A Musical Suite Composed by an Electronic Brain

Reexamining the Illiac Suite *and the Legacy of Lejaren A. Hiller Jr.*

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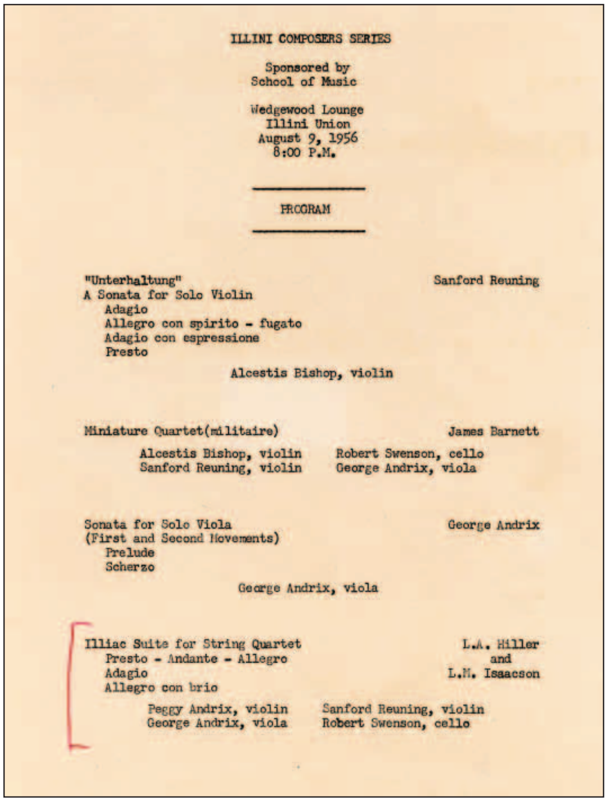
ABSTRACT

In 1956, Lejaren A. Hiller, Jr., and Leonard Isaacson debuted the *Illiac Suite*, the first score composed with a computer. Its reception anticipated Hiller's embattled career as an experimental composer. Though the *Suite* is an influential work of modern electronic music, Hiller's accomplishment in computational experimentation is above all an impressive feat of postwar conceptual performance art. A reexamination of theoretical and methodological processes resulting in the *Illiac Suite* reveals a conceptual and performative emphasis reflecting larger trends in the experimental visual arts of the 1950s and 1960s, illuminating his eventual collaborations with John Cage and establishing his legacy in digital art practices.

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 [1].

In the evening of 9 August 1956, University of Illinois Chemistry Department researchers Lejaren A. Hiller, Jr., and Leonard Isaacson debuted the first three movements of the *Illiac Suite: String Quartet No 4*, the first score composed with a computer. The following day, a United Press news release declared that the *Suite*, "COMPOSED BY AN ELECTRONIC BRAIN" and only "*SPONSORED* BY L.A. HILLER, A CHEMIST-COMPOSER, AND L. M. ISAACSON, A RESEARCH ASSOCIATE," left a "resentful" audience; one self-described "MUSIC LOVER" claimed it presaged a future devoid of human creativity (Fig. 1) [2]. Although Hiller dismissed the hyperbole as "rather silly," the *Suite*'s implementation of algorithmic rules describing the history of composition was overshadowed by the presence of its namesake: the first institutionally owned supercomputer, the Illinois Automatic Computer (ILLIAC) [3].

Hiller reflected on its reception in a *Scientific American* report, observing how the *Suite*'s "tonal" and "atonal" movements sounded similar despite their distinct algorithms; he acknowledged that the final movements were audibly indistinguishable from one another even though their computational processes greatly diverged. He proposed that its sound exceeded human perception, stating, "These


ILLINI COMPOSERS SERIES

Sponsored by
School of Music

Wedgewood Lounge
Illini Union
August 9, 1956
8:00 P.M.

PROGRAM

"Unterhaltung" — Sanford Reuning
A Sonata for Solo Violin
Adagio
Allegro con spirito - fugato
Adagio con espressione
Presto
Alcestis Bishop, violin

Miniature Quartet(militaire) — James Barnett
Alcestis Bishop, violin — Robert Swenson, cello
Sanford Reuning, violin — George Andrix, viola

Sonata for Solo Viola — George Andrix
(First and Second Movements)
Prelude
Scherzo
George Andrix, viola

Illiac Suite for String Quartet — L.A. Hiller and L.M. Isaacson
Presto - Andante - Allegro
Adagio
Allegro con brio
Peggy Andrix, violin — Sanford Reuning, violin
George Andrix, viola — Robert Swenson, cello

Fig. 1. Concert program for 9 August 1956 performance of *Illiac Suite*. Image courtesy the University at Buffalo, SUNY Music Library.

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correspondences suggest that if the structure of a composition exceeds a certain degree of complexity, it may overstep the perceptual capacities of the human ear and mind" [4].

Regarding the future of conceptual art, art critic and activist Lucy Lippard ended her iconic 1973 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 [5].

While Lippard's criticisms of prior interdisciplinary art experiments are well founded, Hiller's expertise in both computational and music disciplines mark him as an artistic outlier. In contrast to these artworks operating on "primitive level(s)," the *Illiac Suite* demonstrated expert computational experimentation; Hiller's methodological approach—moving from simplicity to increasingly complex models—departs from earlier computational art to align more closely with the systems theory and intermedia concerns of conceptual art of the era, reflected in the *Suite*'s inclusion in Jasia Reichardt's 1969 art exhibition *Cybernetic Serendipity* [6]. Although the "ELECTRONIC BRAIN" seemed to forecast a bleak, automated future, a reexamination of Hiller's methodology reveals his focus on process and experimentation in integrating information theory and aesthetics, forecasting his collaborative strengths during his and John Cage's partnership, and substantiates his legacy within conceptual art discourse and current trends in digital art.

ON THE DESIGN OF A VERY HIGH-SPEED COMPUTER

Originally housed in the University of Illinois Graduate College Digital Computer Laboratory, the ILLIAC I was accessible to a host of researchers from across the college (Fig. 2). It adhered to the von Neumann "Princeton architectural" design: Its hardware included a central processing unit (the CPU, determining processing "speed") containing an arithmetic logic unit (ALU), processor registers and a control unit that communicated with internal memory and input and output mechanisms [7]. Auxiliary memory components consisted of drum memory or external magnetic tapes. Maintenance of the computer remained onerous; while later computers in the ILLIAC series converted to more robust components, the ILLIAC I contained 2,800 vacuum tubes, each lasting for only one year, making daily "preventive maintenance"—tube replacement—necessary for the machine to function reliably.

As indicated by the opening quote, programming necessitated constant physical interaction with the computer [8]. The original ILLIAC design instructions emphasize the material aspects of computing, as early software didn't clearly delineate programming and execution phases, or "Off-Line Operations": The ILLIAC had extremely limited core memory, and programming depended upon coding by punching out numbers printed onto stock paper cards or paper tape, transcribed onto magnetic tape and fed into the computer (Fig. 3). Once executed, magnetic or paper ticker tape had to be either run through a teletype machine or printed, and, in the case of the *Suite*, finally hand-transcribed to musical notation [9].

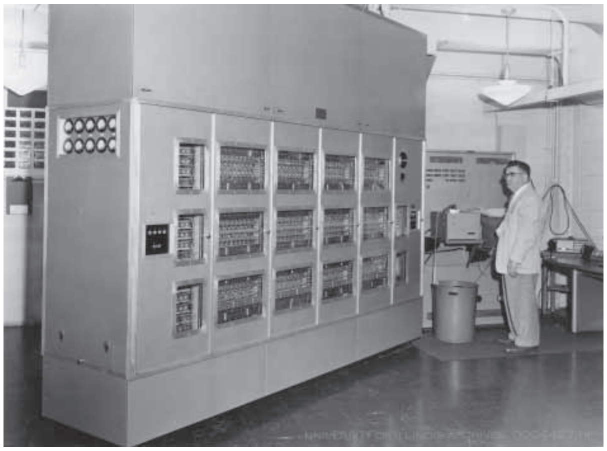


Fig. 2. The ILLIAC circa 1952. Image courtesy of the University of Illinois Archives.

Fig. 3. Printout from Lejaren Hiller Papers. Image courtesy University at Buffalo, SUNY Music Library.

A BOOTLEG JOB

During his employment at a University of Illinois research lab where he analyzed polymers and acetate, Hiller's deep interest in music impelled his transition to algorithmic music composer [10]. In 1955, after learning how to operate the computer on a government-supported contract for synthetic rubber research, Hiller almost immediately began adapting these methods to music composition [11]. Assisted by fellow chemist Leonard Isaacson, Hiller began the long process of working on the *Illiac Suite* as what he called "a bootleg job at night":

> 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 [12].

In his 1959 *Scientific American* article "Computer Music," and elaborated upon in his and Isaacson's *Experimental Music: Composition with an Electronic Computer*, Hiller described the *Illiac Suite* programming process as an exploration of how information theory could be meaningfully applied to music composition. Citing previous forays into compositional analysis, Hiller established the importance of building a conceptual relationship between the *content* of the information and the *method* of generating musical scores to explore aesthetic possibility:

> 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" [13].

Hiller described a recent 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 songs. Hiller observed that averaging simple data produced "only banal tunes," whereas classical and modern compositions provided complex data and thus more complex probability tables [14]. Through the analysis of structural data on the oscillation between "randomness" (or "chance") and "redundant" ("organized") music, he proposed one analyze *aesthetic* methods used by composers rather than quantitative data describing *acoustics*:

> 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 terms of fluctuations between the two extremes of total randomness and total redundancy [15].

High-speed computation presented the opportunity to collect data describing the oscillation of randomness and redundancy, and a reversal of this analysis might generate probability tables mimicking specific composers' styles or emulating entire musical genres [16].

THE *ILLIAC SUITE* IN 4 MOVEMENTS

Many later descriptions summarize the *Illiac Suite* programming process as an attempt to simplify music composition by automating decisions conventionally made by the composer [17]. However, the *Suite* necessitated new physical and conceptual methodologies to effectively integrate information theory into artistic practice. The *Suite's* movements corresponded to four experiments, each requiring new programs with increasingly complex screening rules exploring historical styles and aesthetics. Hiller planned each experiment to reflect a historical progression from simple to complex melodies: The first experiment mimicked Renaissance counterpoint rules, generating "simple" polyphonic melodies; the second produced four-voice segments within the confines of changing rules. Both the second and third experiments used a *random chromatic method* expanding possible tonal values representing the chromatic scale, exploring aesthetic differences between seventeenth- and twentieth-century musical styles [18].

For the third and fourth experiments, Hiller felt it conceptually necessary to build his own stochastic process translating contemporary compositional rules and methods to algorithmic systems that could represent the mounting complexity of serial compositions. Providing a *probabilistic* alternative to previously *deterministic* processes, developing stochastic processes would allow a predetermined amount of *indeterminacy*; in effect, Hiller's was an algorithmic version of John Cage's more interpretive methods of indeterminacy and chance operations. Hiller praised Cage's methods, and before introducing the *Suite's* third and fourth movements he mentions Cage's simplistic, conceptual approach as the ideal:

> Like random music, highly organized music does not lack historical precedent. A notable example is the "isorrhythmic" music of the fourteenth and fifteenth centuries, which was based on abstract formulations that took precedence over conventional rules of harmony. Among contemporary composers, Cage has produced what is probably the most perfect example of the genre in his composition "4:44" [*sic*], which consists of four minutes and 44 [*sic*] seconds of silence [19].

Hiller's take on indeterminacy relied on Markov chains, a stochastic process stringing randomly generated variables representing the present state to model how current changes were to affect future states. This new set of randomly generated variables disregarded any superfluous states, achieving "memorylessness." Hiller and Isaacson generated integers sampled from a calculated probability distribution in the computer's memory until the machine saved a "melody," designated "complete" after reaching a predetermined numeric length. The melody was printed on perforated tape, then hand-transcribed into conventional musical notation. As the composition employed screening passes that could be added modularly, multiple test runs were necessary to achieve the desired result (Fig. 4).

The third experiment benefited from Markov chain memorylessness, mimicking contemporary compositions by eliminating probability favoring certain tones, automating composer Arnold Schoenberg's 12-tone technique:

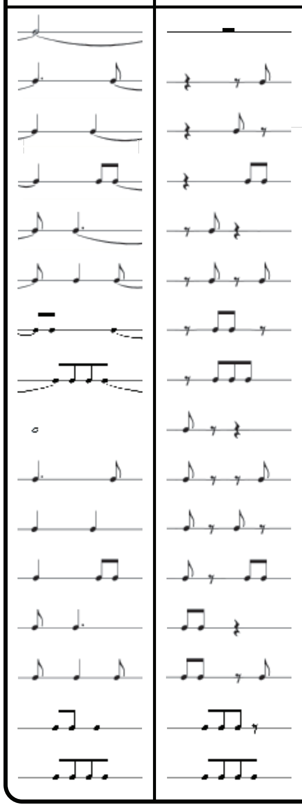
> The machine was first permitted to write entirely random chromatic music (including all sharps and flats). The result was music of the highest possible entropy content in terms of note selection on the chromatic scale, and thus it was strongly dissonant. With the minimal redundancy imposed by feeding 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 [Bela] Bartok string quartet. . . . The experiment concluded with some exploratory studies in Schonberg's 12-tone technique and similar compositional devices [20].

In addition, specific rhythmic passages were assigned corresponding binary and digital numbers, each integer generated using the Monte Carlo method (MCM), saved in memory, printed and hand-transcribed (Fig. 4) [21].

The fourth experiment generated MCM probability tables dictating the frequency of all 12-tone values (Fig. 4). Section "a" indicates a probability of 100% of all four string parts being composed in unison. For section "b," the probability of all parts remaining in unison shifts to 67%, with the remaining 33% resulting in octave intervals between parts. Each subsequent section increases in complexity as fifths, fourths, major thirds, etc. are included with diminishing weights (Fig. 5). By section "e," it becomes increasingly evident that the four voices will continue to increase in complexity to eventually cover the full chromatic spectrum. As noted by researchers Örjan Sandred, Mikael Laurson and Mika Kuuskankare in their experiments in stochastic composition, Hiller and Isaacson engaged in "critical listening" to describe how generated "melodies" would "walk away" into complexity [22]. They noted how the choice of opening note or preceding interval impacted aural results, although the results are not always obvious in the resulting performance.

CLOSED RHYTHMS	OPEN RHYTHMS	BINARY NUMBERS	DECIMAL NUMBERS



BINARY NUMBERS	DECIMAL NUMBERS
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15

Fig. 4. Recreation of Experiment III table designating binary and decimal integers to all possible rhythmic passages. "Closed" and "open" rhythms were based upon a 4/8 time signature (chosen "arbitrarily") with eighth notes as the primary rhythmic unit. (© Tiffany Funk)

INTERVALS	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT	PROBABILITY	WEIGHT
UNISON	1	1.00	2	.67	3	.50	4	.40	5	.33	6	.29	7	.25	8	.22	9	.20
OCTAVE	0	.00	1	.33	2	.33	3	.30	4	.27	5	.24	6	.21	7	.19	8	.18
FIFTH	0	.00	0	.00	1	.17	2	.20	3	.20	4	.19	5	.18	6	.17	7	.16
FOURTH	0	.00	0	.00	0	.00	1	.10	2	.13	3	.14	4	.14	5	.14	6	.13
MAJOR 3RD	0	.00	0	.00	0	.00	0	.00	1	.07	2	.09	3	.11	4	.11	5	.11
MINOR 6TH	0	.00	0	.00	0	.00	0	.00	0	.00	1	.05	2	.07	3	.08	4	.09
MINOR 3RD	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	1	.04	2	.06	3	.07
MAJOR 6TH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	1	.03	2	.04
MAJOR 2ND	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	1	.02
MINOR 7TH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
MINOR 2ND	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
MAJOR 7TH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
TRITONE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

Fig. 5. Recreated excerpt of the probability distribution table described in Experiment IV. (© Tiffany Funk)

CONCLUSION

Like the *Suite*, Hiller's later work was largely collaborative and facilitative; he founded the University of Illinois's Experimental Music Studio in 1958 to enable computer music research within the school and beyond. Even John Cage, during his time as a visiting researcher at the University of Illinois, unknowingly confirmed Hiller's role both at the university and in his own work: Like the United Press release calling Hiller and Isaacson "SPONSORS" of the *Illiac Suite*, Cage called *MUSICIRCUS*—his first major event at the university—a "Reunion" rather than a "performance" and himself a "facilitator" rather than a "composer" [23]. Cage's presence in their collaboration on the ambitious multimedia event *HPSCHD*, the 1969 performance concluding Cage's time in Illinois, often overshadows Hiller's computational accomplishments due to its overwhelming visuals and Cageian approach to indeterminacy. However, more recent performances of *HPSCHD*—like the events at Eyebeam Art + Technology Center in 2013—take on a cooperative, pedagogical model. The venue encouraged workshops and collaborative experimentation, including B.Y.O.B. ("Bring Your Own Beamer") participation and live coding performances (Fig. 6). Events such as these are increasingly common in digital art communities, where trade-based economies rely-

Fig. 6. *HPSCHD*, Eyebeam Art and Technology Center, 3 May 2013. (Photo © Tiffany Funk)

ing upon work exchange and skill-sharing are encouraged by community-based hacker spaces and national organizations like the School for Poetic Computation (SFPC) [24].

Although listening to the *Suite* confirms that unifying themes and stylistic flourishes remain elusive, Hiller emphasized the repetition of motifs from classical and modern music to explore more fundamental aspects of compositional aesthetics. The performance became a venue for analyzing historical compositional clichés through methods informed by information theory, providing novel ways in which to meditate on musical style and aesthetic choice. In her introduction to *Cybernetic Serendipity*, Jasia Reichardt explains that the exhibition

> deals with possibilities rather than achievements, and in this sense it is prematurely optimistic. There are no heroic claims to be made because computers have so far neither revolutionized music, nor art, nor poetry, in the same way that they have revolutionized science [25].

Likewise, Hiller focused on the possibilities engendered by computer composition—he called the first *Suite* "rather fragmentary"—although programming composition provided a new way to critique the aesthetic conventions of human composers and eventually adapt or defy them [26].

Hiller maintained that the "ELECTRONIC BRAIN" could never act alone. The computer-human relationship always privileged the latter, with a "SPONSOR" taking the creative lead to distinguish exercise from art:

> 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 [27].

References and Notes

1 A.H. Taub, et al., *Report No. 80: On the Design of a Very High-Speed Computer* (Digital Computer Lab., University of Illinois, Urbana, 1st Ed., October 1957, 2nd Ed., April 1958) p. 34.

2 United Press, (ILLIAC) CHAMPAIGN, ILL., AUG 10-(UP) (1956) (emphasis added); John Bewley, "Lejaren A. Hiller: Computer Music Pioneer," exhibition notes for *Lejaren A. Hiller: Computer Music Pioneer*, University at Buffalo, SUNY Music Library (Buffalo, NY, 2004) p. 11.

3 Lejaren Hiller, "Composing with Computers: A Progress Report," *Computer Music Journal* **5**, No. 4, 7–21 (1981) p. 10.

4 Lejaren Hiller, "Computer Music," *Scientific American* **201**, No. 6, 109–120 (1959) p. 120.

5 Lucy Lippard, *Six Years: The Dematerialization of the Art Object from 1966 to 1972* (Berkeley: University of California Press, 1973) p. 263.

6 Jasia Reichardt, ed., *Cybernetic Serendipity: The Computer and the Arts* (New York: Praeger, 1969).

7 James Matthew Bohn, *The Music of American Composer Lejaren Hiller and an Examination of His Early Works Involving Technology* (Lewiston, NY: Edwin Mellen Press, 2004) pp. 262–265. Hiller's photographer father encouraged his son's musical talents, and Hiller continued music study even as a chemistry student at Princeton with Milton Babbitt. He remembered, "I still very clearly remember going in and being interviewed by Milton. . . . 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." See Bewley [2] p. 5.

8 Taub [1] p. xv.

9 Bohn [7] p. 43.

10 Bohn [7].

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

12 Bewley [2] p. 9.

13 Warren Weaver held special importance in Hiller's theories regarding information theory due to his popularization of the use of computers for a wide variety of interdisciplinary research subjects, including linguistics, cryptography and systems theory. See Hiller [4] pp. 109–110; Weaver, "The Mathematics of Communication," *Scientific American* (July 1949).

14 Hiller [4] p. 112.

15 Hiller [4] p. 110.

16 Composer David Cope, influenced by Hiller's compositions, expanded upon computational composer style analysis in his Experiments in Musical Intelligence (EMI) software; in his text *Experiments in Musical Intelligence* (Middleton, WI: A-R Editions, 1996) he describes basic principles of analysis, including pattern matching, object orientation and natural language processing.

17 For example, Gerald Strang's analysis of the *Suite* in *Cybernetic Serendipity* suggests the process was solely a step toward automating composing, ultimately resulting in Hiller's MUSICOMP (MUsic SImulator-Interpreter for COMpositional Procedures) software. See Reichardt [6] p. 26.

18 The full *Illiac Suite* score is included in Hiller and Isaacson [11] pp. 182–197. See also Hiller [4] p. 117.

19 Cage's *4′33″* is mistitled "4:44" in the article. See Hiller [4] pp. 5–7.

20 Hiller [4] p. 117. Schoenberg's twelve-tone technique prevents precedence of any of the 12 notes of the chromatic scale. The method uses tone rows, a means of ordering the 12 pitch classes: All 12 notes are given equal importance, and the music avoids being in a key. See Hiller [4] p. 117; Arnold Schoenberg, *Style and Idea*, Leonard Stein, ed., Leo Black, trans. (Berkeley & Los Angeles: University of California Press, 1975) p. 213.

21 Hiller [4] p. 117.

22 Örjan Sandred, Mikael Laurson and Mike Kuuskankare, "Revisiting the Illiac Suite—a rule-based approach to stochastic processes": <www.sandred.com/texts/Revisiting_the_Illiac_Suite.pdf> (accessed 22 July 2015).

23 Stephen Husarik, "John Cage and LeJaren Hiller: HPSCHD, 1969," *American Music* **1**, No. 2 (Summer, 1983) p. 4.

24 Steve Smith, "An Intentional Spectacle: 'HPSCHD' at Eyebeam," *New York Times*, 5 May 2013; Tiffany Funk, "Zen and the Art of Software Performance: John Cage and Lejaren A. Hiller Jr.'s *HPSCHD* (1967–1969)," dissertation, University of Illinois at Chicago, 2016.

25 Reichardt [6] p. 5.

26 Hiller [4] p. 120.

27 Hiller [4] p. 120.

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