These misunderstandings and anxieties regarding the prosthetic relationship described by humans and the rapidly developing computing technologies not only problematized *HPSCHD* as a Cage-ian work, but also continues to intervene in our enjoyment and understanding of computer-based works in the present.

III. “The Agenbite of In/Output”: The Premiere of *HPSCHD* and its Afterlife¹⁹⁹

III. 1. “...people actually doing things”: *Social Cybernetization* and Technological Anxiety

As society cyberneticizes, programming the contacts people make with each other, theater gains importance as a live activity, oscillating between relatively unstructured interactions, say at a party, and totally formalized or mediated exchanges, say a job interview. Theater can be semi-formal, narrative, personal, direct, and fun. Its methods encourage audience participation on many levels, some not so obvious. This aspect of theater has heavily influenced politics, sports, and religious ceremony, all of which have become more theatricalized in recent years.

—Richard Schechner, *Performance Theory*, 1977²⁰⁰

Roger Reynolds: Do you think that lack of theater may be partially responsible for some of the negative response to electronic music?

John Cage: Definitely. I think that the most important thing to do with electronic music now is to somehow make it theatrical, and not through such means as turning the lights out, but rather through introducing live performance elements. That is to say, people actually doing things.

—John Cage in conversation with Roger Reynolds, 1962²⁰¹

On May 16th 1969, at 7:30 in the evening, John Cage and Lejaren Hiller’s *HPSCHD* premiered at the University of Illinois’ Assembly Hall [Fig. 3.1, 3.2]. Stephen Husarik, in his comprehensive review of the event, reported:

At 7:30 on the warm, humid evening in May, [Dean of the College of Fine and Applied Arts] Jack McKenzie gave the order to commence, and a trickle of microtonal electronics began to emanate from the fifty-two speakers. The seven soloists began their performances, and continuously changing displays took shape on the enormous screens above. The final layer of the collage was added as the people entered the Assembly Hall, and the performance began.²⁰²

Though many participants anticipated a larger version of Cage’s recent *Musicircus* (1967), instead they found themselves within a considerably more choreographed event: the architectural

¹⁹⁹ The title refers to Marshall McLuhan’s 1963 article “The Agenbite of Outwit,” 41-44. See footnote #78.

²⁰⁰ Richard Schechner, *Performance Theory* (New York: Rutledge Classics, 1977), 239.

²⁰¹ John Cage and Roger Reynolds, “Interview with Roger Reynolds,” in *John Cage* [Catalog], ed. Robert Dunn (Frankfurt: C.F. Peters, 1962), 46-47.

²⁰² Husarik, 15.

form of the new spaceship-like Assembly Hall not only dwarfed *Musicircus*' Stock Pavilion venue, but also further motivated the techno-utopian-themed celebration inside.²⁰³ Throughout the five-hour performance, the nearly 6,000 participants witnessed a dizzying array of closely-curated visual and auditory elements [Fig. 3.3].²⁰⁴ Participants silkscreened images of Beethoven wearing a University of Illinois jersey with Cage's face onto the Day-Glo paper tunics, and then onto their own garments when the tunics ran out [Fig. 3.4].²⁰⁵ They were offered three silkscreened posters with images chosen by chance operations, and could purchase the original Nonesuch *HPSCHD* vinyl recording, its price dependent on the chart generated from the "ICHING" computer program [Fig. 3.5, 3.6].²⁰⁶ Cage wandered about the crowd as Hiller busied himself checking on the varied machinery. After approximately two hours of tremendous sound and imagery, without crescendo or finale, the event simply ended. A few short days of housekeeping and interviews, Cage returned to New York, and Hiller to his position as professor of music at the State University of New York At Buffalo (SUNYAB).

²⁰³ Ed Borman, "Assembly Hall Can Bring Events Not Possible Now," *The News-Gazette, Champaign-Urbana* (February 6, 1958).

²⁰⁴ Richard Kostelanetz's description of the audience participation in *HPSCHD* suggested a Happening-like reaction amongst spectators: he reported, "All over the place were people, some of them supine, their eyes closed, grooving on the multiple stereophony. A few people at times broke into dance, creating a show within a show that simply added more to the mix. Some painted their faces with Dayglo [sic] colors, while, off on the side, several students had a process for implanting on white shirt a red picture of Beethoven wearing a sweatshirt emblazoned with John Cage's smiling face." Kostelanetz, "Environmental Abundance," 173-174.

²⁰⁵ One of the reasons that the paper tunics ran out so quickly might have been due to the Daily Illini's preview of the event, describing the goodies to be handed out during the performance. Marsha Kuhn, "Hpschd! Woweee!: Cage Schedules May 16 as His Computer Extravaganza," *Daily Illini*, May 6 1969.

²⁰⁶ As noted by John Bewley, "Fewer than 100 copies of each of the three *HPSCHD* posters were printed in 1969. The full-sized posters were so popular that they were stolen from bulletin boards and even from locked glass cases." Bewley, "Lejaren A. Hiller: Computer Music Pioneer," 21.

Cage famously challenged the boundaries of music performance by confronting the preconception that music was to be made by musicians (playing traditional instruments, performing prearranged compositions) by shifting the focus away from the traditional artist/musician/performer and onto the performance environment and the interactions of participants. He recognized that early electronic music also broke from traditional ideas of what constitutes musicians, often by eliminating performers entirely; as exemplified by Hiller's early experiments in generating computer music and transferring sound to magnetic tape, much of early computer-generated sound could only be pre-recorded for playback. In an interview with Roger Reynolds long before his appointment at the University of Illinois, Cage already emphasized the need to generate what he called "theater" in an electronic music environment: he anticipated the importance of shifting focus from specialized performer to "people actually doing things."²⁰⁷ Performance theorist Richard Schechner, influenced by Cage's experiments, called these theatrical, participatory environments examples of a larger movement toward *societal cybernetization*: in *Performance Theory*, Schechner described how theater developed from formalized, determinate strictures, or *ritualized actions*, and that new forms of unstructured, indeterminate action equally influenced—and was influenced by—secular behavior throughout society.²⁰⁸ He observed, "Any ritual can be lifted from its original setting and performed as theater – just as any everyday life event can be," elaborating, "... the late 1960s and early 1970s saw a number of performances based on this premise. A family in Greenwich Village sold admission to their apartment where spectators watched them in their daily lives. Of course the Loud Family [from the PBS documentary series *An American Family* aired in 1971] carried this

²⁰⁷ Cage and Reynolds, 47.

²⁰⁸ Schechner, *Performance Theory*, 239; Schechner, "Approaches to Theory/Criticism," *The Drama Review* 10 (4) (1966).

style of documentary drama to its logical end: the feedback from the weekly series actually affected the life the Louds lived, and so we watched the family change under the impact of their knowledge that they were being watched.”²⁰⁹ This kind of metaphorical reflexivity enacted cybernetics’ definition of feedback, and describes a prosthetic relationship between individual and society hypothesized as a technological, rather than an organic, system.²¹⁰

Though Cage’s strategy of transforming an electronic music space into a theatrical environment by shifting performance away from traditional structures, a more informed critique of the relationship between visual and audio aspects of *HPSCHD* lies in an analysis of the same slippages between stochastic and philosophical/ontological chance that troubled Florian Cramer in his assessment of Cage’s philosophies: creating indeterminacy through algorithms is largely illusory in that “results are foreseeable as the set of potential results, they represent not an ontological, but a deterministic chance.”²¹¹ That is to say, the use of computation was potentially a false promise to its audience, where the ecstatic potential of the visual signifiers contrasted with the determined audio structures. What’s more, the development of many of the visuals also relied on stochastic measures, offering a limited matrix of visual signifiers. Though the disjointedness of visual and auditory aspects may have been lost on casual viewers, the lack of the material evidence of computation was palpable; significantly, physical indicators of the painstaking process of programming the auditory portion of *HPSCHD* figured into the performance solely through pre-recorded magnetic tapes. Without such a material presence, the computational element instead was visually represented through a staggering array of slides and films, dominated by *I Ching* visuals and curated NASA spaceflight paraphernalia.

²⁰⁹ Schechner, *Performance Theory*, 152, 168.

²¹⁰ Hayles, *How We Became Posthuman*, 8.

²¹¹ Cramer, 79.

Furthermore, audience prejudices and preconceptions of technological progress greatly influenced readings of the event. While this well-publicized and highly anticipated performance capitalized on the excitement of the rapidly approaching Apollo 11 mission to the Moon, *HPSCHD* premiered on the campus of a university at the cutting edge of institutional computing but also a locus of tumultuous dissent after 1968; in the months following the performance, protests and arson on the politically-active campus became startlingly common. Even in the months and years prior to the premiere, *HPSCHD*'s spectators had already been inundated by a complicated web of techno-utopian and dystopian events, including the successful Apollo missions, reports of institutional and industrial complicity with the brutality perpetrated in Vietnam, as well as the excitement and debate surrounding the highest-grossing film of the previous year, Stanley Kubrick's *2001: A Space Odyssey*.

2001 proves an especially fitting example of these underlying prejudices and anxieties. Though a challenging film with ambiguous meaning, *2001* had a lasting cultural impact that informed subsequent technologically-focused art, *HPSCHD* among them: in fact, a number of *HPSCHD* reviews drew direct comparisons between the ILLIAC and Kubrick's supercomputer HAL 9000. Even HAL himself, in perhaps the most famous scene of the film, reveals his kinship with the ILLIAC before his forced termination:

Good afternoon, gentlemen. I am a HAL 9000 computer. I became operational at the H.A.L. plant in Urbana, Illinois on the 12th of January 1992. My instructor was Mr. Langley, and he taught me to sing a song. If you'd like to hear it I can sing it for you.²¹²

²¹² Part of the fascination of *2001* among audiences—academics and film-enthusiasts alike—was the care with which Kubrick and his crew attempted to accurately portray historical and technological references. For example, HAL's iconic death scene in which he sings "Daisy Bell (A Bicycle Built for Two)" is a direct reference to the first experiments in speech synthesis: in 1961, an IBM 704 at Bell Labs "sang" the standard "Daisy Bell," constituting the first demonstration of computer speech synthesis. In addition to this detail, Kubrick famously sought out meticulous accuracy in his *mise-en-scène*, consulting astronomical artists, aeronautics specialists, and aerospace engineers from NASA for the designs of spacecraft switch panels and

HAL and the ILLIAC shared more than a birthplace and a penchant for music: they provided the audience a locus for projecting their varied expectations and anxieties regarding the rapid technological changes taking place around them. Significantly, media theorist Gene Youngblood describes a “new nostalgia” (his concept) emphasizing the unprecedented rupture between generations due to the isolating effects exerted by the rapid advancement of technology, with relevant scenes from *2001*.²¹³ Related to Youngblood’s “new nostalgia” are McLuhan’s theories regarding the psychological trauma of autoamputation. Though a number of *HPSCHD* reviews cited McLuhan’s philosophies as one of the techno-utopian voices influencing the performance, these claims oversimplify his theories regarding the more ambiguous consequences of technological advancement.²¹⁴ As outlined in Chapter 1, many facile interpretations of McLuhan’s widely influential 1962 text *Gutenberg Galaxy: The Making of Typographic Man* simplify his thesis into a celebration of humanity’s ascendance into the Digital Age. As will be further discussed in this chapter, critical readings of McLuhan’s concept of “electronic interdependence” described in *Gutenberg Galaxy*, *Understanding Media*, as well as other lesser-known works, particularly his 1963 essay “The Agenbite of Outwit,” explored the ambiguities of the often uncomfortable changes ushered in by technologies supporting his “global village.”²¹⁵

display systems. Famously, both Eliot Noyes—IBM’s industrial design consultant—and MIT’s Marvin Minsky provided guidance in the design of HAL 9000. Piers Bizony, *The Making of Stanley Kubrick’s ‘2001: A Space Odyssey’* (Cologne: Taschen, 2015); *2001: A Space Odyssey*, directed by Stanley Kubrick (1968; Burbank, CA: Warner Home Video, 2001), DVD.

²¹³ Gene Youngblood, *Expanded Cinema* (New York: P. Dutton & Co., Inc., 1970), 142.

²¹⁴ Cage often cited McLuhan’s influence on some of his ideas regarding technology. These concepts are explored more fully in Cage, “McLuhan’s Influence,” in *John Cage*, ed. Richard Kostelanetz, *Documentary Monographs in Modern Art* (New York: Praeger Publishers, 1970), 70-71.

²¹⁵ McLuhan, *Gutenberg Galaxy*, 32; *Understanding Media*, 4-8.

All of these factors contributed to the ongoing misinterpretations and relative obscurity of *HPSCHD*. Even Cage and Hiller both moved on to vastly different projects shortly after its premiere: after his experiences at the University of Illinois and particularly the hardships associated with producing *HPSCHD*, Cage abandoned large-scale work altogether, opting to avoid such large-scale, ambitious performances and complicated technologies.²¹⁶ Though he continued to compose, much of Hiller's work at SUNYAB focused on pedagogy and electronic music research and facilitation; while there, he founded of the Experimental Studio at Buffalo and co-chaired the Center of Creative and Performing Arts in 1974, where he and Robert Moog collaborated on new analogical devices and mixers for electronic music production. Nevertheless, *HPSCHD* provides possibilities for a new generation of creative technologists; despite John Cage and Lejaren Hiller Jr.'s creation remaining an underappreciated computational performance within the larger art historical canon, contemporary revivals of *HPSCHD* excite a whole new generation of D. I. Y. art and technology enthusiasts, welcoming radical adaptations through new creative, participatory technologies.

III. 2. *Suite for Two Pianos and Electronic Tape* (1966) and *Musicircus* (1967)

Though much of Stephen Husarik's overview of *HPSCHD* excluded Hiller's computational contribution to the performance, he emphasized Cage's admiration of Hiller's earlier works and subsequent attraction to the University of Illinois campus. He claimed that even though Cage's interest in Hiller's work might have originated in the *Illiac Suite*, it was their mutual interest in accentuating theatricality in electronic music performance that eventually lead

²¹⁶ In conversation with Stephen Husarik in 1980, Cage remarked, "The experience of making *HPSCHD* was so time and energy consuming that I have since steered clear of institutions and the use of comparable technology." Husarik, 15.

to Cage's appointment and the subsequent development and resulting form of *HPSCHD*. His main example is an event that took place just prior to Cage's appointment in 1966: Hiller staged a performance of his *Suite for Two Pianos and Electronic Tape* at Smith Hall, on the University of Illinois campus.²¹⁷ As noted by Husarik, *Suite for Two Pianos and Electronic Tape* was an excerpt from a larger experimental work entitled *A Triptych of Hieronymus*, "a mixdown of elements... where the word BSCH is spelled out in notation."²¹⁸ Inspired by Hieronymus Bosch's famously grotesque altarpiece *The Garden of Earthly Delights* (1515), Hiller instructed his piano soloists to convey this frenzied action within the composition: the score's final section instructs the soloists to "Pound the keyboard senselessly and wildly—include clusters, glissandi, arpeggios... anything will do!"²¹⁹ Husarik noted, "Such programmatic conditions were not clear to some in attendance, and when the exciting finale concluded it moved one spectator to stage a dramatic scene—thereby adding yet another theatricalism to the evening's entertainment. Hiller said, 'The violent assaults on the piano and the vocal howling of the last part, while not ordinarily appropriate to a concert program, are appropriate to Hell'"²²⁰ [Fig. 3.7].

Husarik's description of these theatrical flourishes paralleled his review of *Musicircus*, Cage's first major event during his appointment at the university. The *Musicircus* premiere was held November 17, 1967 at the University of Illinois' Stock Pavilion [Fig. 3.8].²²¹ Its setting playfully comparing its audience members to livestock: Husarik remarked that the Stock Pavilion

²¹⁷ The performance was eventually recorded and distributed in 1970 as part of the vinyl collection *Avalanche/Nightmare Music/Suite for Two Pianos and Tape*; Hiller, *Avalanche/Nightmare Music/Suite for Two Pianos and Tape*, 1970, Heliodor, Heliodor –2549 006, vinyl LP.

²¹⁸ Husarik, 6.

²¹⁹ Lejaren Hiller, *Suite for Two Pianos and Tape* (New York: Theodore Presser, 1966).

²²⁰ Hiller, *Avalanche/Nightmare Music/Suite for Two Pianos and Tape*, Heliodor Records 2549 006; Husarik, 6.

²²¹ Husarik, 4-6.

was “constructed like a turn-of-the-century exhibition armory, the pavilion had tan-bark floor and had been used for showing livestock. It was a great place for people to mill about in because that is exactly what cattle did in it.”²²² The instructions for the performance remained intentionally vague: it was an invitation to bring together a number of performers of any kind, instructing them to perform simultaneously anything they wished for a few hours. While later performances of *Musicircus* range from relatively organized to chaotic (Cage purposefully included very few instructions with the official “score”), the first performance featured multiple performers instructed to commence and stop playing at two particular time intervals, with instructions on when to play individually or in groups within these two periods. The result was a chaotic juxtaposition of many different theatrical and musical performances on top of one another, determined by chance operations. This disjointed mash-up of elements was reflected in its advertising, a poster depicting Beethoven's face pasted on the cartoon body of a ballet dancer with the caption, “You won't hear a thing. You'll hear everything.”²²³

However, comparing the theatrical elements of *Musicircus* to *Suite for Two Pianos and Electronic Tape* overemphasizes Hiller's theatrical intentions. As discussed in Chapter 2, Hiller's interest in music composition was primarily in its relationship to information theory, as it provided conceptual, experimental analysis exploring aesthetics and computation. His approach to theater was far more tentative, and perhaps even peripheral to his performances; in a 1963 essay overview of electronic music experimentation at the University of Illinois, Hiller wrote, “The problem of presenting electronic music in the concert hall is not quite so simple, as everyone knows, because the absence of performers creates a problem of how to focus attention

²²² Ibid., 4.

²²³ Hugo Cole, “Musicircus,” *Guardian*, December 19, 1972.

in this group situation. One solution to this difficulty has been the recent use of compositions for tape recorder and instrumental groups.”²²⁴ Early on, Hiller was aware that computer-generated music had the unique problem of excluding human performers and thus eliminating the focal point of the traditional concert, which is why his performances often mixed magnetic tapes and human musicians. Aside from his many unperformed works that survive as recordings, his live performances often only involved excerpts from larger works: for example, the premiere of the *Illiad Suite* in 1956 included the first three movements, and the *Suite for Two Pianos and Electronic Tape* constituted only a portion of the much longer *Triptych of Hieronymus*.

In contrast, it was Cage that insisted on “performances of results.”²²⁵ Cage agreed with Hiller that early electronic music posed the problem of excising real-time performance. However, as he explained in his interview with Roger Reynolds, his response was to “somehow make it theatrical” with “people actually doing things,” essentially proposing that by shifting the focus of the performance onto each participant as a locus of reception, it would heighten their experience.²²⁶ In his 1955 article “Experimental Music: Doctrine,” Cage insisted:

A sound does not view itself as thought, as ought, as needing another sound for its elucidation, as etc.; it has no time for any consideration—it is occupied with the performance of its characteristics: before it has died away it must have made perfectly exact its frequency, its loudness, its length, its overtone structure, the precise morphology of these and of itself... Relevant action is theatrical (music-imaginary separation of hearing from the other senses-does not exist), inclusive and intentionally purposeless. Theater is continually becoming that it is becoming; each human being is at the best point for reception.²²⁷

²²⁴ Hiller, “Electronic Music at the University of Illinois,” *Journal of Music Theory*, Vol. 7, No. 1 (Spring, 1963): 124-125.

²²⁵ Cage, *Silence*, 6.

²²⁶ See opening quote from Reynolds interview; John Cage and Roger Reynolds, “Interview with Roger Reynolds,” in *John Cage* [Catalog], ed. Robert Dunn (Frankfurt: C.F. Peters, 1962), 46-47.

²²⁷ Cage, “Experimental Music: Doctrine,” in *Silence*, 14.

By “sound,” Cage intentionally widened the scope of noise entering into the performance space; each sound, regardless of source, gained meaning once it was located within the reception of each participant. Fittingly, Cage referred to *Musicircus* a “Reunion,” in which he was not a “composer,” but simply a “facilitator” of such a unique spectator experience.²²⁸

Of the more positive reviews of the experience, filmmaker and musician Ronald Nameth said, “*Musicircus* was great fun. As you moved around the great oval ring, you could hear so many varieties of sounds merging into each other. If you stood in the middle of the ring, you could hear all the sounds at once.”²²⁹ While many enjoyed the performance, not all participants appreciated the modulation of sound in the work, particularly the high volume. Husarik reported:

One participant walked up to Cage during the event, however, to complain about the continuously loud roar. They discussed at it length, mouthing their words; but without having understood each other they parted, each one satisfied that he had communicated his meaning to the other. Coordinator Jack McKenzie said the sound level peaked beyond the threshold of pain at least twice during the evening, and a review of the event bewailed its general disorder: “On and on went the noise until one became so numbed with the overloading... that on leaving the Pavilion the quiet, cold black night seemed to be the strange world.”²³⁰

Many critics complained that *Musicircus* felt too disorganized, their evidence that some participants acted out by interrupting performers, stealing equipment, and damaging props. Later, even Cage expressed frustration with these misinterpretations and subsequent participant outbursts. In his essay “*HPSCHD*—Ghost or Monster?” Brandon Joseph observed Cage’s increasing frustration over misinterpretations by participants that indeterminacy meant “anything goes.” After struggling with these disruptions throughout the four-hour performance, Joseph noted a marked decline in Cage’s emphasis on anarchic methods in subsequent projects.²³¹

²²⁸ Ibid.

²²⁹ Ibid., 5.

²³⁰ Husarik, 5.

²³¹ Joseph, 154.

HPSCHD, as an even larger scale multimedia performance, proved an interesting pilot project in refocusing his emphasis from the more anarchic participatory methods of *Musicircus* to a more focused theatrical event motivated by chance operations.

III. 3. “The Integration of Visual Elements by *I-Ching* Philosophy and Gestalt Psychology”:
Visualizing *HPSCHD*²³²

In contrast to *Musicircus*, *HPSCHD* constituted a more tightly choreographed exploration of techno-utopian concepts, concentrating on computation within the context of space travel. As noted by Sara Heimbecker:

The late sixties was a time of physical transition as the realm of human influence extended into space. The issue of physical ‘space’ once again had become problematic, just as it was in the early 16th century with the discovery of the New World. Just as Thomas More’s *Utopia* was written in the gap between the old world and the new, Cage created *HPSCHD* on the eve of yet another New World of space travel.²³³

The 1969 *HPSCHD* performance acted as an ecstatic preamble to the moon landing of Apollo 11, occurring only a little over two months after the premiere. In fact, the Apollo 10 “dress rehearsal” was to take place only two days after the *HPSCHD* premiere on May 18th, a fact of which *HPSCHD*’s spectators—predominantly a mixture of university students and faculty, as well as Cage enthusiasts who had travelled to attend the event—could not help but be aware. In addition, the design of the University of Illinois’ spaceship-like Assembly Hall, *HPSCHD*’s chosen performance venue, perfectly echoed this space-race excitement: completed in 1963, the clamshell structure was one of the most impressive engineering feats of its time, meant to host a

²³² As will be discussed below, Calvin Sumsion’s graphic design graduate thesis, entitled “The Integration of Visual Elements by *I-Ching* Philosophy and Gestalt Psychology, Showing the Communicative Value of Form” (MA thesis, University of Illinois, 1969) provides descriptions of the *I Ching*-inspired found imagery, and describes the usage of the “ICHING” transcription to designate image placement and number on the performance slides.

²³³ Sara J. Heimbecker, “John Cage’s *HPSCHD*” (PhD. diss., University of Illinois at Urbana-Champaign, 2011), 11.

variety of programming, from music performances to sports events [Fig. 3.9, 3.10]. With a concrete-poured roof supported by 48 massive exterior buttresses, Assembly Hall was designed to maximize space, as the growing University of Illinois campus demanded a far larger volume than its predecessor, the Illini Union Building, could handle.²³⁴

Cage addressed the challenge presented by Assembly Hall's vast, open interior nearly disastrously late in the *HPSCHD* planning process, with less than two months to spare before the scheduled premiere. This did not deter him from pursuing ambitious visuals to match its programmed sound elements: in a letter to Minna and Mell Daniel on March 21, 1969, Cage wrote, "Am busy implementing performance of *HPSCHD* which is no simple matter... It will also be elaborate visually: stars, planets, travel through space. Trying to get coop of NASA!"²³⁵

By far the most demanding of the visuals were the procurement and generation of slides: Cage et al. borrowed and created nearly 8,400 slides, 100 each for the 84 loaned Rotomatic 707 AQ Slide Projectors, each projector suspended from the central rigging of Assembly Hall to cast images onto a gigantic circle of suspended plastic serving as a screen [Fig. 3.11].²³⁶ One source for slides was through Cage's long-time friend, Buckminster Fuller. Cage had met Fuller years before during their tenure at Black Mountain College, and professed a keen interest in his work

²³⁴ Student enrollment was 18,813 in 1958-58, and was predicted to swell to 24,500 by 1965, and 34,000 by 1970. Borman, "Assembly Hall Can Bring Events Not Possible Now."

²³⁵ John Cage to Minna and Mell Daniel, March 21, 1969, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

²³⁶ Cage requested corporate help in producing the visual elements for *HPSCHD*, including the company 3M and General Aniline & Film Materials (GAF) Corporation. After agreeing to loan the university slide projectors for the performance, Allan Rodd, a project manager from the company Sawyer's Slide Projectors, communicated via telegram that he was hoping to be in attendance. Cage, in return, made sure to give all of the companies that supported the performance the appropriate credit, painstakingly listing sponsorship on all the promotional materials personally. Allan Rodd to John Cage, April 30, 1969, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois; Heimbecker, 245.

ever since.²³⁷ Fuller, whose counter-cultural sympathies had greatly boosted his popularity by the late 1960s, had long been identified with his enthusiasm for spaceflight, particularly as a metaphor for human achievement. By the 1960s, his term “Spaceship Earth” communicated a techno-utopian message meant to enervate every individual as a steersman in Earth’s bright future. Fuller was more than happy to intercede on Cage’s behalf: with his help, Cage and Sumsion borrowed slides from NASA, the Palomar Observatory at the California Institute of Technology, the Adler Planetarium in Chicago, and the University of Illinois’ “guest institution,” the Mount Wilson Observatory in California.²³⁸

Calvin Sumsion, at the time a graduate student in design working closely with Cage, detailed his process for creating visuals in his master’s thesis, “The Integration of Visual Elements by *I-Ching* Philosophy and Gestalt Psychology, Showing the Communicative Value of Form.” The thesis focused on the method of integrating imagery onto the various *HPSCHD* visuals: tunics, posters, banners, and the time-consuming, 1,600 hand-inked abstract slides, painted by hand to resemble the computationally-produced *I Ching* sound components. The inking process involved the use of the same printouts originally generated by Hiller for the “ICHING” oracle subroutine. Sumsion included an interview with Cage detailing this process:

We simply made a chart relating the 26 [inks] and 64 and then through hexagrams we were able to discover what inks to be used. Then we divided the total number that we needed by 64 and found out how many of each recipe or each *I Ching* determination of colors was needed, and then we worked... One person would then read the ICHING

²³⁷ John Cage’s partner, dance pioneer Merce Cunningham, remembered Fuller as one of the first faculty they met having arrived at the college. Dickenson, *CageTalk: Dialogues with & about John Cage* (Rochester, NY: University of Rochester Press, 2006), 60.

²³⁸ Cage’s insistence on procuring slides from such prestigious institutions—with the help of Buckminster Fuller, no less—recalls Cage’s quotes regarding dedication and seriousness in all of his many pursuits: “I didn’t study music with just anybody; I studied with Schoenberg,” likewise, “I didn’t study Zen with just anybody; I studied with Suzuki. I’ve always gone, insofar as I could, to the president of the company.” Richard Fleming and William Duckworth, eds., *John Cage at Seventy-Five* (Lewisburg: Bucknell University Press, 1989), 25.

numbers, another one translating them into the categories of the slides, and then there was simply the work of putting the slides in the proper slot, in the proper tray.²³⁹

Finishing the hand-drawn slides and organizing them was a mammoth task demanding all available help. Ronald Nameth remembered that Merce Cunningham, right after he arrived from a flight from New York, was conscripted into painting slides even as he recounted his many strange and tiring misadventures travelling to Illinois.²⁴⁰ Additional slides, made by collaging images culled from the University of Illinois' vast library system and assembled with the help of the art department, depicted Mozart and a variety of computer instructions, the images' size and number again dictated by the "ICHING" subroutine charts.²⁴¹

The mammoth task of arranging these slides, as well as choosing films and lighting Assembly Hall, went to artist and filmmaker Ronald Nameth. Alongside the installation of a disco ball and black lights, Nameth oversaw the construction of 48 screens placed in the outer windows, as well as an additional eleven semi-transparent screens hanging in the center of the hall. Ron Resch, a pioneer of computer-generated art, created thirty 30-foot banners with harmonograph output images also determined by the "ICHING" chart.²⁴² Gene Youngblood described the arrangement of the projected visuals in his *Expanded Cinema*:

Over the central arena hung eleven opaque polyethylene screens, each one hundred feet wide and spaced about two feet apart. Enclosing this was a ring of screens hanging one hundred and twenty-five feet down from the catwalk near the zenith of the dome... Seven amplified harpsichords flanked by old-fashioned floor lamps stood on draped platforms on the floor of the central arena beneath the galaxy of polyethylene and light. In addition to playing his own solo, each harpsichordist was free to play any of the others. Each tape composition, played through loudspeakers circling the hall in the last row of seats near the ceiling, used a different division of the octave, producing scales of from five to fifty-

²³⁹ Sumsion, 8.

²⁴⁰ Ronald Nameth to Stephen Husarik, January 6, 1980, quoted in Husarik, 13-14.

²⁴¹ Husarik, 14.

²⁴² The harmonograph images, mechanically-produced images employing the use of a pendulum, though rendered by hand, had the appearance of many early examples of computer art. Sumsion, 9-10.

six steps. Only twice during the five-hour performance were all channels operating simultaneously; these intervals were stipulated by Cage.²⁴³

The overall effect, claimed Youngblood, transformed Assembly Hall into an architectural analogue of the planetary system: concentric circular promenades and long radial aisles stretching from the central arena to the eaves of the domed ceiling. Each of the forty-eight huge windows, which surrounded the outside of the building, was covered with opaque polyethylene upon which slides and films were projected: thus people blocks away could see the entire structure glowing and pulsing like an enormous magic lantern.

The techno-historical mash-up was Nameth's intentional parallel to Cage and Hiller's soundscape. In an interview with Youngblood, Nameth described his image curation as intending to communicate human techno-evolution, providing a succession of images beginning with prehistoric cave drawings, to ancient astronomical diagrams, ending with the provided NASA footage. This "telescopic" effect was meant to parallel the musical source material by expressing a meta-narrative of man's evolving ideas of the structure of the universe. Nameth described the mix of documentary and fiction footage, culled from the history of film:

The visual material explored the macrocosm of space... while the music delved deep into the microcosmic world of the computer and its minute tonal separations. We began the succession of images with prehistoric cave drawings, man's earliest ideas of the universe, and proceeded through ancient astronomy to the present, including NASA movies of space walks. All the images were concerned with qualities of space, such as Méliès' *Trip to the Moon* and the computer films of the Whitney family. The people who participated in *HPSCHD* filled in the space between sound and image.²⁴⁴

The remaining curated visuals incorporated the participants themselves, serving as mobile projection screens. With their smocks inked in fluorescent colors, black lights made each spectator glow, appearing almost as stars in the vastness of the dark space of Assembly Hall.

²⁴³ Youngblood, 375-378.

²⁴⁴ *Ibid.*, 378.

Sumsion wrote of the intention behind these smocks: “It is hoped that as the black light selects individuals at random they will feel some involvement and individual participation in *HPSCHD*.”²⁴⁵ Frances Ott Allan, an audience member, described the lighting effects as it turned Assembly Hall into “outer space—so black and far away,” continuing, “It was like being on a small planet sitting in space. You could get a feeling too of being in space and seeing a planet from high in the seats... The black spotlight catches people at the edge of the circle and in the seats, and playfully and at random shows a beautiful color here, another there” [Fig. 3.12].²⁴⁶ In agreement with her ecstatic space-time description, another *HPSCHD* attendee sent John Cage a letter gushing, “I remember looking up within the Assembly Hall dome and feeling that we were deep inside a space ship voyaging to another galaxy (perhaps celebrating the equivalent of crossing the line).”²⁴⁷ Some spectators, inundated with promotional materials and other varieties of swag, left Assembly Hall that night with a sense of joy and merriment, having experienced another of Cage’s unique spectacles.²⁴⁸

III. 4. “Utopia of Escape”: A Holistic *HPSCHD* Critique

Though reports of euphoric celebration appear genuine, they present what seems a stereotypical, dated response often associated with 60s-era cultural touchstones involving space-opera science-fiction and psychedelia. In direct opposition to Hiller et al.’s methods of programming the *HPSCHD* sound elements, the methodology for creating the performance

²⁴⁵ Sumsion, 33.

²⁴⁶ Fetterman, 254.

²⁴⁷ Author unknown to John Cage, December 30, 1969, John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

²⁴⁸ The remaining visual elements involved in *HPSCHD* constituted printed and promotional materials, including *I Ching*-designated posters designed by Calvin Sumsion, as well as banners produced by artist and designer Ron Resch.

visuals revealed the slippages between the more material, process-based discipline of system theory and the more metaphorical, currently popular readings of cybernetics. Though some aspects of creating slide imagery relied upon the “ICHING” subroutine printouts provided by Hiller, much of the resulting visual aesthetic largely mimicked the popular psychedelic style of the era. Nameth’s film choices, particularly Georges Méliès’ *Voyage to the Moon*, provide some of the goofier examples of the spaceflight films revelers enjoyed that night; images of college-aged hippies dancing to a cacophony in Day-Glo tunics likewise paint a rather *Laugh-In*-esque spectacle which could only happen in the late 1960s. Investigating these techno-utopian aspects, Heimbecker described such reactions as a kind of late 60’s naiveté. In reference to these celebratory, techno-utopian gestures, she quotes Lewis Mumford’s analysis of utopia:

According to Mumford, the utopia of escape ‘seeks an immediate release from the difficulties or frustrations of our lot,’ whereas, the utopia of reconstruction ‘attempts to provide a condition for our release in the future.’ The utopia of reconstruction attempts to change the world, and in this way, *HPSCHD* is a utopia of reconstruction, informed not only by Cage’s optimistic view of technology, but also by his Thoreauvian anarchist politics.²⁴⁹

Though Mumford’s designation of a “utopia of reconstruction” seems to fit *HPSCHD* as it celebrates human achievement through technological means, casting the performance within the rhetoric of “chang(ing) the world” provides a stereotypical, even naïve interpretation of the larger tumultuous historical context of the late 1960s. In addition, reading *HPSCHD* through Mumford’s concept of “utopia of reconstruction” discounts his pronounced criticism and distrust of technology. In his text *The Myth of the Machine Vol II: The Pentagon of Power*, Mumford criticized modern technology’s unrestricted expansion:

The ideology that underlies and unites the ancient and the modern megamachine is one that ignores the needs and purposes of life in order to fortify the power complex and extend its dominion. Both megamachines are oriented toward death; and the more the

²⁴⁹ Heimbecker, 34-35; Lewis Mumford, *The Story of Utopias* (New York: Viking, 1962), 15.

approach unified planetary control, the more inescapable does that result promise to become.²⁵⁰

Though Cage, Sumsion, and Nameth's curation of the *HPSCHD* visuals meant to facilitate techno-utopian interpretations, the very same visuals could be read as complicit with much of the qualities Mumford levelled at the "megamachine": the space race was funded largely by Cold War anxieties, and institutional supercomputers would increasingly become the focus of academic and the student unrest regarding the military-industrial research and development contractors involved in the Vietnam conflict. If Mumford's thoughts about technology and utopia have any relationship with *HPSCHD*, it is as a performance that promotes a "utopia of escape," particularly in its exclusion of technological anxiety or failure, facilitating escapism rather than problem-solving. This kind of escapism appealed to the audience attending *HPSCHD*: a related criticism of the performance, as well as other large-scale Cage projects, claimed it catered to a homogenous, elite audience, already self-selected to react in expected ways. Contributing to this observation was its location: it took place on a university campus with its own set of strictly limiting rules, influencing students and outside participants through both the tacit knowledge of embedded campus rituals, and the adherence to certain behaviors on account of the surveillance state enacted on campuses during the late 60s.

Related to these influences that largely discouraged antagonism, Cornelius Cardew, a past student of Cage turned avid critic, criticized Cage's particular approach to anarchism:

HPSCHD creates an image of society as a jumble of sense stimuli, flashing lights and tinkling sounds, in which the individual is reduced to the position of a mere spectator. These negative, pessimistic effects created by Cage's music reflect the surface character of the capitalist world, they do not reflect its essence. They don't indicate the direction of its change and development and worst of all they deny the positive contribution that individuals are capable of making towards this

²⁵⁰ Mumford, *The Myth of the Machine Vol II: The Pentagon of Power* (New York: Harcourt Brace Jovanovich, 1970), 260.

change.²⁵¹

He panned *HPSCHD* as “a king-size electronic multi-media freak-out, and I don’t recommend anyone to go to it.”²⁵² Similarly, Yvonne Rainer criticized *HPSCHD* as “an impenetrable web of undifferentiated events set in motion by and referring back to the original flamboyant artist-gesture,” a “manifestation of yet one more Artist as Transcendental Ego.”²⁵³ Reviewer Virgil Thomson even accused Cage and Hiller of capitulating to advanced capital:

... this “artistically activated” space is not very different from the Wagnerian *Gesamtkunstwerk*, or music drama (also a mixedmedia affair), except for a very modern emphasis on the mechanics of show business. Wagner took these for granted, preferring to use them less as glamor items than for underlining myths and morals. In both cases, I think, the production of ecstasy was the aim; and in both cases surely music (or sound, in any case) was the main merchandise. For Wagner’s music is what has survived best out of his whole splendid effort to create a new kind of tragedy. And as for the Cage-Hiller *HPSCHD*, it was already on sale as a musical recording, completely shorn of its visual incidents and compacted down to twenty-one minutes of playing-time, when the great mixed show of it all was put on in Urbana.²⁵⁴

Though Thomson does not use the term *spectacle*, his criticism of the “show business” atmosphere of *HPSCHD*, alongside his use of the phrase “artistically activated” in scare quotes emphasized his suspicion of its material parameters, underscoring what he identified as the superficial qualities of the performance. Furthermore, in addition to obliquely referencing Guy Debord’s concept of spectacle regarding its problematic relationship to capital, Thomson suggested that the attempt at a Wagnerian arc of *HPSCHD* was its ultimate failing: even if the *Gesamtkunstwerk* was flawed in other ways, its attempt to civically unite its viewers leaves

²⁵¹ Cornelius Cardew, *Stockhausen Serves Imperialism* (Latimer New Dimensions Limited, 1974), 85, 158.

²⁵² *Ibid.*, 39-40.

²⁵³ Rainer, 69-70.

²⁵⁴ Virgil Thomson, “Cage and the Collage of Noises,” *The New York Review of Books* (April 23, 1970).

HPSCHD in the unfavorable position of a thinly-veneered merchandizing effort of mass distraction instead of unification.²⁵⁵

These critiques of *HPSCHD* may appear persuasive in retrospect, especially in light of how so many art and media theorists continue to draw a direct relationship between media performance, spectacle, and Wagnerian *Gesamtkunstwerk*. The *Gesamtkunstwerk* is often used as a conceptual model for the format and conceptual thrust behind contemporary new media installations, providing what seems a clear historical narrative stretching from the Romantic era to the present.²⁵⁶ However, interpreting complicated, multi-faceted works such as *HPSCHD* within the context of a historical trajectory including the *Gesamtkunstwerk* to new media at best hinders a fresh reading of its experience and impact, and at worst, forces technologically-deterministic readings of all art and technology experiments, often ignoring their specific material, historical, and cultural context.

²⁵⁵ For Guy Debord and the social revolutionary organization Situationist International, the concept of the spectacle constituted a sharp critique of advanced capitalism; Debord identified the tendency towards the increasing mediation of social relations, where lived experience and authentic desire-fulfillment give way to individual expression by proxy through the exchange or consumption of commodities. Succumbing to the spectacle by having passive, second-hand, and inauthentic experiences, society suffers devastating damage to its quality of life. Guy Debord, "Definitions," *Internationale Situationniste* 1 (June, 1958).

²⁵⁶ The description of multimedia installation/performance as *Gesamtkunstwerk* is present in many foundational media texts, including Chris Salter's *Entangled*, Mark B.N. Hansen's *New Philosophy for New Media*, as well as the essays and lectures of Lev Manovich and Erkkhi Huhtamo. Salter quickly pushes the importance of this philosophical theory of performance out of the way, commenting "We need not, however, dwell on Wagner the composer or as the theorist of the *Gesamtkunstwerk*, although obviously such a concept plays a key role in making sense of our utterly confusing, multisensory, audiovisual media society of the present. I want here to focus on Wagner as an experience architect of a machine that utilized the technologies of the time to create unprecedented control over the perceptual and affective experience of his spectators." Salter, *Entangled: Technology and the Transformation of Performance* (Cambridge, MA: MIT Press, 2010), 2.

In contrast, a holistic examination of these varied *HPSCHD* reviews, both positive and negative, reveals the consequences of the disjointedness of its visual and audio aspects on audience reception, and the overall invisibility of its computational performance. Tellingly, most reviews simply ignore the computationally-derived audio, attempting instead to describe the more spectacle-driven, psychedelic aspects of the performance that appealed to a college-aged, late 60s audience. Many of the most negative reviews take on a much more trivializing tone: Donal Henahan, music critic for both the *Chicago Daily News* and the *New York Times*, later reflected upon *HPSCHD* as a prime example of “parametric” music performances that “are best left unheard,” stating, “Those who subsequently heard the work performed either live at the University of Illinois or on record may also remember what ‘*HPSCHD*’ sounded like: World War III played backward.”²⁵⁷ Henahan’s description remains the kind of flippant dismissal distressingly common in its computational ignorance, not only ignoring *HPSCHD*’s fundamental importance as an experimental work of computer composition, but also unintentionally capitulating to a deeply-embedded historical narrative that painted the computer as some unknowable, impenetrable object to be mocked, feared, or simply ignored.²⁵⁸ This kind of uncritical stance encouraged complacency toward developing technical skills like programming, contributing to what Ted Nelson, early computing activist and author of the 1974 *Computer Lib*:

²⁵⁷ Donal Henahan, “CLASSICAL VIEW; Paramusical Notions That Turn to Dust,” *New York Times* (March 3, 1991).

²⁵⁸ In the same review, Henahan disparaged Lejaren Hiller: “Even the most modestly talented human composers, in fact, seldom produce anything so hilariously amateurish as computer music—unless they mean to. So, fair play: mightn’t it be interesting to hear a symphony orchestra making sounds like an ineptly instructed computer trying to compose music?... The result was the musically primitive but famous “Illiac” Suite, an experimental creation not intended as art but perhaps as a foot in the door. We music critics listened to the piece and almost regretfully determined that it was the work of a raw beginner.” Ibid.

You Can and Must Understand Computers Now, called “the computer priesthood.”²⁵⁹ It also ignored the growing trends in performance that valued the cybernetic, *networked* aspects of theater so often confused with the *Gesamtkunstwerk* by traditionalists.

Avoiding comparisons to the *Gesamtkunstwerk* and Happenings, particularly as practiced by Cage alum Allan Kaprow, allows readings of *HPSCHD* that more actively engage in a critique of its dichotomies, particularly its audio and visual elements, as well as the information theory aspects in place of the more philosophical/ontological metaphors so prevalent in its visuals.²⁶⁰ It is essential to examine how these dichotomies were being challenged within the context of Performance Theory, particularly in the context of the philosophies popularized by the rise of cybernetics. As the more general tenets of Performance Theory were highly influenced by Cage’s past performance work, some of Richard Schechner’s concerns can be recognized throughout Cage’s own writings:

Wholeness. Participatory democracy, self-determination on the local, national, and international levels. Therapies which start from the one-ness of mind/body/feelings. ‘Getting it together.’ Total theater, intermedia, integrated electronic systems, McLuhanism. An end to dichotomies, so that:

a whole person	not mind/body
families	not fragmented individuals
communities	not government vs. governed
jobs like play	not alienated work
art where we are	not in museums far away

²⁵⁹ Theodor Nelson, *Computer Lib: You Can and Must Understand Computers Now* (Self-published, 1974).

²⁶⁰ Though Cage deeply influenced the development of happenings—particularly as they were theorized and practiced by Allan Kaprow, a former student from his time at the New School—Cage himself remained critical of their procedures regarding “policemen” influencing or instructing participants as to their actions within an artwork. Cage largely avoided referring to both *Musicircus* and *HPSCHD* as happenings, despite the works often being referred to as “happening-like.” Brandon Joseph explored Cage’s suspicions and prejudices toward Kaprow’s happenings in “*HPSCHD—Ghost or Monster*”; Joseph, 153-154; Cage’s “policemen” comment was made in conversation with Michael Kirby and Richard Schechner, “An Interview with John Cage,” 69.

one world in peace not wars and international rivalries
human one with nature not ecological warfare²⁶¹

Here Schechner attempted to outline the goals new forms of theater pursued, many of which coincided with those Cage pursued in the *HPSCHD* visuals: the emphasis on “communities,” as represented by the interactions of audience members and interactive props like the Day-Glo tunics; “art where we are” represented by the multi-use Assembly Hall venue (as opposed to a designated art institution); “human one with nature” concretized as the practice of Zen Buddhism and the use of the *I Ching* in particular. These general tenets describing the dissolution of dichotomies, though influenced by cybernetics, were also deeply influenced by the dominant counter-cultural movement of the late 60s. In addition, as outlined in Chapter 1, the popularized version of cybernetics often oversimplified the materials and processes so endemic to the disciplines contributing to its interdisciplinary goals, among them information theory. Regarding *HPSCHD*, one of the most noticeable oversimplifications involved interpreting Marshall McLuhan’s theories as overwhelmingly techno-utopian: Schechner’s name-drop of “McLuhanism” undoubtedly suggested a direct relationship between the media theorist’s ideas and the metaphor of “Getting it Together,” the name “McLuhan” becoming synonymous with vague concepts of world peace and unification.²⁶² To suggest the rapid advancements McLuhan

²⁶¹ Schechner, *Performance Theory*, 31.

²⁶² The suggestion that McLuhan’s theories promote world peace and international compromise overlooks later developments in his theories, particularly his overall neutral stance in terms of U.S. action in Vietnam. From a Guardian article considering McLuhan’s legacy: “Far from sharing sympathy for countercultural forms of life, or the forms of media they embraced, McLuhan made a point of withholding judgment, refraining from moral evaluation of the processes he was describing and explaining. If anything, it was the conservative side of McLuhan that sometimes shone through his stance as a scientific observer. He never condemned the Vietnam war, suggesting instead that it was more of a media event than an actual happening. He discussed the possibility of using media as a form of control, ‘using TV in South Africa ... to cool down the tribal temperature raised by radio’, with no acknowledgement of the Orwellian

described constituted optimistic developments, however, is to ignore some of his more troubling predictions, as well as his professed philosophical neutrality.

For example, in his 1962 text *The Gutenberg Galaxy: The Making of the Typographic Man*, McLuhan's techno-utopian concept of "the global village" constituted an electrical cross-linking of the globe, regardless of space and time.²⁶³ In the global village, participation is essential: the world becomes a "village" insofar as citizenship requires commitment and sympathy through virtual means; one can participate regardless of physical location, and would interact as if physically present. The consequence of this networking sacrifices not only the concepts of individualism and nationalism, but also conceptual boundaries of the self. Regarding the extent to which the global village could penetrate the human body, McLuhan wrote, "It is possible now to program conditions of the senses in such a way among themselves that they come close to the condition of consciousness (...) If we expanded our central nervous system to the electromagnetic technology, it is only one step more for the transmission of our consciousness also into the world of the computers."²⁶⁴ The computer, as further extension of the body, would take over the task of the human brain. McLuhan foresaw technology becoming a necessary counterpart, or prosthetic, of humans during this last stage of development.

Regardless of how his theories were interpreted by the general public, McLuhan never placed value judgements on any of these observations. In fact, after the popularization of many of his ideas, he professed surprise at the techno-utopian or dystopian readings placed upon his work: in an interview with Gerald Stearn, McLuhan denied that he meant for the global village to

implications." Lance Strate, "Marshall McLuhan's message was imbued with conservatism," *The Guardian* (July 26, 2011).

²⁶³ McLuhan, *The Gutenberg Galaxy: The Making of the Typographic Man* (Toronto: University of Toronto Press, 1962), 30-31.

²⁶⁴ McLuhan, *Understanding Media*, 464.

be read as utopian, especially in that he predicted that its diversity would *create*, rather than *quell*, disagreements. The global village would never become a tranquil utopia, as it necessitated division and difference among members in order to adapt and survive.²⁶⁵

Another example of McLuhan's neutrality was his prediction of a technocratic future in which the computer could act as a substitute for consciousness, and that the human nervous system was primed for extension by the proliferation of mass media. In "The Agenbite of Outwit," McLuhan described the terror involved in wearing your nervous system on the outside of your body, but also the great potential that could result from this automation:

When we put our central nervous system outside us we returned to the primal nomadic state. We have become like the most primitive paleolithic man, once more global wanderers, but information gatherers rather than food gatherers. From now on the source of food, wealth and life itself will be information. The transforming of this information into products is now a problem for the automation experts, no longer a matter for the utmost division of human labour and skill. Automation, as we all know, dispenses with personnel. This terrifies mechanical man because he does not know what to do about the transition, but it simply means that work is finished, over and done with. The concept of work is closely allied to that of specialization, of special functions and non-involvement; before specialization there was no work. Man in the future will not work—automation will work for him—but he may be totally involved as a painter is, or as a thinker is, or as a poet is...

I believe that artists, in all media, respond soonest to the challenges of new pressures. I would like to suggest that they also show us ways of living with new technology without destroying earlier forms and achievements. The new media, too, are not toys; they should not be in the hands of Mother Goose and Peter Pan executives. They can be entrusted only to new artists.²⁶⁶

While this statement did not necessarily indicate techno-utopianism—certainly, as prophesied by McLuhan, the substitution of biology for technology was a terrifying transition for "mechanical man" and could initially thrust him into a pre-historical paradigm—it proposed an increased ability to predict future actions and capitalize from that knowledge, thereby creating optimal

²⁶⁵ Gerald Emmanuel Stearn, *McLuhan: Hot & Cool* (New York: Signet, 1968), 272.

²⁶⁶ McLuhan, "The Agenbite of Outwit," 42-44.

futures. Interestingly, he claimed these optimal futures were best anticipated by those already primed to think creatively: the artists. Though the algorithmic calculations of the new digital computer performed as an advanced prediction machine, he predicted that it could not replace this human interpretive element. This proposal proved especially fascinating to Cage; despite the terrifying transition automation presented, Cage interpreted this artistic role as one that could instigate a “mind change” that proved impossible without new technologies.²⁶⁷ Though admitting that much of McLuhan’s ideas still defied his present interpretations—perhaps leading to some of the techno-utopian misinterpretations that informed the visual presence of *HPSCHD*—Cage saw the mysteries therein as proof of McLuhan’s status as techno-sage:

I remember being with [Marshall McLuhan] at lunch, not what we ate. He asked me questions (he wanted to know what patterns in society I heeded). I couldn’t respond; my mind doesn’t work that way. For me his books, his questions, his statements were all mysterious and therefore useful. They still are. They keep understanding at a safe distance. He continues to protect us from what we see is happening.²⁶⁸

III. 5. Dematerialization and the “New Nostalgia”: HAL & *HPSCHD*

Reflecting upon *HPSCHD* in 1991, Henahan made the direct connection between the “composer” ILLIAC and the actions of the malevolent HAL 9000 (*Heuristically programmed ALgorithmic computer*), the sentient computer that controls the systems of *2001*’s spaceship:

Worshippers of machinery must take heart, however. The Illiac computer, though only a composer in embryo, still lives in song and story. Movie fans honor its memory as the distant ancestor of Hal, the murderously inclined computer in ‘2001: A Space Odyssey,’ which went to its death singing, clumsily and sadly, ‘Daisy, Daisy, Give Me Your Answer True . . .’ Sometimes, if only in fiction, human beings can prevail over the tyranny of their tools.²⁶⁹

²⁶⁷ Cage, “McLuhan’s Influence,” 70-71.

²⁶⁸ Barrington Nevitt and Maurice McLuhan, *Who Was Marshall McLuhan? Exploring a Mosaic of Impressions* (Toronto: Stoddart, 1996), 269.

²⁶⁹ Henahan, “CLASSICAL VIEW.”

Though Henahan's claims may seem hyperbolic, the escalating Vietnam conflict and widespread political unrest of the late 60s and early 70s lends this technological/computational fear some credibility. Gene Youngblood provided an especially relevant description of this mounting anxiety in *Expanded Cinema*: in a chapter entitled "2001: The New Nostalgia," Youngblood analyzed the 1968 Kubrick film to explain his concept of the "new nostalgia," in which he claimed material signifiers of advanced technology emphasized the abstractions of "radical evolution in the living present."²⁷⁰ To explain, Youngblood recalled the *2001* scene in which astronaut Gary Lockwood's parents send a videophone birthday message to their son, who, despite the overtures of his parents, appears startlingly aloof. The material signifiers that represent Lockwood—the modernist, ultra-designed spaceship interior with its blinking lights and white palette—greatly contrast with the analog video message from his parents, as well as the soundtrack used to represent them: the adagio movement "Carpet Weavers" from Aram Khachaturian's *Gayane Ballet Suite No. 3*, from a Soviet ballet emphasizing cultural divergence and unrest.

Youngblood's "new nostalgia" formed a kind of hyper-accelerated version of generational divides of the past, prompted by relationships with advanced technologies that fundamentally transform the humanity's experience of the world. Existentialism becomes a daily experience, taking forms "both physical and metaphysical."²⁷¹ Similarly to how *HPSCHD* constituted an attempt to encapsulate the progression and pinnacle of music composition through computational methods, *2001* also provided an intense meditation on the progression from Neo-Classical to Romantic sublimity and beyond by juxtaposing classical music and technological

²⁷⁰ Youngblood, 142.

²⁷¹ Ibid.

achievement. *HPSCHD* emphasized the parallels between ancient and classical algorithmic study through composition—specifically the *I Ching* and Mozart’s dice game—and modern computational achievement, represented euphorically by documentary and science-fiction depictions of spaceflight. The *2001* soundtrack similarly emphasizes these themes, but through the chromatic tone-poem *Thus Spake Zarathustra* by Richard Strauss; Strauss’s work referenced Friedrich Nietzsche’s philosophical novel of the same name describing the prophecy of the *Übermensch*: rather than explore a secular state of being, the portrayal is a new conception of spirituality still tied to the detritus and ritual of religion.²⁷² Youngblood suggested this movement also described the rising climax of *2001*, stating: “Ironically, no sooner has Existentialism moved from theory to experience than it is given a new dimension by science, which has replaced the church as our temple of worship and has disclosed man's teleologic, anti-entropic function in the universe, something the church never was able to do.”²⁷³

While Youngblood’s analysis highlighted the shifting paradigm of technology that separates parent/child relationships in the space age in philosophical terms, the humans of *2001* are also clearly *physically* affected by their distancing from tangible material and information.

²⁷² The dominant piece of music used in the film, Richard Strauss’s 1896 tone poem *Thus Spoke Zarathustra*, *Op. 30 (Also sprach Zarathustra)*, was inspired by Friedrich Nietzsche’s philosophical text of the same name in which he famously returned to his concepts of “the eternal recurrence of the same,” the “death of God,” and the *Übermensch*. Kubrick did not declare God dead in the final scene, but seemingly supplants him, as Dave Bowman achieves evolutionary transcendence in becoming the Star Child. Several points are important to remember here: Nietzsche’s text is not necessarily the death of God in the total sense, but the presentation of an alternative to the Christian concept of an all-powerful deity; his use of the name “Zoroaster” was an attempt to re-interpret Zoroastrianism, in which human beings have the free will to choose between good and evil. Dave Bowman, as the Star Child, is just this figure: he is the new deity, with a whole new perspective on what might constitute the “good” and “evil” of the vast unknown universe. This movement toward transcending the good and evil binary parallels the concerns of Schechner and popular cybernetics.

²⁷³ Youngblood, 142.

Youngblood stated that audience interpretation tended toward “an indictment of the ‘dehumanizing’ effects of technology,” and that Lockwood “is seen as a kind of ‘space zombie’ because he appears indifferent to the effusions of his parents.”²⁷⁴ However, Lockwood is both literally and metaphorically distanced from his parents; they are physically far away and temporally displaced. They are also mediated through screen technology, which serves as a major signifier of dematerialization. These signs of the “new nostalgia” echoed the more frightening aspects of McLuhan’s “Agenbite of Outwit,” extending his concept of “the global village” as a technologically-advanced communication system such as the one employed by the Lockwoods: even though technology could send and receive information between parents and son, it also emphasized the physical and metaphysical distance between them. The limitations of technology—its inability to mimic anatomical vision and failure to provide physical contact—either become pronounced to those used to the previous paradigm, or they become an accepted fact of dematerialization that in turn requires adaptations further distancing generations.²⁷⁵ As Marshall McLuhan lamented in “Agenbite of Outwit”:

A special property of all social extensions of the body is that they return to plague the inventors in a kind of *agenbite of outwit*. As Narcissus fell in love with an outering (projection, extension) of himself, man seems invariably to fall in love with the newest gadget or gimmick that is merely an extension of his own body. Driving a car or watching television, we tend to forget that what we have to do with is simply a part of ourselves stuck *out there*. Thus disposed, we become servo-mechanisms of our contrivances, responding to them in the immediate, mechanical way that they demand of us.²⁷⁶

Equally disturbing are the two most identifiable signifiers of dematerialization: the “characters” HAL 9000, the technological replacement for a ship’s navigator, and the black

²⁷⁴ Ibid.

²⁷⁵ Cage, “McLuhan’s Influence,” 70-71.

²⁷⁶ McLuhan, “Agenbite of Inwit,” 41-42.

obelisk, the entity instigating the space mission. HAL performs an imitation of polite human conversation, as Frank Lockwood and Dave Bowman's seemingly benign, but ultimately unnerving, conversation with him implies:

Frank: Listen HAL. There has never been any instance at all of a computer error occurring in the 9000 series, has there?

HAL: None whatsoever, Frank. The 9000 series has a perfect operational record.

Frank: Well of course I know all the wonderful achievements of the 9000 series, but, uh, are you certain there has never been any case of even the most insignificant computer error?

HAL: None whatsoever, Frank. Quite honestly, I wouldn't worry myself about that.

Dave: Well, I'm sure you're right, HAL. Um, fine. Thanks very much.²⁷⁷

It is specifically this theatrical representation of a supercomputer replacing and imitating human empathy, as well as the physical parallel of the strange appearance and ambiguous manipulations of the black obelisk, that remains a potent icon of anthropomorphic technologies with ambiguous motives and agency. Though it can only be assumed the portrayal of HAL and the obelisk elicited an equally heightened response shortly after the film's release, there are clues that its themes tapped into a cultural wellspring deeper than Hollywood's influence. For example, it is worth noting that Michael Fried's influential essay, "Art and Objecthood," originally published in 1967, vehemently objected to "literalist" sculpture because of its "theatricality": as a human-sized, vaguely anthropomorphic monument, these minimal forms confronted a human as another entity, claiming a relationship emphasizing experience over absorption.²⁷⁸ While Kubrick and the

²⁷⁷ *2001: A Space Odyssey*, DVD.

²⁷⁸ Though Fried does not necessarily accept this theatrical presence as one of horror, the idea that such a sculptural presence as this could evince something extremely unsettling. Robert Smithson, in his essay "Entropy and the New Monuments," lists many artists—many of whom were Minimalists—whose work was supposedly inspired by horror cinema, in which art objects could evince a terrifying presence or atmosphere. Robert Smithson, "Entropy and the New Monuments," in *Robert Smithson: The Collected Writings*, ed. Jack Flam (Berkeley: University of California Press, 1996), 10-23; Michael Fried, "Art and Objecthood," *Artforum*, V, 10 (Summer 1967); repr. in *Minimal Art: a Critical Anthology*, ed. Michael Battcock (New York: E. P. Dutton, 1968), 157.

many *HPSCHD* participants might not have been aware of these objections, it remains useful to note the pervasiveness of such pronounced anxiety that overtook both the larger cultural conscious as well as the discipline of art history and theory regarding non-human entities with a sense of autonomy or purpose outside of our own.

III. 6. Conclusion: The Afterlife of the ILLIAC & *HPSCHD*

In her analysis of the work of media theorist Vilém Flusser in relation to his analyses of the works of George Orwell, William Gibson, and Stanley Kubrick, Sjoukje van der Meulen paid special attention to Flusser’s avoidance of analyzing “a futurization of the fantastic.”²⁷⁹ A decade after the premiere of *HPSCHD*, Flusser would write about humanity controlled by technical apparatuses as a serious threat to the future of critical thinking and historical/cultural consciousness, directly citing Stanley Kubrick’s *2001: A Space Odyssey*—in particular, the emergence of HAL 9000—as an example of such a machine that could “automate,” and thus eradicate humanity’s ability to critically engage with its history and future. In examining the growing fear of a Cold War society, Flusser meant for his media analyses of these works to reflect present fears, particularly the reversal in the relationship between humans and technology: technology was increasingly dominant over humanity. He claimed this reversal was sharply felt in the climax of *2001: A Space Odyssey*, in which HAL makes the decision to kill the crew when they compromise his mission. Flusser’s “critique of the present” strips away the spectacularization of contemporary science fiction media to tease out real fears behind a force

²⁷⁹ Van der Meulen’s excellent analysis of Flusser presents his theory as a crucial voice that both critically connected and advanced the work of Marshall McLuhan and Walter Benjamin through highly influential science-fiction writers and directors; van der Meulen, 200.

such as HAL, and to reflect upon how our daily interactions with machines might be influenced, or even directed, in ways we hadn't yet realized.²⁸⁰

A similar “critique of the present” in regards to *HPSCHD*, considering its socio-cultural context in 1969, helps explain the fear a “creative” computer such as the ILLIAC might have on an art audience. However, attitudes toward computers have evolved greatly from the late 1960s to the present, and are deeply influenced by the commodification of the personal computing revolution, fomented almost entirely by IBM, and later, Apple, Microsoft, and Google. Though today the three latter corporations wield massive economic power, IBM ruled the computer industry unchallenged for seven decades and left an indelible mark on operations, systems design, and overall computing philosophy. By the late 1930s, IBM was the sole purveyor of machines able to process large amounts of data. Because of the incredible power granted by its machines’ ability to process such substantial amounts of data, IBM shaped the computer industry through large-scale government contracts in research and design. By the mid-1960s, the NASA space program used IBM computers to track the flight paths of the Mercury, Gemini, and Saturn astronauts; in 1969, IBM machines put NASA on the moon. At the same time, IBM was also greatly accelerating research into private business computing. In a deft move making their products increasingly marketable, IBM developed a “computer system family,” the IBM/System/360, a scalable set of computers allowing businesses to upgrade models without the fear of losing applications and past work. The IBM/360 models marked the invention of backward compatibility (an upgrade path and concurrent vendor lock-in).²⁸¹

²⁸⁰ Vilém Flusser, *Towards a Philosophy of Photography* (New York: Reaktion Books, 2000).

²⁸¹ All documents pertaining to the IBM/360 System, including press announcements, lists of compatibility features, principles of operation, and functional characteristics can be accessed through the comprehensive IBM history and exhibits website; accessed December 1, 2015,

As mentioned previously, many early computer enthusiasts and engineers warned of this locking down, most notably computer pioneer Ted Nelson in his 1974 manifesto *Computer Lib*. Though highly influential to many D. I. Y. computer-enthusiasts, Nelson's plea—to transform the superficial notion of “computer literacy” into a working understanding of the materials and processing of hardware and software—initially only reached a niche market of the already-converted. He decried the “Cybercrud” that caused what he deemed the “centralization of computers” transpiring by the industrial and commercial forces of IBM, a movement he claimed intentionally kept non-computer literate people from a deeper understanding of computing. Though his text *Dream Machines*, self-published simultaneously with *Computer Lib*, expanded upon the creative potential of computing, his warnings against the centralization of computation had largely become a reality by the time IBM launched their highly popular and accessible 1980s models, which rapidly became the status quo in both business and educational computing.²⁸²

Simultaneous to this proliferation of IBM products, the re-emergence of HAL in both popular media and IBM advertising strangely absorbs and obscures the critiques Kubrick embedded in the original film; instead of regarding HAL as a technological entity whose programmed dominance over human control makes him incredibly dangerous, HAL is reborn as a technological marvel, a model for the kind of intelligent computer we are supposed to be attempting to achieve. As stated by Clarke in *3001*, HAL's comparison to a computer model such as “Big Blue”—IBM's chess-playing triumph—was a real-life version of what HAL was meant to achieve.

http://www-03.ibm.com/ibm/history/exhibits/mainframe/mainframe_FS360.html. An interactive history timeline can be accessed at <http://www-03.ibm.com/ibm/history/interactive/index.html>.

²⁸² Theodor Nelson, *Computer Lib*.

The ILLIAC series, in comparison to both the dominance of the IBM personal computing model and the related ascendance of HAL, has been relegated to a footnote. After the the 1970s, the subsequent life of the ILLIAC II, as well as the ILLIAC series in general, became a point of contention on the University of Illinois campus. The construction of the ILLIAC IV off-site was claimed to have been largely conducted in secret, and students demonstrated in opposition to the kinds of secret military operations conducted using the supercomputer. The director of the ILLIAC IV project, Daniel Slotnick, was averse to the idea of running classified programs on the machine, and was greatly against the orders that ARPA demanded the machine room be encased in copper to prevent off-site detection of classified data. When the computer was still in production at the Burroughs Corporation's Great Valley Lab, it was met with great hostility by student protesters suspicious of its connection with the US government Department of Defense, claiming that it would be used to develop nuclear weapons. The protests culminated on May 9, 1970, with flyers calling for a day of "Illiaction" [Fig. 3.13].²⁸³ Because of the negative attention the construction had drawn by the protesting students, Slotnick advised the computer never arrive in Urbana. One quadrant was delivered to NASA at Ames Research center to conduct nuclear simulations, but none of the components ever reached Illinois.²⁸⁴

HPSCHD, with an afterlife not as high-profile as HAL's or as easily forgotten as the ILLIAC's, seems an eccentric footnote rather than Cage essential listening. Regardless, re-stagings of *HPSCHD* have found their way into various venues in both the U.S. and Europe since

²⁸³ Flyer for the day of "Illiaction": University of Illinois Archives (RS41/66/969) from "Byte of History: Computing at the University of Illinois" exhibit, March 1997.

²⁸⁴ Slotnick et al., *Illiack IV system manual*. Pieces of the ILLIAC II, III, and IV are currently in the collection of the Computer History Museum in California in Palo Alto. The Computer History Museum in California holds many components to the original ILLIAC series, including this integrated circuit from the ILLIAC IV, accessed December 16, 2015.<http://www.computerhistory.org/collections/catalog/102651993>.

its initial premiere in 1969.²⁸⁵ When I attended one of the most recent *HPSCHD* performances at New York’s Eyebeam Art and Technology Center on May 3rd and 4th, 2013, I was able to experience a contemporary rendition of Cage and Hiller’s work firsthand [Fig. 3.14, 3.15, 3.16]. It benefitted both from the vast social media presence of its organizers and from the enthusiastic participation of many varied New York area new media artists, musicians, and programmers.²⁸⁶ Bruce Neely, one of the original harpsichord soloists in 1969, performed from his original copy of the *HPSCHD* score on one of the borrowed harpsichords and entertained questions and demonstrations afterward [Fig. 3.17]. Numerous do-it-yourself art and technology enthusiasts behaved as if the spectacle were a BYOB event—a “bring your own beamer” party—in which they used their own projectors and computers to curate a vast number of shifting images and videos, and the performance was all the more fun and informative for it [Fig. 3.18].²⁸⁷ A Brooklyn-area screen printer inked t-shirts during the performance with one of the poster designs from the 1969 performance [Fig. 3.19]. The collaborators, composer Joel Chadabe and artist Bradley Eros, together designed and invited participation in the event, launching a blog detailing

²⁸⁵ One high-profile 1980 performance of *HPSCHD* at Albright-Knox Art Gallery had both Cage and Hiller in attendance, alongside other icons of experimental music, including Morton Feldman, and original performers David Tudor and Neely Bruce.

²⁸⁶ The event was organized by Eyebeam in collaboration with ISSUE Project Room and the Electronic Music Foundation (EMF), with the collaboration of composer and director of the EMF Joel Chadabe, keyboardist Neely Bruce, and artist Bradley Eros. Eyebeam “Essential Repertoire” website, accessed December 16th, 2015, <http://www.eyebeam.org/press/eblast/items/2013-03/john-cage-lejaren-hiller-hpschd>.

²⁸⁷ The BYOB (Bring Your Own Beamer) event is an informal art exhibition built upon free participation, where screen-based artists bring a projector (beamer) to an open space and project moving images. Though its history is hazy and often debated, many attribute the birth of the BYOB to new media artist Rafaël Rozendaal in 2010, and since the first BYOB parties, exhibitions have been launched in cities all over the world. Rozendaal’s “BYOB Worldwide” website, accessed May 10, 2016, <http://www.byobworldwide.com/>; Rafaël Rozendaal’s portfolio website, accessed May 10, 2016: <http://www.newrafael.com/>.

many of the historical facts regarding their own efforts, as well as describing the original production of *HPSCHD* and subsequent performances.²⁸⁸

A critique of the event—a kind of Flusserian “critique of the present”—strips away much of the mystique of Cage and leaves an event dominated by the kind of present manifesto guiding many participants in the digital art media movement. Despite the event being touted as a John Cage Happening, it felt much more like a DIY, hacktivist party, largely community-based and fiercely internally loyal because of a perceived marginalization from the more traditional arts. While it was undeniably a performance of *HPSCHD*, it was more importantly an event fitting within the current trend of new media: a participatory atmosphere that encouraged questions, connection, and engagement both as a performance, but also a kind of pop-up workshop. The varied audience, knowledgeable of Cage but seemingly less interested in the determined musical aspects of the work, discussed participatory methods of creating computer images from varied algorithms, explored glitch effects from popular media sources, compared consumer and open-source software for designing and animating 3D models, and demonstrated experiments with reactive environments producing digital imagery. In short, Cage and Hiller’s *HPSCHD* presented a venue for applied digital collaboration, and while the performance did not exactly match their conception, this kind of radical, applied approach to prying open the black box and exploring computation would have made Cage, and certainly Hiller, enormously happy. Ultimately, though John Cage and Lejaren Hiller’s *HPSCHD* holds a historical importance for experimentation in computation and the arts, perhaps its most contemporarily relevant legacy, what makes it particularly attractive to a new generation of performers, musicians, and artists, lies in its techno-

²⁸⁸ Nick Hallet, “*HPSCHD*.”

utopian ethos, inviting new radical adaptations with a variety of new technological and participant-fueled creative possibilities.

IV. Concluding Remarks

IV. 1. “Command-line Bullshittery” and the Myth of Computer Literacy: The Legacy of *HPSCHD* in Art and Technology

this reader[ror] is de[a]dicated
to all those pixels and programs
who gave their lives in the hope
of making something wrong,
right.

—GLI.TC/H 20111 READER[R0R], “DE[A]DICATION”²⁸⁹

Stop me if you’ve heard this one. A mechanical engineer, a chemical engineer, and a computer scientist are driving down the street. The car breaks down and all three get out to see what’s wrong. The mechanical engineer says, “I know what’s wrong, it sounds like the the piston rods are misaligned, if we just fix that it’ll work again.” She takes out her tools, starts messing with the engine, and 30 minutes later the car still isn’t running. The chemical engineer says, “No, no, it sounds like we’re having a problem with the oxygen mixture, it’s too rich and we just need to tune that.” She pulls out the oxygen sensor and starts tweaking, but 30 minutes later the car still doesn’t go. The computer scientist says, “I don’t know what you two are talking about. Just turn the car off, slam the left passenger door three times, walk around the car twice, turn it back on and it will work again.” They do that, and lo and behold, the car starts.

—Eytan Adar, “In defense of command-line bullshittery,” 2014²⁹⁰

Computer scientist Eytan Adar’s retelling of this popular joke, told amongst frustrated computer science students, represented a rebuttal to Philip Guo’s article “Helping my students overcome command-line bullshittery,” in which Guo decries the methods computer scientists employ to wrestle with the obscure command-line prompts and commands free software tools are based upon. In his original article, Guo, a practicing professional programmer and educator, took his discipline to task by asking whether computer science is fundamentally built upon an adeptness for research in figuring out these halting methods, and not an adeptness at actual

²⁸⁹ “DE[A]DICATION,” in *GLI.TC/H 20111 READER[R0R]*, ed. Nick Briz, Evan Meaney, Rosa Menkman, William Robertson, Jon Satrom, Jessica Westbrook (Chicago: Unsorted Books, 2011), 3.

²⁹⁰ Eytan Adar, “In defense of command-line bullshittery,” accessed November 4, 2015, <https://medium.com/@eytanadar/on-the-value-of-command-line-bullshittery-94dc19ec8c61>.

programming.²⁹¹ Though Adar's opposed position—that students need to learn these methods as an important lesson for real-life, on-the-job experience—is pragmatic, Guo's distress hit a nerve in the computing community. Commenters on the article, comprising students, teachers, and professionals, empathized deeply with Guo; these non-rational, time-consuming processes interrupted or completely halted their workflow, a circumstance familiar to any computer user.

In the context of the joke, the roles of both mechanical and chemical engineer become very similar, as they observe the car as a literal prosthetic: they treat the inner-workings of the car as a problem to be solved, as they are part of a reflexive system maintaining the transportation relationship. The system is, after all, a knowable relationship that relies on smaller subsystems with a number of gauges built specifically for this purpose. They ask pragmatic questions of the system: what of the gas gauge? is the check engine light on? is this an electrical, chemical, mechanical, or maybe even an operator—human—problem?

The computer scientist's response, however, is not at all reasonable: in fact, it appears downright shamanistic.²⁹² The joke emphasizes how the computer science discipline maintains a culture of cultish-ness, where Ted Nelson's "computer priesthood" initiates not only capitulate to the irrational, but idolize the members of their order who master the "magic."²⁹³ Guo's frustration with the status quo reflects not only the inaccessibility of programming to those

²⁹¹ Philip Guo, "Helping my students overcome command-line bullshittery," accessed December 18, 2015, <http://www.pgbovine.net/command-line-bullshittery.htm>.

²⁹² A recent interview featured on Vice's *Motherboard* website profiles a self-proclaimed reverend and "witch" whose job is casting spells that combat computer viruses. Tracy Chabala and Reverend Joey Talley, "We Talked to a Witch Who Casts Viruses Out of Computers with Magic," *Motherboard: Vice*, last updated January 12, 2016, accessed January 13, 2016, <http://motherboard.vice.com/read/we-talked-to-a-witch-who-casts-viruses-out-of-computers-with-magic>.

²⁹³ Theodor Nelson, *Computer Lib: You Can and Must Understand Computers Now; Dream Machines: New Freedoms Through Computer Screens—A Minority Report* (Self-published, 1974).

indoctrinated in the discipline, but a longer history of disrupted prosthetic relationships. Though faintly echoing Freud's own struggle with prosthetics and his critique of technology and civilization, Guo's complaints more specifically reference Nelson's frustration with the "priesthood," in which the workings of computers and the intricacies of programming remain largely obscured. Nelson's discontent during the 1970s, though fairly obscure both in its time and in the present, has remained relevant to the struggles of subsequent generations of computer scientists and computer users.²⁹⁴ Though Guo and Nelson express their frustration as referencing a problem within the computing community, they implicate a much larger issue of human agency: this narrative reinforces the increasing technological dysphoria described by both media theorists Friedrich Kittler and Vilém Flusser, where the reversal of the power dynamic between technology and humanity creates a present in which the technological prosthesis controls the resulting outcomes.²⁹⁵ It's no wonder, then, that many artists and designers have found it difficult to incorporate computer programming into their own work, and why so many curators, critics, and art historians find both contemporary and historical digital artworks anachronistically formalist at best, and inscrutably techno-formalist at worst.

Perhaps because of its ambition and scale, John Cage and Lejaren Hiller Jr.'s *HPSCHD* remains a difficult performance to describe much less analyze, even among other early computer artworks from its era. As an attempt to provide a model for future early computer art analysis,

²⁹⁴ Ibid.

²⁹⁵ Though Flusser focused on photography in his text—where the camera is the technological apparatus forcing its agency upon the user—he suggested that this is only one of the more obvious examples of the reversal of the power dynamic between humans and technology. As mentioned in Chapter 5, Sjoukje van der Meulen, in her essay "Between Benjamin and McLuhan: Vilém Flusser's Media Theory," expounds upon Flusser's theory to explore the disruption amongst new media more generally, particularly as it is emphasized in popular culture. Flusser, *Towards a Philosophy of Photography* (New York: Reaktion Books, 2000), 198; van der Meulen, 181-207.

the previous chapters demonstrate how the study of computer artworks such as *HPSCHD* necessitate non-traditional, interdisciplinary methods. As such, Chapter 1 provided an investigation of *HPSCHD* as coming from a deeply networked history, necessitating an understanding of the nexus of the histories of prosthetics, information theory/cybernetics, prognostication and its relationship to computation, and Zen Buddhism's transformation as it travelled from East to West. Chapter 2 described the challenges Hiller and his research assistants faced in programming *HPSCHD*, ultimately demonstrating how programming constitutes a performance, its dematerialization of both information and art placing it within the larger movement of conceptual performance practices of the 1960s and 70s. Chapter 3 explains the conceptual impetus and methods for creating the *HPSCHD* visuals as curated by Cage et al., and how these methods revealed the slippages between the more material, process-based discipline of system theory and popular readings of cybernetics; these misunderstandings—alongside fundamental anxieties of the autonomous, “creative” computer—helped fuel the fear and distrust some critics felt towards a performance they found largely impenetrable due to the treatment of its technological elements.

Despite *HPSCHD*'s complicated relationship with computational and cybernetic disciplines—as well as its rather unreceptive historical and cultural context, mixed reception, and subsequent relative obscurity—the accomplishments achieved by Cage and Hiller in constructing such an ambitious, large-scale computer-assisted artwork with a stunning variety of audio-visual components still constitutes a strandline among early art and technological experiments.

Computer art pioneers like Lejaren Hiller Jr., Roy Ascott, Jasia Reichardt, Jack Burnham, and many other artists of their era and shortly afterward—Myron Kruger, Dan Sandin, Lillian F. Schwartz, Jeffrey Shaw, David Rokeby, and more recently Aaron Koblin, Casey Reas, Camille

Utterback, Jason Salavon, Rafael Lozano-Hemmer, and Cory Arcangel among many others—have found a new and growing audience of enthusiasts and practitioners for their own impressive computational art experiments. This renewed excitement can be observed in the overwhelming expansion of digital art genres with permeable, inclusive boundaries: telematics, 3D animation, software aesthetics, surveillance art, videogame art and modification, virtual art, robotics, 3D printing, and interactive/responsive installation art, data visualization, and a litany of other new and expanding areas of digital inquiry.²⁹⁶

Many of these artists' works unabashedly explore coding as a state of being in the Digital, or the Information Age, a present marked by the accumulation, storing, analysis, and interpreting of large datasets, commonly called “big data.”²⁹⁷ Their practices assume McLuhan's assertions in *The Gutenberg Galaxy*—that vast shifts in communication technology, specifically electronic media, fundamentally transforms social organization—as a given, ultimately focusing upon how the complex systems formed by the collection and retrieval of data both constitutes meaning and reveals an aesthetic unique to our digital present. Though new media arts theorist and curator Christiane Paul uses the term “database aesthetics” to describe what she interprets as a subtopic of digital art, she provides a useful clarification of how these large datasets can reveal “patterns of knowledge, beliefs, and social behavior” in current art practices:

In discourse on digital art, the term is frequently used to describe the aesthetic principles applied in imposing the logic of the database to any type of information, filtering data collections, and visualizing data. In that sense, database aesthetics often becomes a

²⁹⁶ Recognition for software and hardware-based art practices, though long celebrated in Western Europe, have only recently become commonplace in contemporary art exhibitions around the U.S. Notably, the first new media artworks to grace the cover of *Artforum* were Cory Arcangel's *Mario Clouds* (2002) and Dara Birnbaum's *Technology Transformation: Wonder Woman* (1978-1979), in March 2009. Arcangel's retrospective at the Whitney Museum, *Cory Arcangel: Pro Tools*, debuted in 2011. *Artforum* 47, No. 7 (March 2009).

²⁹⁷ Big data is most commonly used to describe data sets so large or complex that they demand new kinds of data processing methods to capture, analyze, visualize, share, and store it.

conceptual potential and cultural form—a way of revealing (visual) patterns of knowledge, beliefs, and social behavior. The term is seldom used to refer to the aesthetics of the database as structure itself, although it certainly implies that meaning and the structure of a database is inherently connected to the results produced by the filtering of the data contained in it and the nature of its visualization.²⁹⁸

As first expounded upon by McLuhan, the database has replaced “oral cultures of the past where the elders... would pass down information from generation to generation,” its information retrieval and archival systems have fundamentally transformed our relationship to information.²⁹⁹ These contemporary digital artists—regardless of their intent to engage solely with the “database” as a medium—all grapple with the complexities of vast quantities of both current and historical materials, often transformed through digitization. They subsequently interpret these quantities through performative, process-based means, all of which fundamentally informs their resulting aesthetic and audience interpretation.

For example, Jason Salavon’s practice of creating custom computer software—usually coded using the computer languages C and C++—to aggregate, layer, and average large quantities of archived digital images, provides a visual analog for the common practice of using big data for statistical analysis.³⁰⁰ His works *76 Blowjob* (2001), *Every Playboy Centerfold, the Decades (normalized)* (2002), and *Portrait* (2009-2010) illustrate the accumulation of many digital images into one final, hazy visualization representing the whole. His more recent work is less pictorial, relying instead on performative interactions between programmer and participant. *The Master Index* (2014), cleverly abbreviated as “TMI” (or “too much information”) is a table of 5 million of the most visited English language Wikipedia articles from December 2007 to

²⁹⁸ Christiane Paul, “The Database as System and Cultural Form: Anatomies of Cultural Narratives,” in *Database Aesthetics: Art in the Age of Information Overflow*, ed. Victoria Vesna (Minneapolis: University of Minnesota Press, 2007), 95.

²⁹⁹ Ibid.

³⁰⁰ Brooke E. O’Neill, “Data Sets,” *University of Chicago Magazine*, March-April 2009, 30-34.

November 2013. The index is interactive in that it can be ranked by page view, or sorted alphabetically. *TMI*, as a sortable database, is less about a static aesthetic and more about ongoing interactions between Wikipedia editors and the remote internet audience, as it is purely web-based and thus can be accessed from a variety of web-enabled devices.³⁰¹

Many contemporary art communities, most notably the *glitch* and “Dirty New Media” movements in Chicago, have found inspiration in the concept of programming as performance uniquely determined by its participants and their agonistic relationships with technology. Artists like Jon Satrom, Rosa Menkman, Nick Briz, and Jon Cates use programming as a platform for radical performance art, using their knowledge of computing to interrogate proprietary software production through diverse methods of computational intervention.³⁰² Many of these works bear the mark of John Cage’s performances. For example, Jon Satrom’s prepared desktop real-time performances, such as his series *100 Force Quit Noise Cancel Calculators* (2013) and *Plugin Beachball Success* (2012), specifically reference John Cage’s performance practice: the “prepared” description references Cage’s “prepared piano” pieces, wherein Cage inserted screws, nuts and bolts, and a variety of other objects between the strings of a piano to replicate non-piano sounds. While Cage wrote, “Composing for the prepared piano is not a criticism of the instrument,” Satrom’s prepared laptop instead places criticism squarely on the personal

³⁰¹ These works can be viewed on Jason Salavon’s website: “Jason Salavon,” accessed January 13, 2016, <http://salavon.com/>.

³⁰² The international GLI.TC/H conference and festival, held in Chicago annually since 2011, celebrates all varieties of radical software and hardware intervention. The event’s accompanying text, *GLI.TC/H 20111 READER[ROR]*, features articles and manifestos by many of its artists, who interrogate technological systems “...to explore the aesthetic and conceptual potential of glitches, to examine the politics embedded in technological systems, to create digital psychedelic and/or synesthetic experiences, to practice hacktivism, to explore themes of failure, chance, memory, nostalgia, entropy, etc.” *GLI.TC/H 20111 READER[ROR]*; “GLI.TC/H - the F.A.Q. Page,” accessed January 13, 2016, <http://gli.tc/h/faq/>; “GLI.TC/H,” accessed January 13, 2016, <http://gli.tc/h/>.

computing paradigm.³⁰³ Satrom performs solo with his laptop, its monitor shared with a digital projection behind him. He begins with a fake-out: Satrom begins at the login window, where he struggles to access the desktop. From there, he tries to install a plugin, fails repeatedly, resulting in a what culminates in a choreographed multitude of download windows, their error sounds rhythmically echoing and eventually blending into one another. System requests, errors, and installation file locations multiply and dance across the screen, constituting comprehensive audio-visual performance where the main characters are system error messages. His struggles, though staged, embody our own frustrations with the proprietary operating systems that fundamentally influence our behavior and productivity.³⁰⁴

Though one can't assume a direct relationship between Satrom's demos and Cage's technological performances, certain comparisons—particularly Cage's *Variations VII* performance with the E.A.T. 9 Evenings: Theatre and Engineering (1966)—still bear mentioning, if only for the frenetic energy and impenetrability of the once familiar technologies transformed through performance; for example, during his *Variations VII* performance, Cage's rapt focus on manipulating the photocells that triggered whines and bleats from the hacked consumer-grade transistor radios distracted him from the fact that his tie had caught fire from an unprotected soldered connection.³⁰⁵ Even more relevant, however, are how Satrom's visual elements, though staged, share a commonality with Cage's intent regarding the *HPSCHD* visuals in sheer abundance and aggregation: after its premiere, Cage reflected on the *HPSCHD*

³⁰³ John Cage. *Cage: Sonatas and Interludes for Prepared Piano*, 1998 by C.F. Peters Corporation, Compact disc. Liner notes.

³⁰⁴ Documentation of these performances can be accessed on Jon Satrom's portfolio website: "Jon Satrom," accessed January 13, 2016, <http://jonsatrom.com/>.

³⁰⁵ Details such as these are shared throughout the John Cage: *Variations VII/ 9 Evenings in Theatre & Engineering*. 1966. ArtPix, *Experiments in Art and Technology (E.A.T.)*, 2008. DVD.

performance, “While the random conversation of people had become an extension of the sound, the random nature of their movements had become an extension of the visuals. Each thing had settled into its own place in the natural disorder... Each layer of the event was supercharged with abundance: an abundance of sounds, people, visuals, events; and each layer had been meticulously disorganized to set it apart from the others, while at the same time retaining a strict family connection—all of this distributed over a sloping grid of radiating aisles and concentric promenades.”³⁰⁶

Similarly, Jon Cates (or jonCates, as he is credited) manipulates electronic equipment that produce effects that fluctuate between chaos and order. He performs multimedia performance sets that reference DJ (disc-jockey) and VJ (video-jockey) culture, clearly referencing Cage works such as *Water Walk* (1959) and *Variations VII* (1966); Cates references Cage’s influence not only in the profusion of equipment he manipulates, but also in his intention of creating a meditative experience through noise abundance. In his *ERRORRUNNINGWWWATERNOISES* (2012), Cates creates a droning audio feedback loop on a sound mixer and tends to stacks of audio-visual equipment as he is recorded by a black and white security camera feed. The quality of the droning sound and his poetic monologue delivery into a feedback-prone microphone also evoke Cage in their meditative quality, his voice fading in and out of the feedback. But the work also constitutes a criticism of Cage. Cates wrote of the performance:

... as Douglas Kahn says in his *Noise, Water, Meat*: “Water flowed in the arts prior to midcentury, of course” + by this he means not our century but the century before ours “but it was restricted almost entirely to programmatic, depicted, or discursive water: water music, water scenes, water talk.” i want to make this a realtime water talk, flowing in datastreams of mountainfalls

if almost a memory alrdy

³⁰⁶ Husarik, 18.

...

waterfall

waterflow³⁰⁷

These performances share a deep connection with Lejaren Hiller's interest in the oscillation between randomness and redundancy, a concept deeply embedded in the development of systems theory. However, as a pioneer in the field of electronic composition with a keen interest in breaking down the barriers between computation and aesthetics, Hiller understood that his reputation as an artist was regularly questioned or outright mocked due to the fact that computation remained, and remains today, "...a more obscure, difficult, and controversial topic... difficult to define, difficult to limit, and difficult to systematize. As with any kind of composing, work in this field tends to be highly personalized and hence less accessible to others."³⁰⁸ Though writing specifically about computer-assisted music composition, his words hold true to any artistic engagement with computation. Like Lejaren Hiller, Cates and Satrom place clear emphasis on the power of real-time processing to illustrate the circuitous, reflexive flow of one's personal relationship with technology; for Cates, its purpose is to evince a Zen meditation on the flow of data, while Satrom's "flow" is emphasized through the performance of a broken workflow, morphing into stacking, choreographed feedback loops. Both Cates and Satrom benefit from the obscurity of programming by celebrating the messiness of the human-computer relationship.

³⁰⁷ Jon Cates, "*ERRORRUNNINGWWWATERNOISES... Realtime: Reflections and Render-times* by jonCates (2012) DE:SCRIPT," accessed January 13, 2016, <http://glitch.us/files/ERRORRUNNINGWWWATERNOISES.pdf>; Douglas Kahn, *Noise, Water, Meat: A History of Voice, Sound, and Aurality in the Arts* (Cambridge, MA: MIT Press, 2001.)

³⁰⁸ Lejaren A. Hiller, "Composing with Computers: A Progress Report," *Computer Music Journal* Vol. 5, No. 4 (Winter, 1981): 7.

Because of his understanding of the obscurity of computing, Hiller's emphasis on the importance of procedures and conceptual choice in composition, though not apparent in the resulting *HPSCHD* performance, demands re-examination, especially regarding contemporary new media performance. Hiller's experiments with the "ICHING" oracle emphasized how constraints and limitations influence the outcomes of computation, just as the procedural divination methods of the past are influenced by the process, as well as the prejudices of its cultural context. This turns the "computer priesthood" on its head: divination procedures become less "magical," instead becoming pragmatic, process-based actions arriving at largely empirical outcomes: they thusly provide a historical precedent for coding as a performance for predicting possible futures.

In addition, these hands-on, performative methods of real-time computing share a common ethos of cracking open the black box that so often controls our technological interactions. A current interest in the creation of "alternative economies" highlights art/maker-centric alternatives to the dominant capitalist model that "...creatively explore strategies for identifying and building new economic orders."³⁰⁹ Examples include the proliferation of do-it-yourself (D. I. Y.) technology communities participating in trade-based economies, relying upon work exchange and skill-sharing. Important to these communities is not just their online, social media presence, but also their physical meeting spaces: community-based hacker spaces in cities around the U.S., national organizations like the School for Poetic Computation (SFPC) in New York and the recently defunct Free Art and Technology (F. A. T.) Lab, as well as online DIY-

³⁰⁹ These micro-economies have spurred conversation regarding whether the public can productively engage with the nearly insurmountable problems that stem from neoliberal capitalist ideologies. Tiffany Funk, "Explorations of Alternative Economies - Panel Report," *Media-N: Journal of the New Media Caucus* Vol. 11, No. 02 (Summer 2015).

hardware suppliers and tutorial forums like Adafruit Industries and SparkFun Electronics, rely upon both virtual and physical space.³¹⁰ Additionally, the creation of programming tools for artists and designers, like Ben Fry and Casey Reas' Processing and the physical computing module Arduino provide relative newcomers to programming a welcoming entry point into software and hardware development.³¹¹

This present interest in radical software and hardware performance, as well as the flourishing of alternative economies in the arts, makes the recently renewed interest in re-staging Cage and Hiller's *HPSCHD* make sense. The *HPSCHD* performance at New York's Eyebeam Art and Technology Center on May 3rd and 4th, 2013, serves as an excellent example of this movement: the organizers took advantage of the vast social media presence of existing shared arts spaces and organizations, and in addition greatly benefitted from the enthusiastic participation of the strong network of New York-area DIY, new media communities.³¹²

IV. 2. 5 Brief Proposals for Future Study of Computers and Art

³¹⁰ "The School for Poetic Computation (SFPC)," accessed January 13, 2016, <http://sfpc.io/>; "Free Art and Technology (F. A. T.) Lab," accessed January 13, 2016, <http://ffff.at/>; "Adafruit Industries," accessed January 13, 2016, <https://www.adafruit.com/>; "SparkFun Electronics," accessed January 13, 2016, <https://www.sparkfun.com/>.

³¹¹ Processing, "a flexible software sketchbook and language" first developed by Ben Fry and Casey Reas during their time at the MIT Media Lab in 2001, has flourished in its promotion of software literacy amongst creative coders. Similarly, Arduino is an open-source electronic prototyping platform, designed to teach newcomers how to develop interactive objects. "Processing.org," accessed January 13, 2016, <https://processing.org/>; "Arduino.cc," accessed January 13, 2016, <https://arduino.cc/>.

³¹² Joel Chadabe and Bradley Eros' tumblr blog of the Eyebeam *HPSCHD* event features many photos and videos documenting the experience: "*HPSCHD*: A blog about John Cage and Lejaren Hiller's 1969 multimedia Gesamtkunstwerk *HPSCHD*, presented by Nick Hallett for Darmstadt Essential Repertoire on May 3 & 4, 2013 at Eyebeam Art + Technology Center, produced by ISSUE Project Room in collaboration with Electronic Music Foundation, and NYU-Poly," accessed December 16, 2015, <http://johncagehpschd.tumblr.com/>.

These movements—their seeds present within the early days of computing—have found programming as performance a powerful tool in breaking down the neo-liberal capitalist roadblocks discouraging experimentation and creative computing. The examples listed above celebrate the act of programming, engineering, adapting, and even breaking technology to explore the messiness inside often sleekly-designed exteriors. Because of the growing popularity of this thriving trend in creative computing practices, I would like to make five brief proposals for understanding the history of computing in regard to current and past creative hybrid art and technology practices. While many of these points are well-known to the programming/DIY community, a greater awareness of these issues among artists, curators, art historians, and art critics is necessary to promote a new kind of computer literacy, and to further legitimize new methods in digital artmaking within the art community and beyond.

1) Software and hardware are symbionts, and marking a definitive boundary between the two engenders misunderstandings of both.

In light of recent exhibitions and art acquisitions, most notably the Museum of Modern Art's videogame displays within its design galleries, it is apparent that understanding the relationship between software and hardware as symbiotic is crucial to creating a meaningful discourse with historical computing. By placing hardware under glass as one would a Modernist artifact, the object is not only robbed of its functioning, but it is also robbed of accessibility to its contextual and historical meaningfulness. Likewise, displaying software through emulators, though a reasonable way to preserve or document programs, should be understood as what it is: a “remake” or “documentation.”

2) Programming is a reflexive practice: a performance between programmer and the software/hardware entity.

Without an understanding of the performance and labor of programming, we undervalue the work of programmers, engineers, and designers who create our technological devices. Software fundamentally influences our interactions with it, and thus influences outcomes. For example, Adobe Photoshop is not capable of any creative action, but the user of this software is presented a limited set of creative tools within the software's graphical user interface (GUI), and even more limited ways to physically manipulate the software (via mouse, touchpad/screen, keyboard, etc.). A project constructed using the Photoshop software will have a Photoshop aesthetic, and the same can be said of any creative software. As detailed throughout this dissertation, this influence is described by artist Daniel Sauter's phrase "implied aesthetics."³¹³

3) Software is a continuation of this performance, and is an action (or, as noted by Roy Ascott, a *behaviourable*).

Current understanding of software casts it as a commodity: a *thing* that can be bought and sold. Software is merely a set of instructions directing hardware to perform specific operations. Software companies essentially grant licenses to users, and contemporary propriety software is engineered to discourage long-term holding of these licenses through upgrades, cloud-based applications, encryptions, and user keys. Open source development (a model promoting universal access to product design, including software with available source code, allowing users to study,

³¹³ New media artist Daniel Sauter coined the phrase "implied aesthetics" to describe motion-awareness in 4th generation mobile devices; however, a more general reading of the term can apply to design placing limitations on the kinds of interactions one has with personal technologies; it ultimately describes the kinds of aesthetic choices that are made for us by the way in which digital tools are designed, rendering the output of these tools similar in pre-designed ways. Sauter, "Implied Aesthetics: A Sensor-Based Approach to Mobile Devices," in *Design, User Experience, and Usability, Pt. II*, ed. A. Marcus (Berlin Heidelberg: Springer-Verlag, 2011), 645–654.

adapt, and distribute it) constitutes a radical alternative to propriety production, often functioning through alternative economies that rely on collaboration.

4) The “virtual,” like software, is not a thing or commodity; however, it is useful as a concept proposing a paradigm of possibilities afforded by the sped-up actions of digital computing (much like Ascott’s *futuribles*).

“Cloud storage” is, in reality, the opposite of what it sounds like: information is saved on server farms that have actual, literal locations and dimensions. The internet actually is, in a sense, a series of tubes, constituting cables, fiber-optics, etc. Misunderstandings regarding technological elements so embedded in our daily lives discourages the acknowledgement of the labor necessary to produce our technologies, and blinds us to the dangers of relying on systems over which we have no control.

5) Data needs to be treated like any artistic medium: it has embedded meaning and significance, and merely transforming it in arbitrary ways strips away meaning.

As previously cited, Lejaren Hiller emphasized the important practice of making data meaningful: “My music tends to proceed from disorder to order. It starts with random generation of musical elements and proceeds with the imposition of more and more constraints on the elements' acceptability... Not only does this procedure work, but it seems philosophically satisfying. The trap in writing a completely deterministic set of algorithms is that they reduce the whole process to mere data transformation.”³¹⁴ Careful consideration needs to be made of technology and its historical, social, and cultural influence. Now more than ever, data—whether an accumulation of world temperatures from the past to the present, or the rising numbers of incarcerated individuals in the U.S. prison system—needs to be understood not through its

³¹⁴ Lejaren A. Hiller, 7-8.

conglomeration of numerical values, but its underlying meaning. Hiller's warning to avoid "mere data transformation" is especially relevant in the age of data visualization, in which artists and designers increasingly try to confront ways in which they can make sense of big data.

These five proposals, though brief, are meant to make sense of both historical and contemporary examples of computer art, greatly influenced by an analysis of the creative and physical labor thrust into such a sprawling, techno-utopian computational work such as *HPSCHD*. This in-depth examination of Cage and Hiller's *HPSCHD* allows a unique opportunity to interrogate the history and context of the computer as a radical, yet embattled artistic tool. Rather than dismissing *HPSCHD* as an anomalous misstep in the oeuvres of both Cage and Hiller, we can re-examine the performance as a progenitor of the more recent arts movements celebrating DIY, process-based technological art-making, functioning as the spiritual successor to Lejaren Hiller's pedagogical praxis. *HPSCHD* does not simply constitute a single entry in the history of computer art, but exists as a watershed in the rapid escalation of, and criticality toward, technological experimentation in the arts, reflecting our present in which a new generation of new media artists engage with computation as a radical act, a relationship between humans and a technological tool capable of producing challenging, radical art.

BIBLIOGRAPHY

- Adorno, Theodor W. *Prisms*. Cambridge, MA: MIT Press, 1983.
- Agamben, Giorgio. *What is an Apparatus? and Other Essays*. Stanford: Stanford University Press, 2009.
- Artaud, Antonin. *The Theater and its Double*. Translated by Mary Caroline Richards. New York: Grove Press, 1958.
- Ascott, Roy. "Behaviourist Art and the Cybernetic Vision," *Cybernetica* 10 (1967): 25-56.
- . *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness by Roy Ascott*. Edited by Edward Shanken (Berkeley: University of California Press, 2003).
- Augusta, Countess of Lovelace, Ada. "Notes upon the Memoir by the Translator, note 'G', in *Sketch of the Analytical Engine Invented by Charles Babbage*, by L. F. Menabrea of Turin, Officer of the Military Engineers, from the Bibliothèque Universelle de Genève, October, 1842, No. 82." Accessed July 22, 2015.
<http://www.fourmilab.ch/babbage/sketch.html>.
- Austin, Larry. "An Interview with John Cage and Lejaren Hiller." *Computer Music Journal* Vol. 16, No. 4 (1992): 15-29.
- . "HPSCHD by John Cage, Lejaren Hiller." *Computer Music Journal* Vol. 28, No. 3 (Autumn, 2004): 83-85.
- . "John Cage and Lejaren Hiller, HPSCHD." In *Source: Music of the Avant-garde, 1966–1973*. Edited by Larry Austin, Douglas Kahn, and Nilendra Gurusinghe. Berkeley: University of California Press, 2011.
- Benjamin, Walter. *Illuminations: Essays and Reflections*. Edited by Hannah Arendt. New York: Schocken Books, 1968.
- Bernstein, David W. and Christopher Hatch, editors. *Writings through John Cage's Music, Poetry, and Art*. Chicago: University of Chicago Press, 2001.
- Bewley, John. "Lejaren A. Hiller: Computer Music Pioneer." In University at Buffalo, SUNY Music Library. Buffalo, NY, 2004.
- Bewley, John, Judy Jungels, and Cort Lippe. "Preserving Lejaren A. Hiller's Flowcharts: A Case Study." In University at Buffalo, SUNY Music Library. Buffalo, NY, 2007.
- Borman, Ed. "Assembly Hall Can Bring Events Not Possible Now." *The News-Gazette, Campaign-Urbana*, February 6, 1958.

- Borup, Jørn. *Volume 1, Regional, Critical, and Historical Approaches*. Edited by Peter Antes, Armin W. Geertz, and Randi R. Warne. Berlin: Verlag de Gruyter, 2004.
- Braidotti, Rosi. *The Posthuman* (Cambridge: Polity Press, 2013).
- Braidotti, Rosi and Timotheus Vermeulen. "Borrowed Energy." *Frieze Magazine* Issue 165 (September 2014).
- Brearley, H. C. "ILLIAC II—A Short Description and Annotated Bibliography," *IEEE Transaction on Electronic Computer* Vol. EC-14, No. 3 (June 1965).
- Brichford, Maynard. "A Brief History of the University of Illinois." The University of Illinois at Urbana-Champaign Archives, 1970, revised June 1, 1983. Accessed April 24, 2016. <http://archives.library.illinois.edu/features/history.php>.
- Brown, Bill. "Thing Theory." *Critical Inquiry* Vol. 28, No. 1 (Autumn, 2001): 1-22.
- Broyles, Michael. *Mavericks and Other Traditions in American Music*. New Haven & London: Yale University Press, 2004.
- Bruce, Neely. Lecture. Atlantic Christian College, Wilson, North Carolina, November 5, 1969.
- Burkert, Walter. *The Orientalizing Revolution: Near Eastern Influence on Greek Culture in the Early Archaic Age*. New York: Thames and Hudson, 1992.
- Burnham, Jack. *Beyond Modern Sculpture: The Effects of Science and Technology on the Sculpture of this Century*. New York: George Braziller, 1968.
- . *On the Future of Art*. New York: Viking, 1970.
- . *Software: Information Technology: Its New Meaning for Art*. New York: Jewish Museum N.Y., 1970.
- . "Systems Esthetics." *Artforum* 7, No. 1 (September 1968): 30-35.
- Cabana, Pierre. *Dialogues with Marcel Duchamp*. Translated by Ron Padgett. New York: Viking, 1971.
- Cage, John. *Silence: Lectures and Writings*. Middletown, CT: Wesleyan University Press, 1961.
- . *A Year from Monday*. Hanover, NH: Wesleyan University Press, 1969.
- . "Choosing Abundance." *North American Review* 254, No. 3 (1969): 9-17.
- . *Composition in Retrospect*. Cambridge, MA: Exact Change, 1983.

- . *Diary: How to Improve the World (You Will Only Make Matters Worse), A Great Bear Pamphlet*. New York: Something Else Press, 1967.
- . “The East in the West.” *Asian Music* Vol. 1, No. 1 (Winter, 1968-1969): 15-18.
- . *Empty Words*. Wesleyan University Press, 1979.
- . “McLuhan’s Influence.” In *John Cage: Documentary Monographs in Modern Art*. Edited by Richard Kostelanetz. New York: Praeger Publishers, 1970, 70-71.
- . “Things to Do.” *North American Review* 254, no. 4 (1969): 12-16.
- . *Variations VI*. New York: Henmar Press, 1966.
- . *Variations IV*. New York: Henmar Press, 1963.
- . *X: Writings ‘79-’82*. Middleton, CT: Wesleyan University Press, 1983.
- Cage, John and Daniel Charles. *For the Birds: John Cage in Conversation with Daniel Charles*. London: Marion Boyers Publishers Ltd., 2010.
- Cage, John, Marjorie Perloff, et al. *John Cage: Composed in America*. Edited by Marjorie Perloff and Charles Junkerman. Chicago: University of Chicago Press, 1994.
- Cage, John, Michael Kirby, and Richard Schechner. “An Interview with John Cage.” *Tulane Drama Review* 10, No. 2 (Winter 1965): 50-72.
- Cage, John and Richard Kostelanetz. “His Own Music: Ur-Conversation with John Cage Produced by Richard Kostelanetz.” *Perspectives of New Music* Vol. 25, No. ½, 25th Anniversary Edition (Winter-Summer 1987): 88-106.
- Cage, John, Richard Kostelanetz, et al. *John Cage: Documentary Monographs in Modern Art*. Edited by Richard Kostelanetz. New York: Praeger Publishers, 1970.
- Cage, John, and Roger Reynolds. “Interview with Roger Reynolds.” In *John Cage [Catalog]*. Edited by Robert Dunn, 45-52. Frankfurt: C.F. Peters, 1962.
- Cardew, Cornelius. *Stockhausen Serves Imperialism*. Latimer New Dimensions Limited, 1974.
- Ceruzzi, Paul E. *A History of Modern Computing*. Cambridge, MA: MIT Press, 2003.
- . *Computing: A Concise History*. Cambridge, MA: MIT Press, 2012.
- Chabala, Tracy and Reverend Joey Talley. “We Talked to a Witch Who Casts Viruses Out of Computers with Magic.” *Motherboard: Vice*. Last updated January 12, 2016. Accessed

- January 13, 2016. <http://motherboard.vice.com/read/we-talked-to-a-witch-who-casts-viruses-out-of-computers-with-magic>.
- Chadabe, Joel and Bradley Eros. "A blog about John Cage and Lejaren Hiller's 1969 multimedia Gesamtkunstwerk *HPSCHD*, presented by Nick Hallett for Darmstadt Essential Repertoire on May 3 & 4, 2013 at Eyebeam Art + Technology Center, produced by ISSUE Project Room in collaboration with Electronic Music Foundation, and NYU-Poly." Accessed December 16, 2015. <http://johncagehpschd.tumblr.com/>.
- Charles, Daniel. *For the Birds: John Cage in Conversation with Daniel Charles*. London: Marion Boyars, 1981.
- Clarke, Arthur C. *2001: A Space Odyssey*. New York: New American Library, 1968.
- . *2010: Odyssey Two*. New York: Grenada Publishing Ltd., 1983.
- . "2001 Double Take: I was a Teenage Centenarian." *Wired*, January, 1997. Accessed January 10, 2016. <http://www.wired.com/1997/01/ffclark/>.
- . *3001: The Final Odyssey*. New York: Del Rey, 1997.
- Cole, Hugo. "Musicircus." *The Guardian*. December 19, 1972.
- . "John Cage." *The Guardian*. May 11, 1972.
- . "An Easy Composure." *The Guardian*. May 22, 1972.
- Collins, Derek. "Mapping the Entrails: The Practice of Greek Hepatoscopy." *American Journal of Philology* 129 (2008): 319-345.
- Comte de Lautréamont. *Maldoror (Les chants de Maldoror)*. Translated by Guy Warnham. New York: New Directions, 1965.
- Cramer, Florian. *Words Made Flesh: Code, Culture, Imagination*. Rotterdam: Piet Zwart Institute, 2005.
- Debord, Guy. "Definitions." *Internationale Situationniste* 1 (June, 1958).
- . *Society of the Spectacle*. Detroit, MI: Black and Red Publishing, 2000.
- DeLapp-Birkett, Jennifer. "Aaron Copland and the Politics of Twelve-Tone Composition in the Early Cold War United States." *Journal of Musicological Research* Vol. 27, Issue 1 (2008): 31-62.
- Deleuze, Gilles. *Bergsonism*. Translated by Hugh Tomlinson and Barbara Habberjam. NY: Zone, 1991).

- . “Postscripts on the Societies of Control.” *October* Vol. 59 (Winter, 1992): 3-7.
- Derrida, Jacques. “Excerpt from ‘Of Grammatology.’” In *Art in Theory: 1900 – 1990*. Edited by Charles Harrison and Paul Wood, 918-923. Oxford: Blackwell, 1996.
- Descartes, René. “Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences (Discours de la méthode pour bien conduire sa raison, et chercher la vérité dans les sciences) Part IV.” *Project Gutenberg*. Accessed July 13, 2015. <http://www.gutenberg.org/files/59/59-h/59-h.htm#part4>.
- Dewey, John. *Art as Experience*. London: Perigree Trade, 1934.
- . *Democracy and Education: Introduction to the Philosophy of Education*. New York: Courier Dover Publications, 1916.
- Dick, Philip K. *The Man in the High Castle*. New York: Ace Books, 1988.
- Dickenson, Peter. *CageTalk: Dialogues with & about John Cage*. Rochester, NY: University of Rochester Press, 2006.
- Dowson, Mark. “Norbert Wiener on Cybernetics.” In *Cybernetic Serendipity: The Computer and the Arts, a Studio International special issue*. Edited by Jasia Reichart, 9-11. London: Studio International, 2nd edition, Set. 1968.
- . “Notes on Cybernetics.” In *Cybernetic Serendipity: The Computer and the Arts, a Studio International special issue*. Edited by Jasia Reichart, 9-11. London: Studio International, 2nd edition, Set. 1968.
- Duckworth, William. “Expanding Notational Parameters in the Music of John Cage.” PhD diss., University of Illinois at Urbana-Champaign, 1972.
- Dumonlin, Heinrich. *A History of Zen Buddhism*. New Delhi: Munshiram Manoharlal Publishers Pvt. Ltd., 2000.
- Eglash, Ron. *African Fractals: Modern Computing and Indigenous Design*. New Brunswick: Rutgers University Press, 1999.
- . “Appropriating Technology: An Introduction.” In *Appropriating Technology: Vernacular Science and Social Power*. Edited by Ron Eglash, J. Croissant, G. Di Chiro, and R. Fouché, vii-xxi. Minneapolis: University of Minnesota Press, 2004.
- Faure, Bernard. *An Epistemological Critique of the Chan Tradition*. Princeton: Princeton University Press, 1993.
- Fetterman, William. *John Cage's Theatre Pieces*. London: Harwood Academic Publishers, 1996.

- Fleming, Richard and William Duckworth. *John Cage at Seventy-Five*. Lewisburg: Bucknell University Press, 1989.
- Fletcher, Neville Horner and Thomas D. Rossing. *The Physics of Musical Instruments, 2nd edition*. Berlin: Springer Science and Business Media, 1998.
- Flusser, Vilém. *Towards a Philosophy of Photography*. New York: Reaktion Books, 2000.
- Foster, Hal. "An Art of Missing Parts." *October* Vol. 92 (Spring 2000): 128-156.
- . *Prosthetic Gods*. Cambridge: MIT Press, 1995.
- Freud, Sigmund. *The Freud Reader*. Edited by Peter Gay. New York: W. W. Norton & Company, 1995.
- Fried, Michael. "Art and Objecthood." *Artforum* 5 (June 1967): 12- 23.
- . "Art and Objecthood." In *Minimal Art: A Critical Anthology*. Edited by Michael Battcock, 116-147. New York: E. P. Dutton, 1968.
- Fuegi, J. and J. Francis. "Lovelace & Babbage and the creation of the 1843 'notes'." *Annals of the History of Computing IEEE* Vol. 25, Issue 4 (October–December 2003): 16-26.
- Funk, Tiffany. "Explorations of Alternative Economies - Panel Report." *Media-N: Journal of the New Media Caucus* Vol. 11, No. 02 (Summer 2015).
- Gadamer, Hans-Georg. *Gadamer in Conversation: Reflections and Commentary*. Translated by E. Palmer. New Haven: Yale University of Press, 2001.
- Gagne, Cole and Tracy Caras. "Interview with John Cage." *New York Arts Journal* 1, No. 1 (May 1976).
- . *Soundpieces: Interviews with American Composers*. New York: Scarecrow, 1986.
- Galison, Peter. "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision." *Critical Inquiry* Vol. 21, No. 1 (Autumn 1994): 228-266.
- Garfinkel, Simson. "Happy Birthday, HAL." *Wired* Issue 5.01, January, 1997. Accessed January 10, 2016. <http://www.wired.com/1997/01/ffhal/>.
- Gillmor, Alan. "Interview with John Cage [1973]." *Contact* 14 (Autumn 1976).
- Glaser, Anton. *History of Binary and other Nondecimal Numeration*. Los Angeles: Tomash Publishers, 1971.

- GLI.TC/H 20111 READER[ROR]*. Edited by Nick Briz, Evan Meaney, Rosa Menkman, William Robertson, Jon Sotrom, and Jessica Westbrook. Chicago: Unsorted Books, 2011.
- Grau, Oliver. *Virtual Art: From Illusion to Immersion*. Cambridge, MA: MIT Press, 2004.
- Hallet, Nick. *A blog about John Cage and Lejaren Hiller's 1969 multimedia Gesamtkunstwerk HPSCHD*. <http://johncagehpschd.tumblr.com/>.
- Hamm, Charles. *Putting Popular Music in Its Place*. London: Cambridge University Press, 1995.
- Hansen, Mark B. N. *Bodies in Code: Interfaces with Digital Media*. London: Routledge, 2006.
- . *New Philosophy for New Media*. Cambridge, MA: MIT Press, 2004.
- Haraway, Donna. *Simians, Cyborgs and Women: The Reinvention of Nature*. New York: Routledge, 1991.
- Harvey, Peter. *An introduction to Buddhism: Teachings, history and practices*. Cambridge: Cambridge University Press, 1995.
- Hayles, N. Katherine. *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago: University of Chicago Press, 1999.
- . "Virtual Bodies and Flickering Signifiers." Accessed February 7, 2015. <http://www.english.ucla.edu/faculty/hayles/Flick.html>.
- Heidegger, Martin. "The Question Concerning Technology." In *Basic Writings*. Edited by David Farrell Krell. Harper & Row, 1977.
- Heimbecker, Sara J. "HPSCHD, Gesamtkunstwerk, and Utopia." *American Music*, 26.4 (2008): 478-481.
- . "John Cage's *HPSCHD*." PhD diss., University of Illinois at Urbana-Champaign, 2011.
- Henahan, Donal. "CLASSICAL VIEW; Paramusical Notions That Turn to Dust." *New York Times*, March 3, 1991.
- Higgins, Dick. "Statement on Intermedia," *Dé-coll/age (décollage) * 6*, *Typos Verlag*, Frankfurt. Edited by Wolf Vostell. New York: Something Else Press. Accessed January 9, 2016. <http://artpool.hu/Fluxus/Higgins/intermedia2.html>.
- Higgins, Hannah. "Enversioning Fluxus: A venture into whose fluxus where and when." PhD diss., University of Chicago, 1994.
- . *Fluxus Experience*. Berkeley: University of California Press, 2002.
- Hiller, Lejaren A. Sr. *Sutures in Ancient Surgery*. New York: Davis and Geck Inc., 1950.

- Hiller, Lejaren A. "Computer music." *Scientific American* 201, No. 6 (December 1959): 109-20.
- . "Computer Music." In *Cybernetic Serendipity: The Computer and the Arts*. Edited by Jasia Reichardt, 21-23. New York: Frederick A. Praeger, 1969.
- . "Music Composition with Computers—a Historical Survey." In *The Computer and Music*, ed. Harry Lincoln, 47. Ithaca: Cornell University Press, 1970.
- . "Programming the *I-Ching* Oracle." *Computer Studies in the Humanities and Verbal Behavior* 3 (1970): 130-143.
- . "Computer music." In *Readings from Scientific American: Computer and Computation*. 113-122. San Francisco: W. H. Freeman, 1971.
- . "Composing with Computers: A Progress Report." *Computer Music Journal* Vol. 5, No. 4 (Winter 1981): 7-21.
- . "Composing with Computers: A Progress Report." In *The Music Machine*. Edited by Curtis Roads, 75-89. Cambridge, Mass.: MIT Press, 1989.
- Hiller, Lejaren A. and James W. Beauchamp, "Research in Music with Electronics," *Science* Vol. 150, No. 3693 (1965): 161-169.
- Hiller, Lejaren A. and Leonard M. Isaacson, *Experimental Music: Composition with an Electronic Computer*, New York: McGraw-Hill, 1959.
- Holstein, Victoria. "Abstract Expressionism's Counterculture: The Club, the Cold War, and the New Sensibility." Lecture. Museum of Modern Art, New York, February 25, 2011.
- Husarik, Stephen. "John Cage and LeJaren Hiller: *HPSCHD*, 1969." *American Music* Vol. 1, No. 2 (Summer 1983): 1-21.
- Isaacson, Walter. *Steve Jobs*. New York: Simon & Schuster, 2011.
- . *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*. New York: Simon & Schuster, 2014.
- Izenberg, Gerald N. *The Existentialist Critique of Freud: The Crisis of Autonomy*. Princeton: Princeton University Press, 1976.
- Jain, Sarah S. "The Prosthetic Imagination: Enabling and Disabling the Prosthesis Trope." *Science, Technology, & Human Values* Vol. 24 (Winter 1999): 31-54.
- Jensen, Marc G. "John Cage, Chance Operations, and the Chaos Game: Cage and the 'I Ching'." *The Musical Times*, Vol. 150, No. 1907 (Summer 2009): 97-102.

- Jones, Ernest. *Sigmund Freud: Life and Work. Vol 3: The Last Phase 1919-1939*. London: Hogarth Press, 1957.
- Joseph, Brandon. "HPSCHD—Ghost or Monster?" In *Mainframe Experimentalism: Early Computing and the Foundation of the Digital Arts*. Edited by Hannah B. Higgins and Douglas Kahn, 147-169. Berkeley: University of California Press, 2012.
- Jung, Carl G. *Synchronicity: An Acausal Connecting Principle*. London: Routledge, 1985.
- Kahn, Douglas. "Silence and Silencing." *The Musical Quarterly*, Vol. 81, No. 4 (Winter 1997): 556-598.
- . *Noise, Water, Meat: A History of Voice, Sound, and Aurality in the Arts*. Cambridge, MA: MIT Press, 2001.
- . *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts*. University of California Press, 2013.
- Kaprow, Allan. *Assemblage, Environments and Happenings*. New York: Abrams, 1966.
- . *Essays on the Blurring of Art and Life*. Edited by Jeff Kelley. Berkeley: University of California Press, 1993.
- Kapur, Nick. "Japanese Literature and Art after ANPO." Paper presented at the Asian Studies Conference Japan (ASCJ), June 2010.
- . "Art in Japan after the 1960 US-Japan Security Treaty Crisis." Paper presented at the College Art Association Conference, February 2015.
- Kepes, György. "The Landscape of Art and Science." In *The New Landscape of Art and Science*. Chicago: Paul Theobald and Co., 1956.
- Kern, Martin. "Early Chinese literature, Beginnings through Western Han." In *The Cambridge History of Chinese Literature, Volume 1: to 1375*. Edited by Stephen Owen, 1-115. Cambridge: Cambridge University Press, 2010.
- Kirby, Michael. "The New Theatre." In *Happenings and Other Acts*. Edited by Mariellen R. Sanford, 27. New York: Routledge, 1995.
- Kittler, Friedrich. *Discourse Networks 1800/1900*. Stanford, CA: Stanford University Press, 1992.
- . "There is no Software," *CTHEORY.net* (October 18, 1995). Accessed March 15, 2014. <http://www.ctheory.net/articles.aspx?id=74/>.

- . *Gramophone, Film, Typewriter*. Stanford: Stanford University Press: 1999.
- . *Optical Media*. Cambridge: Polity Press, 2010.
- Klein, Lothar. "Twentieth-Century Analysis: Essays in Miniature." *Music Educators Journal* LIV, No. 9 (May, 1968): 57-60.
- Klüver, Billy. "Statement of Purpose." New York: Experiments in Art and Technology (E.A.T.), 1966.
- Kostelanetz, Richard. *The Theatre of Mixed Means; An Introduction to Happenings, Kinetic Environments, and Other Mixed Means Performances*. New York: Dial Press, 1968.
- . "They All Came to Cages 'Circus'." *New York Times*, May 25, 1969.
- . *John Cage*. New York: Praeger Publishers, 1970.
- . "John Cage as a Hörspielmacher." In *Writings About John Cage*. Edited by Richard Kostelanetz. Ann Arbor: University of Michigan Press, 1989.
- . "The Keystone of the Cagean Canon." In *Innovative Music(Ian)S*, 43. New York: Limelight Editions, 1989.
- Kottick, Edward L. *History of the Harpsichord, Vol. 1*. Bloomington: Indiana University Press, 2003.
- Krueger, Myron. *Artificial Reality*. Boston: Addison-Wesley, 1983.
- . *Artificial Reality II*. Boston: Addison-Wesley, 1991.
- Kuhn, Marsha. "Hpschd! Woweee!: Cage Schedules May 16 as His Computer Extravaganza." *Daily Illini*, May 6 1969.
- Kyushu-ha ten (Group Kyushu Exhibition)*. Exhibition Catalogue. Fukuoka: Fukuoka Museum of Art, 1988.
- Leibnitz, Gottfried Wilhelm von. *G.W. Leibniz, Selections*. Edited and translated by Philip P. Wiener. New York: Scribner's, 1951.
- Lippard, Lucy. *Six Years: The Dematerialization of the Art Object from 1966 to 1972*. Berkeley: University of California Press, 1973.
- Lowenberg, Richard. "The Secret Lives of Plants." Accessed March 31, 2015. <http://datagarden.org/43/richard-lowenberg-interview/>.

- Marotti, William. "Political aesthetics: activism, everyday life, and art's object in 1960s' Japan." *Inter-asia Cultural Studies* Vol. 7, No. 4 (2006): 606-618.
- . "Japan 1968: The Performance of Violence and the Theater of Protest." *The American Historical Review* Vol. 114, No. 1 (Feb., 2009): 97-135.
- . *Money, Trains, and Guillotines: Art and Revolution in 1960s Japan*. Durham, NC: Duke University Press, 2013.
- Martin, James. *Programming Real-time Computer Systems*. Englewood Cliffs, NJ: Prentice-Hall Inc., 1965.
- Massumi, Brian. *Parables for the Virtual: Movement, Affect, Sensation*. Duke University Press, 2002.
- McHale, John. *The Future of the Future*. New York: George Braziller, Inc., 1969.
- McLuhan, Marshall. *The Gutenberg Galaxy: The Making of the Typographic Man*. Toronto: University of Toronto Press, 1962.
- . "The Agenbite of Outwit." *Location* 1, No. 1 (1963): 41-44.
- . *Understanding Media: The Extensions of Man*. New York: Routledge, 1964.
- Menabrea, Luigi Federico. "Sketch of the Analytical Engine Invented by Charles Babbage," *Scientific Memoirs* 3 (1843), archived from the original on September 15, 2008. Retrieved August 29, 2008, with notes upon the memoir by the translator, Lady Ada Lovelace. Accessed January 10, 2016. <https://www.fourmilab.ch/babbage/sketch.html>.
- Merleau-Ponty, Maurice. *The Primacy of Perception and Other Essays on Phenomenological Psychology, the Philosophy of Art, History, and Politics*. Edited by James L. Edie, 163. Evanston: Northwestern University Press, 1964.
- Mozart, Wolfgang Amadeus. *Musikalisches Würfelspiel, K³.Anh.294d; K⁶.516f*. Bonn, Germany: N. Simrock, 1787.
- Mumford, Lewis. *The Story of Utopias*. New York: Viking, 1962.
- Nelson, Theodor. *Computer Lib: You Can and Must Understand Computers Now; Dream Machines: New Freedoms Through Computer Screens—A Minority Report*. Self-published, 1974.
- Nevitt, Barrington and Maurice McLuhan. *Who Was Marshall McLuhan? Exploring a Mosaic of Impressions*. Toronto: Stoddart, 1996.
- "Of Dice and Din." *TIME Magazine*, Vol. 93 Issue 22, May 30, 1969.

- Paul, Christiane. "The Database as System and Cultural Form: Anatomies of Cultural Narratives." In *Database Aesthetics: Art in the Age of Information Overflow*. Edited by Victoria Vesna, 95-109. Minneapolis: University of Minnesota Press, 2007.
- Perle, George. *Serial Composition and Atonality: An Introduction to the Music of Schoenberg, Berg, and Webern*. Berkeley, Los Angeles, and London: University of California Press, 1977.
- Pugh, Emerson W., Lyle R. Johnson, and John H. Palmer. *IBM's 360 and early 370 systems*. Cambridge, MA: MIT Press, 1991.
- Rainer, Yvonne. "Looking Myself in the Mouth." *October*, No. 17 (Summer 1981): 65-76.
- Reich, Willi. *Schoenberg: A Critical Biography*. New York, Washington, 1971.
- Reichardt, Jasia. *Cybernetic Serendipity: The Computer and the Arts, a Studio International special issue*. London: Studio International, 2nd edition, Set. 1968.
- Revill, David. *The Roaring Silence: John Cage: A Life*. New York: Arcade Publishing, 1992.
- Rivest, Joan. "In Advance of the Avant Garde: John Cage at the University of Illinois, 1952-69." EMF Institute (1999). Accessed May 11, 2014.
<http://emfinstitute.emf.org/articles/rivest99/rivestoncage991.html>.
- Said, Edward. *Orientalism*. New York: Vintage, 1978.
- Salter, Chris. *Entangled: Technology and the Transformation of Performance*. Cambridge, MA: MIT Press, 2010.
- Salzman, Eric. "Cage-Hiller: Hpschd." *Stereo Review* 24, No. 1 (1970): 94.
- Sandred, Örjan, Mikael Laurson, and Mike Kuuskankare. "Revisiting the Illiac Suite—a rule based approach to stochastic processes." Accessed July 22, 2015.
http://www.sandred.com/texts/Revisiting_the_Illiac_Suite.pdf.
- Sauter, Daniel. "Implied Aesthetics: a Sensor-Based Approach to Mobile Devices." In *Design, User Experience, and Usability, Pt. II*. Edited by A. Marcus, 645-654. Berlin Heidelberg: Springer-Verlag, 2011.
- Schechner, Richard. "Approaches to Theory/Criticism." *The Drama Review* Vol. 10, No. 4 (1966): 20-53.
- . *Performance Theory*. New York: Routledge Classics, 1977.
- Schiffer, Wilhelm. "Review: Zen and Japanese Buddhism by Daisetz T. Suzuki." *Monumenta Nipponica* Vol. 14, No. ½ (April-July 1958): 228-229.

- Schoenberg, Arnold. *Style and Idea*. Edited by Leonard Stein and translated by Leo Black. Berkeley & Los Angeles: University of California Press, 1975.
- . *Theory of Harmony*. Translated by Roy E. Carter. Berkeley: University of California Press, 1978.
- Schorske, Carl. *Fin-de-Siècle Vienna: Politics and Culture*. New York: Vintage Books, 1980.
- Shanken, Edward. “Gemini Rising, Moon in Apollo: Attitudes on the Relationship Between Art and Technology in the US, 1966-71.” In *ISEA97 (Proceedings of the 8th International Symposium on Electronic Art)*. Edited by A. Nereid. Chicago: ISEA97, 1998.
- . “The House that Jack Built: Jack Burnham's Concept of ‘Software’ as a Metaphor for Art.” In *Reframing Consciousness: Art and Consciousness in the Post-Biological Era*. Edited by Roy Ascott. Exeter: Intellect, 1999.
- . “Art in the Information Age: Cybernetics, Software, Telematics and the Conceptual Contributions of Art and Technology to Art History and Aesthetic Theory.” PhD diss., Duke University, 2001.
- . “Art in the Information Age: Technology and Conceptual Art,” *Leonardo* Vol. 35, No. 4 (2002): 433-438.
- . “Telematic Embrace: A Love Story? Roy Ascott's Theories of Telematic Art.” Accessed November 16, 2016. http://telematic.walkerart.org/timeline/timeline_shanken.html.
- . “From Cybernetics to Telematics: The Art, Pedagogy, and Theory of Roy Ascott.” In *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness by Roy Ascott*. Edited by Edward Shanken. Berkeley: University of California Press, 2003.
- . “Historicizing Art and Technology: Forging a Method and Firing a Canon.” In *Mediaarthistories*. Edited by Oliver Grau, 44. Cambridge MA: MIT Press, 2007.
- Shannon, Claude. “Communication Theory of Secrecy Systems.” *Bell System Technical Journal* Vol. 28, No. 4 (1949): 656–715.
- . “A Mathematical Theory of Communication.” *Bell System Technical Journal* Vol. 27, No. 3 (July 1948): 379–423.
- . *The Mathematical Theory of Communication*. Urbana: University of Illinois Press, 1949.
- Slotnick, Daniel et al. *Illiac IV system manual*. Accessed December 16, 2015. <http://archive.computerhistory.org/resources/text/Burroughs/Burroughs.ILLIAC%20IV.1974.102624911.pdf>.

- Smith, Brian Cantwell. "The Owl and the Electric Encyclopaedia." *Artificial Intelligence* 47 (1991): 251-288.
- Smith, Marquard. *The Prosthetic Impulse: From a Posthuman Present to a Biocultural Future*. Edited by Marquard Smith and Joanne Morra. Cambridge MA: MIT Press.
- Smith, Steve. "An Intentional Spectacle." May 5, 2013. Accessed January 9, 2016. <http://www.nytimes.com/2013/05/06/arts/music/hpschd-at-eyebeam.html>.
- Smithson, Robert. "Entropy and the New Monuments." In *Robert Smithson: The Collected Writings*. Edited by Jack Flam, 10-23. Berkeley: University of California Press, 1996.
- Snow, C. P. "The Two Cultures." *Leonardo* Vol. 23, No. 2/3 (1990): 169-173.
- Snyder, Ellsworth. "Review: Source: Music of the Avant Garde. Vol. 1, No. 1 by Larry Austin." *Notes Second Series* Vol. 24, No. 2 (Dec., 1967): 348-349.
- Sontag, Susan. "Happenings: An Art of Radical Juxtaposition." In *Against Interpretation, and other essays*. New York: Farrar, Strauss, Giroux, 1966.
- Stearn, Gerald Emmanuel. *McLuhan: Hot & Cool*. New York: Signet, 1968.
- Stein, Dorothy. *Ada: A Life and a Legacy, MIT Press Series in the History of Computing*. Cambridge, MA: The MIT Press, 1985.
- Stiller, Andrew. "Hiller, Lejaren." *Grove Music Online. Oxford Music Online*. Oxford University Press. Accessed January 11, 2016. <http://www.oxfordmusiconline.com/subscriber/article/grove/music/13044>.
- Sumsion, Calvin. "The Integration of Visual Elements by *I-Ching* Philosophy and Gestalt Psychology, Showing the Communicative Value of Form." MA thesis, University of Illinois at Urbana-Champaign, 1969.
- Taylor, Grant D. *When the Machine Made Art: The Troubled History of Computer Art*. New York: Bloomsbury, 2014.
- Thomson, James. "On an Integrating Machine Having a New Kinematic Principle." *Proceedings of the Royal Society of London*, 24 (1876): 262-265.
- Thomson, Virgil. "Cage and the Collage of Noises." *The New York Review of Books*, April 23, 1970.
- Tompkins, Dave. *How to Wreck a Nice Beach: The Vocoder from World War II to Hip-Hop, the Machine Speaks*. New York: Stop Smiling Books, 2011.

- Toole, Betty Alexandra. "Poetical Science." *The Byron Journal* 15 (1987): 55–65.
- Turing, Alan. "Computing Machinery and Intelligence." *Mind*, New Series, Vol. 59, No. 236 (Oct., 1950): 433-460.
- The University of Illinois at Urbana-Champaign. "Experimental Music Studios." Accessed June 11, 2015. <http://ems.music.illinois.edu/>.
- "Using the Camera to Illustrate Fiction." *New York Times*, January 6, 1918.
- van der Meulen, Sjoukje. "The Problem of Media in Contemporary Art Theory: 1960-1990." PhD diss., Columbia University, 2009.
- . "Between Benjamin and McLuhan: Vilém Flusser's Media Theory." *New German Critique* 110, Vol. 37, No. 2, (Summer 2010): 181-207.
- Victoria, Brian Daizen. *Zen at War*, 2nd edition. London: Rowman and Littlefield, 2006.
- . *Zen War Stories*. London: Routledge Curzon, 2003.
- Von Neumann, Jon. "First Draft of a Report on the EDVAC." Moore School of Engineering University of Pennsylvania, Philadelphia, June 30, 1945.
- . "First Draft of a Report on the EDVAC," *IEEE Annals of the History of Computing* Vol. 15, No. 4, (1993).
- Wargin, Matt and Michelle Denney. "2001 fills the theater." *Obelisk Cyberfest*. Accessed December 16, 2015. http://www.boraski.com/obelisk/cyberfest/s_virgshow.html.
- Weber, Samuel. *Mass Mediauras: form technics media*. Stanford: Stanford University Press, 1996.
- Wiener, Norbert. *Cybernetics: Or Control and Communication in the Animal and the Machine*. Cambridge, MA: MIT Press, 1948.
- . *The Human Use of Human Beings: Cybernetics and Society*. New York: Da Capo, 1950.
- Wills, David. *Prosthesis*. Stanford: Stanford University Press, 1995.
- Youngblood, Gene. *Expanded Cinema*. New York: P. Dutton & Co., Inc., 1970.
- Zbikowski, Lawrence. *Conceptualizing Music: Cognitive Structure, Theory, and Analysis*. New York: Oxford University Press, 2005.
- Zurbrugg, Nicholas. *Art, Performance, Media: 31 Interviews*. Minneapolis: University of Minnesota Press, 2004.

Archival Sources

John Cage Collection, New York Public Library, New York, New York.

John Cage Collection, Music Library, Northwestern University Library, Northwestern University, Evanston, Illinois.

Lejaren Hiller Archive, Music Library, University at Buffalo, The State University of New York at Buffalo.

Lejaren Hiller Collection of Compositional Flow Charts, circa 1968-1987, Music Library, The State University of New York at Buffalo.

Sound Recordings/Films

2001: A Space Odyssey. Directed by Stanley Kubrick. 1968. Burbank, CA: Warner Home Video, 2001. DVD.

John Cage: Variations VII/ 9 Evenings in Theatre & Engineering. 1966. ArtPix, Experiments in Art and Technology (E.A.T.), 2008. DVD.

Cage, John. *Cage: Sonatas and Interludes for Prepared Piano*. 1998 by C.F. Peters Corporation. Compact disc.

Cage, John and Lejaren Hiller. *HPSCHD / String Quartet No. 2*. With Ben Johnson. 1969 by Nonesuch Records. Nonesuch –H-71224 .Vinyl LP.

———. *HPSCHD*. 2003 by Electronic Music Foundation. EMF CD 038. Compact Disc.

Hiller, Lejaren. *Avalanche/Nightmare Music/Suite for Two Pianos and Tape*, 1970, Heliodor, Heliodor –2549 006 ,vinyl LP.

Hiller, Lejaren and Leonard Isaacson. *Illiac suite for string quartet (1957); Computer cantata*. 1967 by Heliodor. HS 25053 Heliodor. Vinyl LP.