Human and Machine Cultures of Reading: A Cognitive-Assemblage Approach

N. KATHERINE HAYLES

CULTURES OF READING: THE PLURAL ACKNOWLEDGES DIVERSE readers, their reading practices, and their historical, cultural, social, and ethnic differences. Chances are, however, that all these readers share a trait: they are humans. This essay addresses two different classes of readers: humans and machines. Beginning in the late nineteenth century and accelerating through the mid–twentieth century and beyond, machine reading developed alongside devices with increasingly sophisticated cognitive capabilities, culminating in computational media that can read texts, draw inferences, interpret ambiguous information, make connections between texts, and reach conclusions ("NELL: Never-Ending Language Learning"). These machines often interact with humans to create what I call cognitive assemblages: coordinated systems bound together by flows of information and a kind of meaning making in which reading and writing become collective acts and cognitions are distributed throughout the systems (Hayles, "Cognitive Assemblages").

Like any historical process, the transition to hybrid human-machine writing and reading was marked by various stages of development, some of which will be explored here. Nevertheless, comparing today's cultures of reading with those from a century ago reveals an ontological rupture separating the contemporary era from the centuries when print was dominant. Of course, books continue to be printed, but the methods of production have changed so dramatically that it is more accurate to call contemporary printed books output modes of computational systems rather than extensions of the printing press as Johannes Gutenberg envisioned it. To recognize the differences in these methods, I will refer to bound books produced by computational systems as postprint productions and will consider the transition from the age of print to the age of postprint

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as occurring mainly between the mid–twentieth century and the present.

This essay addresses issues concerned with reading practices in a human-machine cognitive ecology, including the design of computer programs that read "in the wild," (Hayles, *Ho* 70), the ways that algorithms process information, differences between human and machine reading practices, and changes in what reading means when done with cognitive devices such as e-books. It concludes with speculations on how mixed cognitive ecologies lead to contestations over the meaning of meaning. Thus, it may unsettle assumptions embedded in this special issue, a contrarian move helpful in bringing to light presuppositions that otherwise might pass unnoticed.

How Machines Read—and Read Differently

The reading done by machine algorithms differs significantly from human reading. For humans, parsing words implies understanding ideas, concepts, and actions within the context of the human lifeworld. As Hubert Dreyfus argued decades ago, humans have expansive horizons of action and understandings that far exceed the scope of logic alone. Contra cognitivism (the position that human thinking takes place by operating on logical symbols), theories of embedded and embodied cognition emphasize that human thinking evolves within complex, three-dimensional environments enlivened by sights, smells, kinesthesia, proprioception, and a host of external and internal stimuli and supported by an array of cognitive aides, from pencil, paper, and computers to architecture, bridges, and roads (Hutchins; Varela et al.; Clark; Thrift). When machines read, by contrast, they have either no or very limited contact with these environments. For them, reading proceeds by making myriad connections between the same words in different contexts and by comparing and contrasting words with other words, drawing inferences about what linguistic expressions can be linked together in different domains and at different scales.

An example of how machines read is provided by the system called Never-Ending Language Learning (NELL), developed by Tom Mitchell and his group at Carnegie Mellon University. As Andrew Carlson and his colleagues explain, the program was first seeded with 123 categories and 55 relations and left to run for 67 days, by which time it had accumulated over 242,000 new facts with a precision estimated at seventy-four percent. The architecture makes use of a component called the Knowledge Base, created through subsystems that extract relations from Internet texts and, on the basis of those relations, propose candidate facts. These are assigned a probability for correctness, and another component, the Knowledge Integrator, promotes the most promising candidates to what it calls beliefs. The beliefs are then fed back into the Knowledge Base, and each subsystem uses that iteration to retrain itself in preparation for finding and proposing a new round of candidate facts.

The facts that NELL learns are of the type "*x* is a component of *y*." A recent visit to the Web site that displays NELL's facts found these listed: "athens 2004 olympic games is a sporting event"; "remembrance is an emotion"; "slash is a musician who is part of guns n roses"; and "Daihatsu is a specific automobile maker dealer in uk" ("NELL: Never-Ending Language Learning"). Candidate facts are assessed in view of beliefs already present in the Knowledge Base. Therefore, when an error enters, it tends to result in cascading mistakes when it is used as a basis for new relations. For example, the system identified a digital cookie as a baked good, which led to a series of other misidentifications for words related to digital cookies ("NELL: The Computer That Learns"). To compensate, Mitchell and his team use human intervention (according to them, limited to fifteen minutes a day [Carlson et al.]) to review and correct errors in

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the Knowledge Base. Recently they have added a feature to the Web site that invites visitors to review items in the Knowledge Base and, when they find an error, flag it for correction.

This summary reveals what reading means for NELL. Entirely lacking in the NELL system is any idea what its beliefs mean in terms of embodied, human experience. A warm, fragrant chocolate-chip cookie is for NELL as abstract a concept as a digital cookie, both existing on the plane of interconnecting relations that constitute its Knowledge Base. Limitations notwithstanding, NELL and similar systems have formidable advantages, including processing speed and the ability to operate 24-7, something no human can do. NELL's iterative structure means that it continually refines and extends its knowledge every minute of every day. As the number of digitized texts on the Web increases exponentially, and as other knowledge bases grow accordingly larger all the time, machine reading has become a necessary supplement to human reading, which is limited by time, memory, processing speed, and other frailties of embodied, human comprehension (Moretti).

Moreover, programs already in development take advantage of human mobilities and expansive world horizons to coordinate with human users, thus further increasing the scope of machine cognition. An example, which I have discussed elsewhere, is VIV, software being developed by VIV Labs in San Jose, California (*Unthought* 124–25). Like NELL, it is programmed to learn from its experiences, but also from Web reading; it adds geolocation, mobile interactions, and real-time queries to the user (Levy). VIV combines Global Positioning System (GPS) orientation with a system that learns on the fly, parses sentences, and links to Internet sources. I quote the following account from my earlier commentary on this program:

> Developers Dan Kittlaus, Adam Chever, and Chris Brigham say that VIV can parse relatively complex queries such as this . . . : "On the way to my brother's house, I need to pick up some cheap wine that goes well with lasagna." The program first parses "brother" as a family relationship and looks for the appropriate [address] in the user's Google contacts. It then plots the route and, noticing a missing variable, asks the user how far she is willing to deviate to get the wine. With this information, the program searches the web for lasagna recipes, identifying it as a food item containing tomato, cheese and pasta. Searching for wine-food matches yields appropriate varietals, and further inquiries yield price ranges from which a "cheap" spectrum is identified. The next step queries catalogues of the wine stores en route, with the result being a list of wines at the appropriate stores. (*Unthought* 124)

VIV's advantages over NELL are significant, because VIV does not merely learn on its own but actively works with the user's cognitions to direct movements, interpret sensory signals such as location indicators, and respond to queries. As a digital platform, it has the advantages of massive storage space in the cloud, fast processing speed, and computational intensity of data manipulation. Although it still lacks the wider scope of the human lifeworld, it interacts with the user's embodied and embedded cognitions to enhance its own performance and, in the process, learns to read not just texts but everything from urban geography to the user's tastes and preferences. In short, it is learning to read us at the same time we read it.

Programs that read users and interpret their feedback in the light of database knowledge employ collaborative filtering algorithms to anticipate the preferences of a user. The basic idea is that people who share tastes in some areas are likely to have similar preferences in other areas as well. Typically, a user is asked to rate several items in different categories, such as books, television programs, and games. The algorithm compares the responses with large collections of data about user preferences and

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filters for patterns similar to those indicated by the active user. From these, the program projects a preference for an item that the user has not yet rated, like a video. Filtering algorithms are helpful not only to determine user preferences but also to predict patterns in data that result from monitoring activities such as mineral and oil exploration, as well as to integrate data from financial services (Lee et al.).

Assessing the full scope of algorithmic reading requires moving beyond reading as humans conceive of it (a type of reading that NELL and VIV arguably do) and toward kinds of reading remote from typical human experiences. Data derivatives illustrate these far reaches. Louise Amoore suggests that data derivatives are analogous to financial derivatives, which trade on markets separate from those of the underlying assets on which they are based; data derivatives are similarly detached from the identities of specific people and instead analyze for correlating factors. Developed for security screening, data derivatives use pattern-filtering algorithms like those discussed above, but they are designed to detect warning signs. As Amoore explains, this detection involves disaggregating data from relational databases, which associate items with individual users, and reaggregating the chosen data into bundles that can be used to flag persons of interest even when their identities are not known (30–38). Examples of relevant data might include airplane tickets bought fewer than five days before a flight, tickets paid in cash, and requests for vegetarian meals. The security advantage of such algorithms is that they are highly mobile: the items can be detected and changed on the fly, and the algorithms do not require knowledge of the identities or even the nationalities of the persons of interest (Amoore 25–26).

Amoore points out that this approach is fundamentally different from that of a police dragnet that might be watching for a suspicious person, because the algorithms are not directed toward specific people but rather flag anyone whose activities match the bundled data, which themselves can be tagged to indicate different levels of risk assessment, so that they trigger anything from asking additional questions at a border crossing to detaining a person of interest (31–33). It is possible that innocent people may be flagged simply because their activities match certain criteria. To compensate, the algorithms are sometimes constructed to ignore certain categories, such as injured skiers, who routinely need to buy airplane tickets close to the date of departure. Although Amoore rightly highlights the repressive potential of such security measures, the point here is the kind of reading they involve, which relies on correlation rather than causality and requires scanning multiple databases and evaluating hundreds of thousands of items in seconds.

Human Narrative Comprehension and Algorithmic Correlation

The issue of correlation versus causality is crucial. Many psychological experiments have confirmed that human memory is not very good at recalling unconnected items on a list; given a fifteen-word list, most people can remember between four and seven items. In international memory competitions, contestants embed the items in visual, verbal, and aural narratives (Frish); this enables them to access the items through their senses and, in doing so, to perform prodigious feats of memory. This practice suggests that a primary function of narrative is to create a causal sequence that explains why events happen in a certain order and manner, and it is this sequence that facilitates comprehension and bolsters recall. As both Catherine Emmott and David Herman argue, human narrative comprehension typically proceeds by building a storyworld and locating events in it.

By contrast, algorithms are very bad at constructing causal sequences in narrative. A classic example of the attempt to make al-

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gorithms construct a narrative is Tale-Spin, a program developed by James Meehan at Yale University in the mid-1970s and then resurrected and analyzed by Noah Wardrip-Fruin, the digital studies scholar, in the first decade of the twenty-first century. The program simulated rational decision making by generating narratives from predefined rules. Everything in the program's machine-generated narratives was based on goals that the characters had and their plans to achieve them. Once the algorithmic processes were set in motion, another program, called Mumble, translated the results into painfully awkward English. (To be fair, as Wardrip-Fruin points out, rendering the processes into prose was an afterthought for its creator; his research focused on the underlying processes.) What makes the prose so excruciatingly simplistic from a human viewpoint is that nothing can be assumed; for example, if a bear character wants honey, it must first find the honey's location from another character and then walk there so that its hand is adjacent to the prize. Human narratives, by contrast, typically insert gaps that readers and listeners fill in from their knowledge of the storyworld, a well-known strategy that writers employ to increase a reader's investment in a developing narrative (Emmott 3–20; Herman 16–17).

Narrative is virtually omnipresent in human cultures, which suggests that narrative and consciousness may have evolved together, each reinforcing the other; Katherine Nelson makes precisely this argument regarding children's development. Given this connection, it is tempting to think that human brains may be hardwired to construct, transmit, and consume narratives. Moreover, investment in storytelling is constantly reinforced through cultural practices. Humans in all cultures drink in narratives with mother's milk; Jerome Bruner cites research indicating that in Baltimore, in working-class homes with small children, eight-and-a-half narratives were told per hour, or one every seven minutes, three quarters of which came from mothers (83).

By contrast, humans encounter correlation in a scattered fashion; typically, experience in correlating data from multiple sources takes place late in a young person's development, in high school, college, or postgraduate education. Further, a common error addressed by critical-thinking pedagogy is mistaking correlation for causation, another indication that humans are inclined toward narrative constructions rather than correlative pattern matching (Goldin). Today, forms of inquiry concerned with correlation are almost always aided by algorithms performing machine reading. We need not subscribe to Lev Manovich's formulation that narrative and database are "natural enemies" (228; see also Hayles, "Narrative and Database") to conclude that whereas reading and narrative are closely linked for humans, reading and correlation have a strong connection for machines.

Media Archaeology and the Machine Viewpoint

Like a glass that can be seen as half full or half empty, the human penchant for narrative can be positioned either as an argument for narrative's naturalness or as an incitement to resist this tendency toward narrative and seek other modes of inquiry. Among recent arguments for resistance is the one made by media archaeology. The idea behind this field of study is to create a methodology that does not rely on narrative, and one way to do this is to consider events from a nonhuman point of view, particularly the perspective of technical media. As Wolfgang Ernst puts it, "The media-archaeological method . . . is meant as an epistemologically alternative approach to the supremacy of media-historical narratives" (55). Ernst characterizes technical media by pointing to the difference between painting and photography. Whereas the materials required by painting are accessible to human senses, the active processes in photography (leaving aside setting the exposure speed and

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clicking the shutter) are physico-chemical and cannot be directly accessed by human users. The camera, considered as distinct from its human operator, has a viewpoint, and one of the goals of media archaeology is to explore this viewpoint as fully as possible. Working from a different set of premises, Ian Bogost accomplishes a similar goal in his discussion of Sigma's Foveon-equipped digital-image sensor (65–66). As his analysis makes clear, media have bodies—that is, they are materially instantiated, and their bodies are increasingly supplied with sensors, actuators, and information processors. They make interpretations and arrive at meanings specific to the contexts in which they operate and the functions they are designed to perform.

According to Ernst, media archaeology promotes an "awareness of moments when media themselves, not exclusively humans anymore, become active 'archaeologists' of knowledge," particularly in "techno-epistemological configurations underlying the discursive surfaces," meaning their software architectures (55). This may seem a startling claim. Nevertheless, as technical media continue to develop, more of them may gain the ability to mediate between an older operating system and a newer one, the way an emulator, for example, can translate between obsolete and newer code so that files can be read and commands executed that otherwise would be unreadable and inexecutable. Such a machine could be considered an "archaeologist" (whether one of knowledge or not would require a longer discussion about what *knowledge* means in a machine context). Pressing his case, Ernst positions human subjectivity, especially its inclination toward narrative, as a limitation from which a machine viewpoint can liberate us by weaning us away from "wanting to tell stories," which only serves to "reinforce our subjectivity," and catalyzing awareness of the importance of nondiscursive approaches (56).

For the discourse-heavy theoretical orientations of the humanities, this approach has something to recommend it, for it promises to open discussions of machine capabilities in their own right and activate Foucauldian questions about such crucial matters as the nature of an archive in which, as Jussi Parikka puts it, "[p]ower is no longer circulated and reproduced solely through . . . practices of language, but takes place in the switches and relays, software and hardware, protocols and circuits of which our technical media systems are made" (74). This approach is limited by its tendency to create an either-or binary choice between human and machine viewpoints.[1] Today, combinations of machine and human perspectives are typical. In the reading environment of e-books, for instance, human experiences and machine actions are in dynamic interplay, as are the narratives that speak potently to humans and the databases powerfully at work in machine modes of reading.

Cognitive Processes in Humans, Nonhuman Others, and Technical Systems

Turning to e-books, we move from a relatively simple situation in which the site of reading can be identified with humans to a more complex configuration in which reading occurs at multiple levels and with different functionalities in a human-technical cognitive ecology. As the reading device interprets and processes signals, commands, and information, the human reader processes alphabetic symbols; concurrently, the human is inputting information into the device and reading its nonalphabetic displays and icon-driven menus. To discuss e-books, we need a bridging concept that can apply to both human and machine reading cultures. Such a concept, I have argued elsewhere, is cognition, understood as a process of interpreting information in contexts that connect that information with meaning ("Cognitive Nonconscious").

This definition came from considering Claude E. Shannon's information theory, a quantitative approach also central to many

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theorists working in media archaeology. Shannon defined information as the result of a probability function and argued that it depended not on a message's semantic content but only on the likelihood that a given message element would appear, relative to all other elements that could have been selected. Warren Weaver's introduction to Shannon's book emphasized that information in Shannon's sense has nothing to do with meaning. I think Weaver overstated the case (Hayles, *Unthought* 22–23), but his point is valid insofar as it suggests that a further constraint is necessary to make a strong connection between information and meaning. That constraint is supplied by taking into account context: the circumstances of the interpretive process, the capabilities and embodiments of the interpreters, and the environments in which interpretations take place.

Cognition can be understood as prevalent in all living organisms, including microorganisms and plants (Hayles, *Unthought* 15). For a unicellular organism, for example, interpretation may take the form of a cell membrane that decided to block certain chemicals and admit others, avoiding toxins and absorbing food sources (Kováč). Cognition in this sense also applies to technical systems, which make choices about interpreting a signal, as a one or a zero in the case of computational media, for example. Note that choice here does not imply free will but rather the capability of interpreting a signal that could mean more than one thing. This way of looking at cognition sets a low threshold for a system to be considered a cognizer and encompasses both organic and machine systems, thus breaking out of the hegemony of human-only approaches to cognition to address a wide range of nonhuman others. Because context is intrinsic to cognitive processes, this approach reveals the increasingly complex cognitions that occur as the contexts grow more complex, as in the "tower of programming languages" (Raley)—layers of software built on top of hardware—or in the evolution of higher-level consciousness in humans from lower-level sensory and nonconscious processes. The emphasis on context takes into account the profound differences between, on the one hand, the historical and biological determinants of human embodiment (such as evolution), and, on the other, the instantiation of machine cognitions in bodies designed rather than born. It also allows us to see cognition as a process that takes place both in biological organisms and in computational media.

In terms of reading cultures, a human reading an e-book may be thought of as a cognitive assemblage, a system throughout which cognition is distributed (Hayles, "Cognitive Assemblages"). Distributed cognition implies distributed agency; both humans and machines make choices as they interact with each other. In the centuries when print technologies were dominant, the ways in which print books supported human cognition grew increasingly flexible and complex. However sophisticated the art of printing became, print still required a human reader to activate its cognitive potential: there are no self-reading print books. With the advent of technical media, especially networked and programmable media systems, devices became not just supporters of human cognitions but cognizers themselves, performing interpretations in contexts that connect those interpretations to meaning. In short, they do not just passively convey meanings but perform meaning-making activities.

This is the ontological rupture that divides postprint from print. Although the rupture may appear abrupt relative to the centuries-long development of print, it took place over the course of several decades in which the capacities to make choices and perform interpretations became more flexible, wide-ranging, and powerful in their effects. As John B. Thompson explains, concurrent with the invention of cognitive technical devices was a "hidden revolution" that transformed how

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books were labeled, warehoused, and sold; how records were created for book sales; and how and to whom books were advertised (404; see also Striphas). While a complete history of all these factors is beyond this article's scope, a few key points in this history may be discussed, beginning with the Paige Compositor.

Popularly known as the machine that bankrupted one of its key investors, Mark Twain, the Paige Compositor was a remarkable technological achievement, albeit a commercial failure. In retrospect, its fatal flaw was its assumption that mechanical cognition should mirror human cognition. Technical cognition in general started to achieve its full potential only when it broke from this anthropocentric assumption and began to operate in contexts appropriate to its own embodiments.

The Paige Compositor and the Beginnings of Technical Cognition

The Paige Compositor, conceived and patented by James W. Paige, was first manufactured by the Farnham Typesetter Company, which had a workshop in the factory of the Colt's Firearms Company ("Mark Twain"). Begun in 1877, a prototype machine was not finished until late 1878, and then only in rudimentary form. The machine went through several design changes, and its construction was plagued by a lack of capital funds. It was not until September 1894 that a working model was available for a test at the offices of *The Chicago Herald*, which took place over the course of two months (fig. 1).

The compositor was operated by a single person, who sat in front of the machine and typed in the texts to be set. The machine contained over 18,000 components, which allowed it to typeset, justify, and distribute the type through complex arrangements of levers, cams, and other mechanisms. It recognized the type pieces through a series of nicks that uniquely identified each piece; it could also recognize broken or cracked type pieces, as well as any foreign matter, and remove them. The nicks were constructed so that the machine would not mistake the type pieces, even if the pieces were broken or stuck together. The quadrats (pieces used to introduce spaces that were lower in height than letter types) were nicked so that even if they were reversed they would still be distributed correctly. The machine had eleven sizes of spaces it could use to fill lines as needed.

The type pieces were set into vertical channels, and when a channel became full the feed would automatically stop until the type had been set out of the channel. The type pieces progressed toward the right, the justifying spaces moved to the left, and both moved forward toward the operator. The machine knew how to calculate the length of the lines (a parameter set by the operator), and it notified the operator when no more letters or syllables could be added to a line. At that point, it figured out how many spaces were needed to justify a line within five thousandths of an inch and added those to the line.

Even a partial list of the machine's sensors and actuators would be extensive. The compositor had the ability to sense the nicks and, through them, to identify the type pieces and quadrats; it had actuators that could remove damaged pieces; it knew when the line was nearing completion and no more syllables or letters could be added; it knew how to calculate the spaces needed and to add them automatically; it knew when the typesetting channel was full; and it knew how to distribute the used type pieces (dead matter) when printing was complete. Each of these actions constituted an interpretation of an existing situation and resulted in choices about what actions were appropriate. Although the machine knew nothing about the texts' semantic contents, it knew a great deal about the compositing process and the actions required to complete it. In the definition of cognition proposed above, the machine was unquestionably capable of technical cognitive acts.

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The combination of the compositor and the human intelligence of the operator formed a cognitive assemblage of considerable power and efficacy, surpassing in speed, accuracy, and artistic effect the results that even an experienced and accomplished human compositor could achieve working alone.

When I visited the Mark Twain Museum in Hartford, Connecticut, to see the only extant Paige Compositor,[2] I was awed by its sheer size and complexity. Although documentation about its operation exists in the museum's archives, practical knowledge of how it works has been lost, and the machine has not been turned on in decades (possibly the entire twentieth century). Perhaps that is just as well, for it broke down repeatedly during its trial at *The Chicago Herald*, and Paige was the only person who knew enough to repair it. When the newspaper decided to end the test after sixty days, the compositor would never again be used commercially. Paige had designed the machine to duplicate the actions that a human performed when typesetting and compositing. The result was a device of such complexity that it was vulnerable to

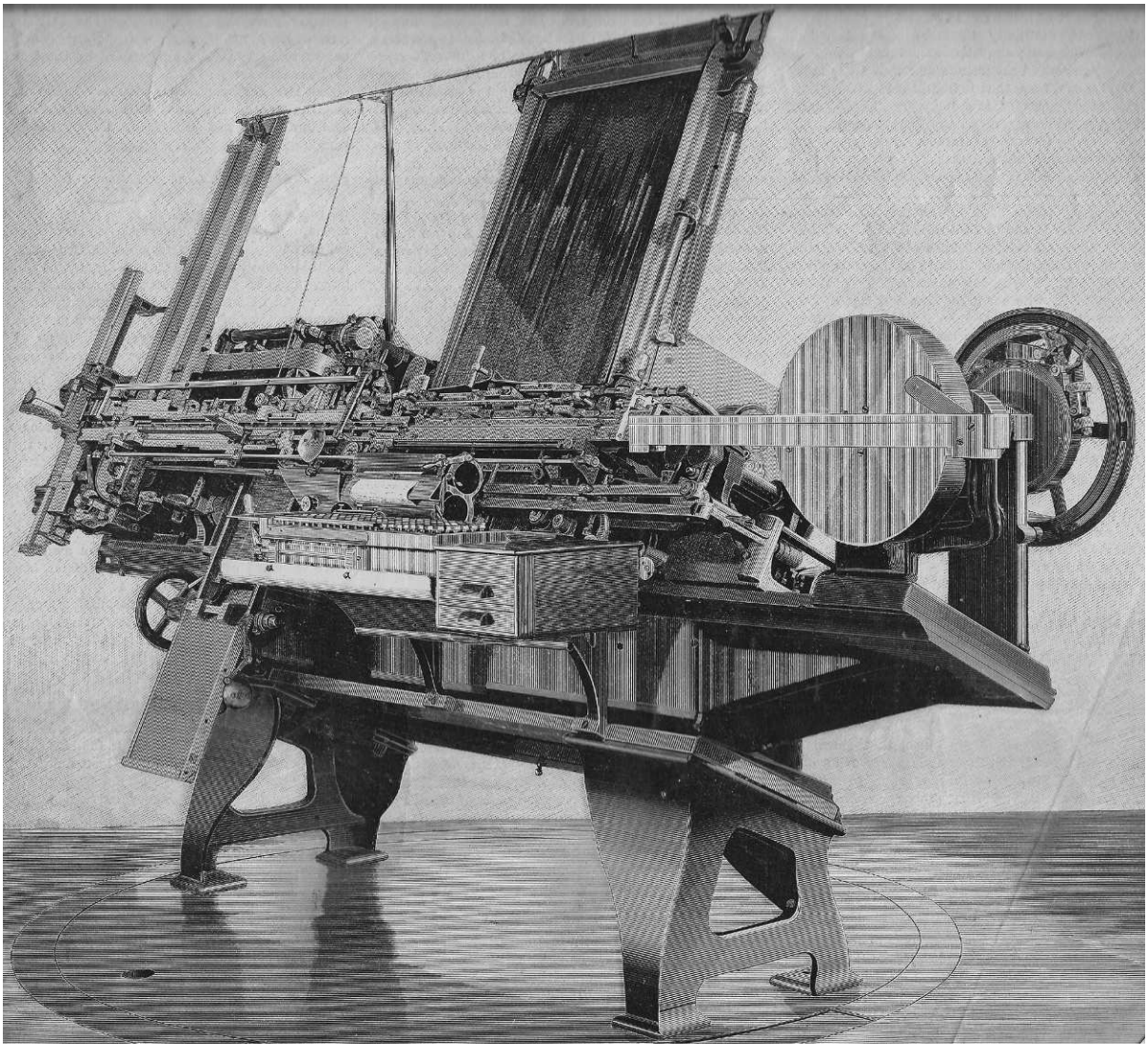
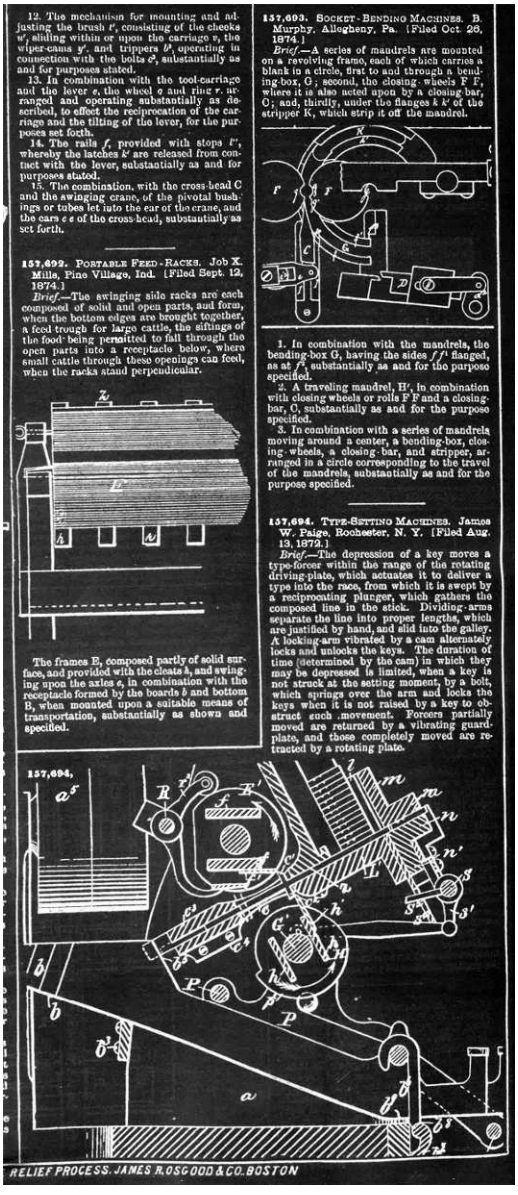


FIG. 1
Front view of the Paige Compositor. From *Scientific American*, 9 Mar. 1901, p. 1. The machine was displayed with the caption "A Machine with 18,000 Elements—The Paige Typesetting Machine."

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frequent breakdowns. Its complexity was apparent in Paige's 1887 patent application (fig. 2), which included 275 drawing sheets, 123 specification sheets, and 613 claims, and became known in the patent office as "the Whale" ("Mark Twain").

The limitations of this design become obvious when the compositor is compared with Ottmar Mergenthaler's Linotype, a machine first used commercially in June 1886 when it was installed at the offices of *The New York Tribune* (*Linotype Machine Principles* 1–39). Rather than try to duplicate human motions involved in setting type by hand using a compositor's stick, the Linotype used molds called matrices to cast an entire line of type at once. The machine was controlled by a ninety-character keyboard, where the operator composed lines of text. Each keystroke released a matrix from the magazine mounted above the keyboard; the matrices varied according to the size and style of the types. The matrix went through a channel to the assembler, where the matrices were lined up in the order in which they were composed. As soon as a line was complete, the machine took over and the rest of the process was automatic. When printing was completed, the matrices were returned to the magazine for reuse. Whereas the Paige Compositor was designed to redistribute dead matter using mechanical cognition, the Linotype simply melted the type pieces and recast them, a method requiring no cognitive decisions. This technique took advantage of mechanization to reconceptualize how type pieces were created and assembled. John M. Maxwell argues this can be seen as a "leveling up." By preserving the rendering system but scrapping the renditions, the Linotype instantiated, in its hot-metal casting technique, a new way to instrumentalize the traditional spatial distinction between type pieces set in forms and type pieces ready for distribution. Precisely because the process reimagined how a manual technique could be mechanized, it reduced the cognitive load on the machine.


12. The mechanism for mounting and adjusting the brush t^2, consisting of the cheeks u^2, sliding within or upon the carriage v, the wiper-cams y^2, and trippers b^2, operating in connection with the bolts c^2, substantially as and for purposes stated.

13. In combination with the tool-carriage and the lever e, the wheel o and ring r, arranged and operating substantially as described, to effect the reciprocation of the carriage and the tilting of the lever, for the purposes set forth.

14. The rails f, provided with stops f^2, whereby the latches k^2 are released from contact with the lever, substantially as and for purposes stated.

15. The combination, with the cross-head C and the swinging crane, of the pivotal bushings or tubes let into the ear of the crane, and the ears $c\,c$ of the cross-head, substantially as set forth.

157,692. PORTABLE FEED-RACKS. Job X. Mills, Pine Village, Ind. [Filed Sept. 12, 1874.]

Brief.—The swinging side racks are each composed of solid and open parts, and form, when the bottom edges are brought together, a feed-trough for large cattle, the siftings of the food being permitted to fall through the open parts into a receptacle below, where small cattle through these openings can feed, when the racks stand perpendicular.

The frames E, composed partly of solid surface, and provided with the cleats h, and swinging upon the axles e, in combination with the receptacle formed by the boards b and bottom B, when mounted upon a suitable means of transportation, substantially as shown and specified.

157,693. SOCKET-BENDING MACHINES. B. Murphy, Allegheny, Pa. [Filed Oct. 28, 1874.]

Brief.—A series of mandrels are mounted on a revolving frame, each of which carries a blank in a circle, first to and through a bending-box, G; second, the closing-wheels F F, where it is also acted upon by a closing-bar, O; and, thirdly, under the flanges $k\,k$ of the stripper K, which strip it off the mandrel.

1. In combination with the mandrels, the bending-box G, having the sides $f\,f^1$ flanged, as at f^2, substantially as and for the purpose specified.

2. A traveling mandrel, H', in combination with closing wheels or rolls F F and a closing-bar, O, substantially as and for the purpose specified.

3. In combination with a series of mandrels moving around a center, a bending-box, closing-wheels, a closing-bar, and stripper, arranged in a circle corresponding to the travel of the mandrels, substantially as and for the purpose specified.

157,694. TYPE-SETTING MACHINES. James W. Paige, Rochester, N. Y. [Filed Aug. 13, 1872.]

Brief.—The depression of a key moves a type-forcer within the range of the rotating driving-plate, which actuates it to deliver a type into the race, from which it is swept by a reciprocating plunger, which gathers the composed line in the stick. Dividing-arms separate the line into proper lengths, which are justified by hand, and slid into the galley. A locking-arm vibrated by a cam alternately locks and unlocks the keys. The duration of time (determined by the cam) in which they may be depressed is limited, when a key is not struck at the setting moment, by a bolt, which springs over the arm and locks the keys when it is not raised by a key to obstruct such movement. Forcers partially moved are returned by a vibrating guard-plate, and those completely moved are retracted by a rotating plate.

157,694.

RELIEF PROCESS. JAMES R. OSGOOD & CO. BOSTON

FIG. 2

Reproduction of a sheet from Paige's patent application for the compositor, from the archives of the Mark Twain Museum. Used with permission of the Mark Twain Museum.

As this description suggests, it is crucially important to consider how cognition was distributed in the cognitive assemblages constituted by the two machines and their operators. Whereas the Paige Compositor tried to re-create complex human interpretations through its levers, cams, and other mechanisms, the Linotype relied on the human operator for many decisions, such as the selection of type pieces. For that reason, the Linotype was more robust, simpler to repair, and

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more economical to manufacture, resulting in a considerably lower purchase price. The Paige Compositor was (literally) consigned to the scrap pile of history, and the Mergenthaler Linotype went on to become the industry standard. Paige sought to give the machine too much cognition at a time when it could only be implemented electromechanically, resulting in a machine of such complexity and fragility that it could not be made commercially viable. The next major advances would come when typesetting machines began to be combined with technical and computational media, in offset lithography printing and computer typesetting respectively.[3]

E-book Cognition: What the Machines Know and How They Know It

Examining e-books from a media archaeology perspective, we may ask what they know and in what senses they use their knowledge. An e-book on a multiuse device such as an iPad typically has access to that device's accelerometer, which knows the object's orientation in space and can shift the screen display accordingly, in ninety-degree increments. An internal GPS knows its geographical coordinates and can report on this if asked. E-books with touch screens can employ capacitance technology to sense when they are touched by a human finger and to respond to gestures according to algorithms that interpret this input. Most e-books have clocks and can report on the time and use the clock to keep track of a number of readerly activities.

In addition to deploying these sensory systems, an e-book can instantaneously transform ASCII strings into binary digits and vice versa, allowing it to do much more than a print book can. It has the ability to resize the font, change font styles, and highlight passages, as well as to record, store, and retrieve notes a reader makes, which can be keyed to specific passages. An e-book with a built-in wireless transceiver can access remote databases to draw content from them and can also report back to a centralized database about its activities. It can use its search, find, and retrieve functions externally, such as when it offers definitions for a word in response to a reader's query. The same functions are available internally to follow a reader's progress through a text, note how long a reader spends on a given section of text, record which portions are highlighted, and sense which sections have notes associated with them. All this information can also be reported back to a database, where it can be harvested by corporations to target an individual reader's interests, habits, and proclivities.

As this list suggests, the cognitive capabilities of an e-book are much greater and more autonomous than those a print book possesses on its own. In some respects, the e-book's cognitive capabilities exceed those of humans in speed and scope, although a human's more expansive world horizon gives a person a far more comprehensive understanding of what the components of an e-book's knowledge mean in a human context. Nevertheless, an adequate understanding of the interactions between a reader and an e-book requires both a model of distributed cognition and, as a necessary corollary, an understanding of those interactions as instances of distributed agency.

Many readers may not devote much thought to an e-book's cognitive capabilities, in part because the extent to which a reader uses an e-book's cognitive potential varies from person to person and in part because e-books are designed, as a deliberate marketing strategy, to screen from readers the full extent of their capabilities, especially their ability to surveil. For someone who regards an e-book as a convenient way to access print content, reading text on an e-book may not seem very different from engaging with a print object. Yet the contents of an e-book and of a print book differ significantly in terms of their legal status. When one buys

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a print book, one owns it, but buying a text formatted for an e-book does not confer possession of its content. Instead, what one buys when purchasing an e-book text is a license to access its content (Masnick). This is very clear when the text itself resides in the cloud rather than on the individual device. Even in the latter case, however, the content may be removed from the device if the relevant corporation judges that the terms of the license have been violated.

One ironic instance of this removal involved Amazon's deleting George Orwell's *1984* and *Animal Farm* from people's Kindles, apparently because the texts had been added to the Kindle store by a company that did not have the rights to them. Other reported instances involved books in the Harry Potter series and the novels of Ayn Rand, apparently also because of copyright issues. Because of the furor that resulted from the removals, Amazon agreed not to delete purchased texts directly from people's Kindles, but it continues to erase texts from Kindle archives—which means that readers may not be able to redownload some archived texts that they have purchased (Masnick). This situation poses special problems for libraries, because it is not clear that they have the right to loan e-book texts to other libraries.

The movement from possession to access, highlighted here in the case of e-books, is part of a much larger movement from physically discrete objects located at specific places to information and data that can be duplicated and sent almost anywhere at almost no cost. Considering the extensive changes that the advent of print books brought about in early modern economies, social structures, religious doctrines, and other areas of the culture, the transition from print to postprint has vast implications for contemporary cultures (Hayles, "Virtual Bodies"; Castells). Because this issue of *PMLA* emphasizes cultures of reading, the rest of my essay will focus on how postprint productions interact with literary cultures of reading and writing. I will approach this very large topic by exploring how cognitive assemblages contain dynamic interplays between flexibility and stability, and transformation and repetition, throughout the history of print traditions and into the contemporary, postprint moment.

Cognitive Assemblages and Their Implications for Cultural and Economic Practices

Considering the history of print technology from a cognitive-assemblage viewpoint focuses attention on the cognitive flows through an assemblage, along with the distribution of agencies these flows imply. In his press, Gutenberg combined two significant innovations: the use of metal type pieces (which had been known in China since the twelfth century) and the use of moveable type. Although the press acted as a cognitive support rather than a cognizer, its interactions with the typesetters and compositors allowed for much more flexibility than did the older process of printing from carved woodblocks, because the work could be distributed among multiple craftsmen as the occasion required and according to their experiences and skills. D. F. McKenzie's classic account of the press at Cambridge University remains unsurpassed in vividly illustrating how flexible this process could be when different compositors worked on a single volume and their work flowed between different manuscripts.

For five centuries the technology pioneered by Gutenberg persisted with minimal changes. The composing stick that Twain used when he was a printer's assistant in 1850 would have been instantly recognizable to Gutenberg. The important innovations during this period were not in the technology but in the institutional, cultural, and legal practices surrounding it. Although these practices are often discussed in isolation from the technology, a cognitive-assemblage approach enables an integrated perspective, from which

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one can see how cognition flows into social, economic, and cultural realms.

Mark Rose's *Authors and Owners: The Invention of Copyright* traces the economic motivations of booksellers and the court cases that established the principles of literary property and, with them, the cult of authorship based on originality and creative genius. These developments had implications for practices of typesetting and composition. Whereas in earlier eras typesetters had felt free to introduce changes into copy when they believed the changes would improve the work, by the mid–eighteenth century authors had begun to insist on more control over how their work appeared in print. Rose documents Samuel Richardson's fierce defense of his literary property when the novelist discovered that a group of Irish booksellers had covertly obtained the text of his new novel, *The History of Sir Charles Grandison*, and advertised it for sale in Dublin before it was marketed in London. Richardson argued, "Never was Work more the Property of any Man, that *this* is his. The Copy never was in any other Hand: He borrows not from any Author; The Paper, the Printing, entirely at his own Expence" (qtd. in Rose 116). The implication is clear: the manuscript belongs entirely to him, and its transformation into a print book is an extension of the agency that he exercises over it.

As Rose ingeniously demonstrates, the cult of authorship, although rooted in the economic concerns of booksellers who celebrated authors in order to make money, underwent metaphoric transformations that gradually suppressed the commercial interests in favor of authorial genius and originality. So Rose concludes that "the sense of the commercial" became "as it were, the unconscious of the text" (118). One of the effects of this suppression was to introduce a sharp divide between the creation of a manuscript and its production as a print book. Not until the professionalization of bibliographic work, beginning in the early twentieth century, would printers and typesetters again come to the fore as important cognitive agents in literary production.

Even then, for decades the author's final intentions formed the gold standard for bibliographers because after the copyright revolution the author became the primary, if not the only, authority on what form the author's physical book should take (Bowers; Tanselle). The sense that print documents had, encoded in themselves, a final form that could be recovered and reproduced to create authoritative editions evolved through a combination of the commercial interests of printers and the patient work of editors and bibliographers who understood that virtually all print documents contain variants and that deciding which variants should be considered final involved innumerable decisions and, consequently, intense cognitive labor. The vaunted stability of print always had a shadowy presence whose uncertainty and variation were overcome, or, better, suppressed, through a redistribution of cognitive labor from typesetter and compositor to editor and bibliographer. Moreover, the extent to which this redistribution was visible to the reader varied enormously. Some editions did not include any comments about what editorial decisions had been made, while variorum productions such as William Gilman's editions of Ralph Waldo Emerson's journals displayed the variants so prominently that Lewis Mumford entitled his review of the editions in *The New York Review of Books* "Emerson behind Barbed Wire."

It took a revolution in bibliographic perspective, spearheaded by Jerome McGann and others, to reveal how print books participate in meaning making through their "bibliographic codes," a phrase obviously indebted to the emerging algorithmic culture (McGann 258). Essentially, McGann sought to portray print documents as malleable, deformable, and mutable, in other words just as fluid as electronic texts, as if print books were actually e-books *avant la lettre*.

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This perspective allows us to see the ways in which print books were produced through complex social, economic, and technological processes, each of which had its share of agency in creating the object with which a reader engaged, as well as the ways in which the bound object directed a reader's cognitions, mobilizing some and suppressing others. Nevertheless, McGann's approach glosses over the crucial distinction between cognitive supports such as books and active cognizers such as authors, readers, editors, proofreaders, typesetters, and compositors. This fluid approach thus tends to underplay, if not altogether erase, the ontological rupture that marks the transition from the print era to the postprint era, in which postprint productions became cognizers in their own right.

Books in the Postprint Era: Flexibility and Stability Renegotiated

As I have argued above, an e-book, which is able to change, among other things, font styles, type sizes, orientations, and margins, has greater cognitive capabilities than any print book ever produced and, consequently, greater agency and flexibility too. Many authors yearned for this kind of mutability before it became technically possible, experimenting with print books in an attempt to achieve it. For example, when Raymond Queneau wanted to create a print book capable of nearly infinite variations, he asked his reader to cut up the pages of *Cent mille milliards de poèmes* (1961; "A Hundred Thousand Billion Poems") so that lines in the ten printed poems could be mixed and matched, relying on the reader's agency to produce this randomized result. By contrast, a relatively simple algorithm enables an e-book (or any computational medium) to achieve this effect automatically, generating endless displays of potential poems for the reader's consumption by using its own, autonomous agency (see, e.g., Rowe). Other writers have also longed for the kind of flexibility now easily attained with computational media. Marc Saporta presented his *Composition No. 1* as unbound printed pages in a box so that the reader could assemble them in any order. He also provided pages with images of drifting letters, as if they were grains of sand randomly distributed by waves or winds. The designers who adapted Saporta's work as an iPad application rightly claim that the work "raises questions we ask ourselves today about user-centric non-linear screen driven ways of reading" ("Composition No. 1"). It can be argued that their adaptation fulfills Saporta's vision better than the original printed unbound pages, insofar as it allows for true randomization by removing the conscious or unconscious biases that a human reader may insert into the process. Like a computerized version of Queneau's work, the iPad version of Saporta's work relies on the device's agency rather than the reader's, demonstrating how agency is negotiated differently by postprint productions than by their print predecessors.

Other writers have taken full advantage of the cognitive capabilities of networked and programmable machines to produce objects that could only exist in the postprint era. An example is Jonathan Safran Foer's *Tree of Codes*. Making extensive use of computational design, the work takes a print book, Bruno Schulz's *Street of Crocodiles*, and eliminates about ninety percent of its words by means of die-cut holes. The result is a bound object that resembles lace, every page perforated so heavily that the paper becomes extremely fragile and turning the delicate pages becomes a test of manual dexterity. The precision required to make the thousands of cuts in the correct locations goes far beyond what electromechanical devices by themselves could achieve; a lovely online video demonstrates the complex processes necessary for the postprint book's production (Visual Editions). Here the important difference between this book and a print book lies less in

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negotiations that redistribute agency than in the algorithms that redistribute cognitive capabilities. In this sense, *Tree of Codes* vividly shows that postprint productions are situated in a cognitive ecology different from that of the print-era books that preceded them.

Not all writers, of course, yearn for or welcome the flexibility that e-books and computational media provide. Jonathan Franzen argues that print books are superior to e-books because they are more robust ("I can spill water on it and it would still work"), more resistant to obsolescence ("it will work great 10 years from now"), and, most of all, more stable and permanent:

> For serious readers, a sense of permanence has always been part of the experience. Everything else in your life is fluid, but here is this text that doesn't change. . . . [I]t's going to be very hard to make the world work if there's no permanence like that. That kind of radical contingency is not compatible with a system of justice or responsible self-government.
>
> (qtd. in Singh)

In fact, all of Franzen's works available in print are also available as e-books, and so as an author he participates in digital culture, whatever his views on the relative merits of print books and e-books. (Thompson reports that Franzen's *Freedom* "sold around 750,000 copies in hardcover and 250,000 ebooks in the US during its first year" [322]). It is surprising to hear him contrasting the cognitive regime of postprint books, in which his print books (along with virtually all contemporary book productions) participate, with something as broad as "a system of justice or responsible self-government." The ahistorical assertion that these are incompatible affirms the ideology of print, declaring that print, itself the site of centuries of negotiations between different kinds of cognitive agents—human and technological authors, producers, and readers—is unequivocally stable and permanent.

Cognitive Assemblages as Modes of Inquiry

As we have seen, the cognitive-assemblage approach shares with that of media archeology the idea that technical media have viewpoints and that these viewpoints matter. However, the cognitive-assemblage approach differs in the privileged position it gives to cognition. It is not concerned with the inaccessibility of media processes to direct human sensing (as Ernst would have it) but rather with the capacity to make choices, perform interpretations, and participate in meaning making.

The explosive growth in the prevalence of cognitive technical devices in the late twentieth and early twenty-first centuries is likely to make the cognitive-assemblage approach seem mere common sense. As this article attempts to demonstrate, this approach can be productively applied to earlier periods as well. It enables insights into technical developments and complicates attempts to construct simple narratives of progress, which contain inevitable distortions and elisions as well as underlying triumphalist assumptions and unexamined privileges accorded to human actors over nonhuman cognizers. Resisting these narratives, the cognitive-assemblage approach provides nuanced and flexible ways to understand how cognition flows through a system, a process in which different players (human and nonhuman) have different cognitive capabilities and exercise different kinds and amounts of agency.

Perhaps the most important contribution of the cognitive-assemblage approach in the context of cultures of reading is to postulate that culture can apply to nonhuman and technical participants. But the approach also provides a principled, conceptually coherent way to distinguish between print and postprint productions. It relies not on readers' experiences (which may be deceptively similar—for example, when e-book reading is compared with print book reading) but rather on cognitive flows throughout an assemblage. This

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approach constructs a model that integrates processes of authorship—editing and production, dissemination and delivery—with cultures of reading, both human and machine.

By defining cognition as a process emerging from flows of information and from interpretations of those flows, the cognitive-assemblage approach invites questions about the nature of meaning and how it differs for human and technical cognizers. The revolutionary thrust of this approach is perhaps most visible here, for even to associate meaning with machines is controversial, especially in the humanities, which have long and rich traditions of thinking about meaning making as a specifically human practice. In challenging this anthropocentric perspective, the cognitive-assemblage approach opens meaning making to nonhuman life-forms as well as to technical systems. For biological organisms from unicellular bodies to complex mammalian species, the most elemental level of meaning is survival. In humans, endowed by evolution and culture with extended consciousness as well as unconscious awareness and nonconscious cognitive capabilities, meaning making involves much more than survival. Human cognition is especially apparent in "ah-ha" moments, when connections between different realms of experience spark into existence and expand, seemingly without limit. The cognition of machines, lacking this evolutionary and cultural heritage, operates in contexts where meaning making emerges in relation to their design parameters, the purposes for which they were created, and the functions they perform.

Today, these functions include reading (and writing, such as the automated composition practices in fields like sports reporting and business reporting). Because human cognitions are increasingly entangled with technical cognitions, it is no longer possible to regard meaning making as an exclusively human (or even biological) prerogative. The questions that confront us shift accordingly, from queries about what, how, where, and why we read to those about the nature of intra-actions in which meaning making occurs as a distributed process circulating in and through human and machine bodies. Among the questions this shift in reading practices raises is whether *cultures*, with its anthropocentric connotations, is still an appropriate term for the sites of reading.

My own view is that the concept of "cultures" should be extensively reworked to include technical cognitions—an enormous project to which this article aspires to contribute—or perhaps jettisoned entirely in favor of a conceptual framework that does not build the nature-culture binary into its foundation. By focusing on cultures of reading, this special issue opens spaces for dialogues about what this phrase means and ultimately invites debates about the meaning of meaning. Although the approach suggested here may at times seem to subvert this issue's goals, I hope it supports them by inviting us to rethink how we conceive of sites of reading when they are embedded in mixed, human-technical cognitive ecologies.

Notes

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1. Siegert argues for "cultural techniques," a methodology that is similar to media archaeology in emphasizing the material conditions for cultural emergences but that, unlike it, does not grant exclusive privilege to media viewpoints or introduce a binary choice between machine and human perspectives.

2. Cornell University also had a Paige Compositor but sold it for scrap iron during World War II to help the war effort.

3. Kirschenbaum discusses how in 1973 John Hersey and Alvin Eisenman connected a Mergenthaler Super-Quick phototypesetting machine to a PDP-10 mainframe computer, making it possible to "typeset a book and deliver camera-ready copy to Hersey's longtime publisher, Knopf" (133).

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