New Leaves: Riffling the History of Digital Pagination

Martin Paul Eve

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Introduction: Against the Page

Page space isn't a given, an a priori static entity.

Johanna Drucker[1]

NLS files were described as early as 1962 as 'scrolls.'

Thierry Bardini[2]

Physical metaphor and analogy saturate contemporary computing.[3] We have a virtual "space" of web "sites," "windows," "menus," "icons," and "pointers." Our internet resources, though, are pages, our word processors open onto A4 sheets, and Portable Document Format (PDF) files mirror the rectangular form of the common printed page.[4] There is an apparently clear reason for such prevalence of metaphors in digital-textual production and reception: to allow users to transpose what they know about the world at large to computer interfaces. However, it is too easy to assume that digital interfaces are transparent and obvious.[5] Metaphors are supposed to help us to understand. Yet explaining why a computer window is called a "window" is actually very difficult. That it can "open" is about as far as you will get. There is almost certainly no food on a computer "menu." Nonetheless, such assumptions about familiarity lead to the well-known paradigm of supposedly intuitive interface designs, when really what is meant by *intuitive* (or, more correctly, *intuitable*) is learned behavioral patterns. Intuitive, as Jeff Raskin puts it, means *familiar*.[6] This is why computer interfaces become "*more* intuitive" the more we use them; metaphor pertains to a familiar relationship strengthened through repetitious encounters.[7] This trope of relation provides a way for new users to imagine how a digital interface might work with respect to its physical correlate, even when the parallels are poor. Such relationality has been as prevalent in the digital reading world as

Book History, vol. 25, no. 2

in other digital user interfaces.[8] Hence, through digital metaphor, we have virtual pages. Digital pages, we are told, serve as descendants of physical familiarity, habituating users to the electronic reading environment, bearing their real-world affordances of easeful, random, and sequential access.

However, this story is more complicated than it appears. Existing histories have overlooked the fact that proposals for computational pages were neither well received nor prioritized in the early days of display unit development. The most striking example of this aversion is that Adobe attempted to cancel the development of PDF, which is perhaps now the most widely-used, paginated document format on the planet. Of course, since the early 1990s, the digital page *has* come to dominate the digital landscape. As such, commentators have frequently stated that the visual metaphor of the page is damaging and that we must overcome the physical page's metaphorical mastership, seeking to undo this presumed historical lineage. Digital formats, we are told, have a persistent yet frustrating (and even unnecessary) "need to acknowledge the historical priority of books and to invoke a link with their established cultural identity."[9] At the same time, we assume that "electronic 'books' will 'supersede the limitations' and overcome the 'drawbacks' of their paper-based forebears," as Johanna Drucker has it.[10] The "Beyond the PDF" conference and subsequent series of events demonstrate this frustration at how physical pagination is artificially sustained in the digital world.[11] Yet, as I will show, this history and the ascendance of the digital page were far from certain. The progress was not a linear move from physicality to digital pagination that must now be unpicked and reversed. Instead, the road taken would fork many times.

Certainly, for as long as pages have existed, even in the physical world of print, there has been a prevalent counter-discourse that has sought their demise. Pages, asserts Alberto Manguel, exert a "tyranny" of format over the text they contain, a tyranny that we must resist: "the shape of a page," he writes, "seems to cry out for counter-action."[12] Perhaps showing disdain for the very "idea of the book" being "the presentation of material in relation to a fixed sequence which provides access to its contents (or ideas) through some stable arrangement,"[13] Henry Burton, in 1636, wrote to his reader of the problem with pages, which forced a layout that distanced his plates from their text: "the foregoing Examples are not orderly placed. Indeed it was the authors minde that they should have beene otherwise."[14] In Shane Butler's reading, the page is "conspicuous for the impertinence and arbitrariness with which it repeatedly barges into the text, chopping up stories, sentences, and even words where it will."[15]

This assault on the page has carried over into the digital document space. From the moment of the inception of the Portable Document Format (PDF), there was anxiety about enforcing the trans-medial constraints of paper on digital forms.[16] As early as 1993, Pete Dyson, who edited an influential report in the late 1980s on the state of desktop publishing, voiced his worry: "my biggest concern with all of these document viewers is that they start with a printed-page image. […] I believe documents should be formatted for the medium that they are intended for."[17] This principle is echoed in many user interface design documents, which stress that, rather than paginating, "designers will be most effective when they design online manuals to fit the electronic medium."[18]

Such anti-pagination sentiment has only grown since the late 1980s; attacks on the PDF are its synecdochical form. For instance, the largest employer in Europe, the United Kingdom's National Health Service, now has a policy to "avoid PDFs" and their trans-media pagination.[19] Reasons given for avoiding the format include: that such paginated files "cannot meet the range of users' accessibility needs"; they "give people a poor user experience, especially on mobile"; they "are hard to maintain and update, so users may get out of date and unreliable content"; and that it is tricky to "identify problems" with such files because "it's difficult to collect data on how people use PDFs."[20] Further, the creator of the prevalent Python programming language, Guido van Rossum, declared in 2014 that "PDF Must Die. Bills, scientific papers, everything in PDF is harder to read than web pages."[21] The list goes on, and by 2001 the critique of PDF and its pagination had gone mainstream. At that point, prominent commentators such as Jakob Nielsen remarked on the format's unsuitability for long-form digital reading.[22]

Despite these attacks, the rise of digital pagination continues unabated, with its consistent artificial enforcement of "extrinsic boundaries."[23] Despite the vocal opposition, many readers like PDFs, which embody the logical digital extension of our physical reading habits. Yet the argument that I will advance here is that the digital page was never a certainty and that there are better historical media forebears for the digital page than its print correlate. Wendy Hui Kyong Chun has rightly cautioned us that analogy is not a singular, one-to-one relationship but provides messy and perspectivized lineages.[24] As early as 1994, Roger Chartier was able to write of "the revolution that has been predicted, […] which transforms the book (or the written object) as we know it—with its quires, its leaves, its pages—into an electronic text to be read on a screen."[25] This "substitution of screen for codex," writes Chartier, "is a far more radical transformation" than

that instigated by Gutenberg "because: it changes methods of organization, structure, consultation, even the appearance of the written word."[26] I argue that it was never a "substitution of screen for codex" in the lineage of the virtual page.

In the remainder of this article I perform a historical re-interrogation of three interrelated phenomena: (1) that digital pages do not behave as do their physical correlates but instead mimic earlier historical forms of print that fused pagination, scrolling, and the tablet form; (2) that the relatively late development of PDF, now the most widespread trans-media digital pagination format, was almost abandoned by Adobe's board of directors, who could see no audience for it; and (3) that there are other more robust lineages of constraint for digital pages from cinema and television. Drawing on new correspondence with the creators of the PDF, I argue from these historical tracings that nothing was certain about the development of pagination in the digital space and that the digital page almost never came to the prominence now presumed.

The Metaphors of the Page and Memory

> It cannot be assumed that a reader will properly understand what is presented on screen.
>
> David McKitterick[27]

Metaphors of pagination are omnipresent in computation, but they are especially linked to concepts of *memory*. At base, contemporary classical computing systems work thus: a central processing unit (CPU) performs calculations on stored binary digits (bits) in its registers, the outcomes of which are then given human meaning by various layers of software and hardware. The low-level hardware storage of these bits varies (among the most usual forms at the time of writing is the metal-oxide-semiconductor cell), but this level is commonly dubbed *main memory* or *random-access memory*, both neuro-cognitive metaphors. The premise is that this fast and uniform-access-time recall unit can most quickly transfer its bits into a CPU's *registers*, the place where the actual arithmetic takes place. Hence, there is a chain wherein digital data move from the slowest media (say, hard drives) into random-access or main memory and then into the CPU's registers.

However, as with many computational metaphors, the analogy to memory is textual. Software that needs to know the contents of memory can "read" its contents via the CPU. It can also "write" to this memory space.

This may seem a poor metaphor. We do not usually think of our brains as mediately reading or writing to our memory to conduct calculations. We instead consider the mind in much more holistic terms of unmediated access. Yet the history of the metaphor of mind is one saturated with reading and writing (supplementing the well-known and long-standing biological analogies between sexuality, reproduction, and the printing press).[28] As far back as Plato, with Homeric and Aristotelian resonance, the mind was viewed as—or in opposing relation to—a wax tablet or a blank slate.[29] In the sixteenth century, as the printing press proliferated across Europe, a print-culture equivalent—the "blank page"—became prevalent in Western cultures for considering memory's operation.[30] By the time of Locke's *Essays on the Laws of Nature* (c. 1660–1664), for example, it was common to mix cognitive metaphors of tablets and paper within the same disjunctive clauses.[31] The march towards neural metaphors of legibility and inscription was also furthered through the early development of the realist novel, which combined a narratorial claim of mental interiority (and memory) with metatextual depictions of reading and writing. The prominent phenomenon of mind reading is another instance of such metaphorical incursion.[32]

However, if we suppose it is true, as David McKitterick argues, that the "computer screen suppresses a sense of time" in its representations of books, it is, coincidentally, also matters of timing and chronology that mark the emergence of the pagination metaphor in computer memory management.[33] Because of the relative descending speeds of access (from register to main memory to secondary storage), memory is addressed in discrete units called *pages*. The act of moving data from main memory to secondary storage to circumvent memory limitations is called *paging*. A *page table* is often created in such systems to ensure that programs can access only their own pages, a security measure that when violated raises a *page fault*. (This is perhaps the equivalent of ensuring that, when one turns the page of a book, one does not find oneself inside a different novel. It is akin to imagining pages as, in Drucker's terms, "force fields," holding their contained elements in a dynamic tension of relation.[34])

Pages in computer memory management unite two differing etymologies of the word *page*. In the first case, *paging* means *fetching* from storage. This use most likely comes from the sense of a servant, referring to summoning someone by sending a page(boy).[35] It is from this meaning of messaging and summoning that the pager technology also derives its name.[36] In the second context, though, pages in computer memory are framed and bounded and read and written; here the etymology is *pagina*, derived from the notion of fixing or binding.[37] They are the leaves and quires of the codex.

Computational memory pages share many features with their print cousins in codices. They are of a uniform size (the page *dimensions*), they can be accessed at random (*flipped to*), and the content within the page runs contiguously in sequence (the *words*—another term in computer memory management—hit the right notes, in the right order). As an instructive example, though, the metaphor only goes so far. The physical contiguity of memory pages to one another is not guaranteed. The ordering is more akin to a choose-your-own-adventure plot or hypertext construction than a contiguously paginated novel. This is a mode in which a chunk of "narrative" within a page is linear and contiguous, but each page ends with an instruction to jump to a different location in the "book," and it is impossible to read cover to cover.

Further, the virtual address of a computational memory page (imagine this as its page number) is distinct from its *page frame* (where you will find it in the "book"/main memory). Indeed, there may not even be a page frame if the data have been offloaded to secondary storage. Much like the scattered pages of B.S. Johnson's *The Unfortunates* (1969), there is no guarantee of finding a page in order in computer memory or even of finding it "in the box" at all.

Dennis Tenen has encouraged us to think of such ubiquitous computational metaphors under the rubric of what he calls "speculative formalism."[38] This is a model that recognizes the mediation and friction of such metaphors, that sees the Saussurean arbitrariness of the skeuomorphic "trash can" in relation to the operations of, say, journaling file systems. It is a strategy that follows in N. Katherine Hayles's footsteps, calling for analyses of "material metaphors."[39] Speculative formalism is a model that acknowledges that "simulations ultimately embody specific power structures in an economy of exchange between physical and mental resources."[40] "What does it mean," asks Tenen, "to turn a page in a medium that sustains neither turning nor pages?"[41] What historical conditioning has led to the prevalence of the visual metaphor of the page in contemporary computing culture? What are the actual histories of the virtual page as a visual form instead of its nominal presence as a metaphorical digital touchstone?

Despite this prevalence of the metaphor in the computational environment, in Drucker's appraisal, pages are among the "most dramatically overlooked graphical forms".[42] They are often classed as "apparently self-evident graphical features of any textual work."[43] Bonnie Mak's 2011 *How the Page Matters*, which conducts a material-textual reading of the fifteenth-century treatise *Controversia de nobilitate*, agrees. For Mak, "we have read

the page"—and perhaps opposition to it—"too quickly" and we are overly keen to see both the "print revolution" and the "digital revolution" as "discontinuities in the history of books and reading."[44] Yet what are the characteristics of a virtual page? Can we define such an entity in terms of its print predecessor? For writeable digital pages behave differently than those that are only readable.

That virtual pages sit in direct ancestry to physical pages is an increasingly less common view. However, the word processor, historically charted in recent days by Matthew G. Kirschenbaum, is designed, at least in part, to mimic book (codex) construction, even while augmenting traditional text-creation procedures. It seems logical that such a system would yield to the architect a virtualized model of the physical artifact that it will produce. However, the use of different fonts, text sizes, page dimensions, screen resolutions, zooms, functional para-tools (scrollbars etc.), and many other factors means that, in the world of inscriptible digital surfaces, the content and flow layout of pages that can be (re)written will *not* be the same across devices. Hence despite Xerox's Bravo billing itself as the first What You See Is What You Get (WYSIWYG) document creation software in the 1970s, the disparity of resolution between the Alto machine on which it was run (which had a portrait screen orientation) and the printer output gave the lie to this description (WYSINWYG).[45] It was explicitly to these problems of write-flexibility, scrolling flow, and the disparity between display and print that PDF was addressed. Yet these inscriptible "pages" do not exhibit even the basic etymological premises of boundness that would only come much later. They are hardly pages at all.

Instead, one of the most critical metaphorical interventions to recognize when it is claimed that we must vanquish the digital page is the well-known and conjoined role played by the *scroll* and the *tablet*. As far back as 1999 Michael Heim noted that computing systems had adopted metaphors of scrolling as their primary descriptions of reading, a metaphor that, for Heim, "takes us back centuries" even as it fused with new technologies.[46] The oN-Line System (NLS), created by Douglas Engelbart in 1962, referred to its files as *scrolls* and moving between scrolls was called *jumping*; a far cry from pages and turning.[47] At the same time as computer systems deploy the scroll metaphor, they also slide between this mask of unending seamless movement and that of discrete, discontinuous "pagination."

Thus, while the history of printing shows a longstanding movement from the continuous to the discrete, the metaphors become mixed: pages that scroll.[48] Lev Manovich famously noted that "cultural interfaces stretch the

definition of a page while mixing together its different historical forms."[49] Yet, this is not strictly true; it is another instance of "the habituated conflation between the page and the page of the codex."[50] For there is a similar story of mixed ancestry within the history of the print codex's development. As Manuel Portela writes, "one of the basic dualities of codex semiotics is the duality between flow (the scroll-like continuous reading surface) and break (the discontinuity between pages)."[51]

Early Christan codices aimed to distinguish themselves from the familial Judaic scroll, but they also overlapped with scrolling.[52] Indeed, the digital co-existence of scrolling and pagination parallels this earliest form of the Biblical codex. The early codex featured "a four-column page layout resembling a section of unfurled scroll," itself echoing the earlier *paginae*.[53] In this sense, the page of the codex was itself once a new media form that mixed its histories, inheriting its hybrid lineage from the intermediate stitched *rotulet* or roll form that is part book, part scroll. For it should not be forgotten that "the page offers a vertical continuity" akin to scrolling and has done since its inception, a fact evident in the embodied encounter with the codex.[54] Of course, such periods of fusion and overlap are symptomatic of introducing any new (bookish) technology.

Digital scrolling occurs when a user amplifies a portion of a virtual page to a virtual size that exceeds the screen dimensions. At this point, the page itself becomes a continuous entity. Hence, a bounded continuity of the discrete page is born, in which scrolling—akin, after all, to the sequential and often continuous nature of reading—finds itself juxtaposed with discontinuous turns and breaks. These conjoined metaphors are now so firmly ingrained within our techno-cultural imaginations that, when describing the reorientation from lateral to mesial inscription, the change wrought by the codex in the scroll's directional orientation is *retroactively* described as being "like the scrolling computer screen."[55] Indeed, it is precisely because of digital scrolling that we now see something new in *pagina* or print columns.

The best illustration of the virtual page's strange immateriality is the 1982 Perfect Writer user manual; the manual contains a diagram used to explain scrolling to the user. The manual visualizes portions of rolled parchment inside the machine, behind the screen.[56] Further, Ryan Cordell and Elika Ortega drew to my attention that the manual for the Apple IIe personal computer, launched in 1983, also had to explain the way scrolling worked by showing users the offscreen portions of the document moving beyond the visual display unit.

Hence, the lineage of the digital page features scrolling, confounding a simple binary change. The history, unfortunately though, gets even more

untidy.[57] For contemporary digital pages also share much in common with their more distant ancestor, the wax tablet. As Shane Butler notes, erasability played a large part in the political economy of ancient Rome and, in particular, in social standing through nominal legibility and erasure. The wax tablet afforded such impermanence. "No Roman citizen," Butler writes, "was so insignificant that he did not sometimes need his name to be written, and none was so powerful that his name could not one day be erased."[58] The digital page has re-inscribed this power of erasure and re-writing atop the form that was supposed to provide a fixity (palimpsests notwithstanding). Indeed, we do not have page computers but tablet computers. Some of the earliest designs for pointer input before the advent of the mouse (or *bug* as it was originally called), such as Alan Kay's "The Flex Machine" from around 1968, featured a tablet and stylus; tabular scrolling, pages that scroll, and paginated tablets.[59]

Digital pages, then, like their print counterparts, are not one thing. Some possess the infinite rewriteability of the wax tablet, while others attempt to enforce a write-once, read-many (WORM) paradigm akin to the pre-printed page. When we open our word processors, the general assumption is the former; we will see a sequence of pages, between which we scroll, in which mutability is vital. When we read a pre-formatted PDF, say of a book, we assume the latter, in which we expect the content to remain consistent and disseminable. WORM in this context is not immutable but rather a software lock-out—a type of technological protection measure—that can be circumvented. However, this type of specificity about mutability is not often mentioned when considering the lineages of the digital page and the metaphors that we use. This will be important later when I will cover the determining characteristics of visual display units.

To return to Tenen's speculative formalism, it is the friction of the pagination metaphor that is of historical significance. Despite our imaginations of familiar intuition, in the mid-1980s world of books in which personal computing emerged, it was "not a straightforward or speedy translation from original to screen," as David McKitterick puts it.[60] Yet, despite the well-known critical assertion by D. F. McKenzie that the lossiness of virtual reproduction of the physical book brings with it a "theft of evidence," it is actually more a *supplementation* of material evidence with mixed metaphors of scrolling, pagination, and tablet form that here takes place.[61] The virtual page sits farther back in the history of its print correlate than is often imagined and required explanation to users upon its introduction. Digital pages were hardly intuitive at all, and, as I will go on to discuss, there are other more compelling historical lineages for their development.

The Late Development and Cancellation of PDF

The main customer was still the printer.

Lucien Febvre and Henri-Jean Martin[62]

One of the reasons that we need a new history of digital pages is that the timescale for the early adoption of read-only pagination is out of joint. There was no enforcement of page-like representation implemented at the outset of computational writing and reading. Not until the 1990s was trans-media substitutability made possible by a then newly-developed technology: PDF This was because early computing software technologies were explicitly *not* designed to replicate pages between devices, despite the Xerox Alto adopting the Letter page format for its display.[63]

The reason for the late arrival of homogenized print representation in the digital environment is that all digital replication is dependent upon material infrastructures. For print replication between devices, the problem was the lack of standardized display resolutions between computer monitors. Indeed, this infrastructure developed in an arbitrary, piecemeal fashion rather than one coordinated to facilitate pagination.[64] This reliance on material infrastructures sits at odds with the flawed logic of the digital imaginary, which is one of abundance. As I have put it previously, we erroneously "conceive of born-digital literatures as abundant and overflowing, disseminable *ad infinitum*. However, when such works come into contact with our systems of finance and labor, which are socially scarce (by definition), we then see the restriction as artificial, even if, at heart, we know that all our systems of currency must be artificially scarce and limited in order to function."[65] The challenge faced by early pagination was contending with the ad hoc development of display-unit technologies: a material constraint on supposed digital abundance.

Hence, we call such digital transmission mechanisms *non-rivalrous* because, in the transfer of an artifact to another site, the original remains with the sender without degradation or loss.[66] Like ideas and ephemeral forms, digital media often can be copied indefinitely and their ownership is not contested through material rivalry.[67] However, the non-rivalry of the digital is underwritten by material economies of computing and networking equipment and "in practice," as Hartley *et al.* put it, "there is always a limit to non-rivalrousness."[68] Without these owned, singular, and rivalrous artifacts, it would not be possible to reproduce copies in this way.

What is critical in such systems is that the material items maintain substitutability among themselves, a type of rivalrous non-rivalry. It does not matter that two visual display units are not the same material object. What is important is the material object's malleability and its ability to reproduce represented forms non-rivalrously (despite the non-recoverable, rivalrous energy cost). Contrary to the established narrative, this is not strictly a new phenomenon in the digital age. Admittedly, pre-printed books do not possess such malleability, but blank paper and a Xerox copier machine do, albeit with the associated unit and time costs.[69] Pre-inscribed scrolls did not yield non-rivalrous malleability, but the erasable wax tablet could. The rivalry of these pre-digital inscription surfaces is not different in *type* to the rivalry of a computer screen (a malleable surface capable of reproducing forms without losing the original). What has changed is a difference in *degree* of fidelity and speed in the translation of forms between malleable surfaces. Yet this slide in degree has been underway for well over a century. As Walter Benjamin remarked in an over-cited passage, "in principle a work of art has always been reproducible. Man-made artifacts could always be imitated by men. [...] Around 1900 technical reproduction had reached a standard that not only permitted it to reproduce all transmitted works of art and thus to cause the most profound change in their impact upon the public."[70] Nonetheless, it remained difficult to introduce such frictionless technology even after the advent of the computer screen.

Digital pagination in the form of a PDF introduced a trans-media substitutability to malleable digital surfaces for the first time, even while it brought a read-only paradigm within the page context itself.[71] The initial iteration of PDF, "The Camelot Project," specifically aimed to solve two fundamental problems in the world of computer graphics and typography:

1. "how to build a computer representation, in a resolution-independent way, of any printed page"; and

2. "how to represent text, and typefaces, that are compatible with a solution to the first problem."[72]

At the core, the problem here is one of device—and material page—substitutability. The laser printers that John E. Warnock (a founder of Adobe, the original developer of PDF) used at Xerox PARC ran at 240 dots-per-inch (dpi). Meanwhile, computer monitors at the time used a 72 dpi format.[73] To solve this initial problem of scalability, Warnock and his team developed the page description language, PostScript (originally called *JaM*, for **J**ohn **a**nd

Martin, after John Gaffney and Martin Newell, who worked on the project alongside Chuck Geschke and Doug Wyatt).[74] This replaced the earlier manual system wherein researchers at PARC had "laboriously crafted type designs for each font size," an approach that meant that "complete type libraries would have to be constructed," by hand, "for every new, different-resolution device that might be invented."[75] This created a situation where it was possible to display documents in a unified way across different devices but only given the prerequisites of much tedious background labor and foreknowledge of future device specifications. This is akin to having wax tablets of five different sizes and accurately replicating an image across just those five, provided one has undertaken extensive preparatory work. Another good analogy is the creation of manual printers' typesetting blocks. It is the same situation that Joseph A. Dane describes within earlier print cultures where scribes could "vary the size of their scripts at will to conform to the format of the page they write on, just as they can vary script styles" while "typesetters can do neither of these things."[76]

The additional problem was that PostScript was a Turing-complete programming language, bundling full-featured variable calculation that required a heavy-duty interpreter to sit on top of the format. This came with several drawbacks for its use as a typographic and page-layout system. First, the transmission of executable programs brings significant security risks in networked computing environments. Second, using full programming languages to generate documents can result in infinite loops and indeterminate pagination. Third, due to its full dynamic specification, PostScript outputs cannot jump (to use that earlier term) to an arbitrary point in the page sequence without a complete recalculation of preceding elements and pages in the document; a computationally expensive operation.[77] Fourth, and finally, PostScript was slow. Indeed, Warnock had a contract with Steve Jobs at Apple to build the implementation that would be used on the LaserWriter, announced in January 1985.[78] The examples that Warnock built, however, "took over two minutes to execute on the LaserWriter," and Jobs did not want to demonstrate this live on stage.[79]

PDF was developed as an enhancement of PostScript to solve the problems of viewing and printing the "same" document anywhere.[80] Originally billed as Interchange PostScript (IPS), this format was engineered to restrict some of the more outlandish and computationally intensive components of PostScript and instead to create a device-independent system that ran a purely graphical subset of the language. As Warnock describes it, he "went to work and used a trick [he] had developed that would flatten all the loops

and subroutine calls in the program into a file that would contain only graphics calls. This trick reduced the computation time from over two minutes, to twenty-two seconds. After doing this Steve [Jobs] demonstrated the file at the announcement."[81]

To be clear, although it has subsequently been enshrined as an open standard, the initial rationales for PDF and Camelot were corporate and driven by profit. The primary motivating rationale was to "[consider] all the requirements of corporations regarding documents" and "to structure Camelot components so that they can be sold in ways that are useful to the corporations." The institutional office environment is as much a driver of pagination in the digital space as is the resemblance to codex construction. PDF and Camelot were also premised on a WORM-like write-once-by-one, read-many-times-by-many paradigm of consumption, a model in which "the distribution of information is to many people. In these latter cases a corporation would like a copy of the viewer for every PC."[82] Yet, there is no mention of mass peer-to-peer dissemination or, at this time, the facility for many creators to send to many receivers. The dissemination network is envisaged as a spoke system that radiates outwards.

A critical point, however, is that it is often assumed that PDF took off immediately. John B. Thompson, for instance, notes that "PDF quickly established itself as the de facto standard in publishing and in the graphic arts."[83] This is not quite the case. While PDF eventually came to dominate the industry, Warnock and Geschke write that they were "surprised" by PDF's "slow growth."[84] In Warnock's view, PDF was widely misunderstood at the time of its inception. "Quite frankly," he told me, "the industry 'did not get it'."[85]

Most shockingly, despite some limited early adoption by the IRS and the US Center for Disease Control, the Adobe board of directors suggested that Warnock abandon PDF development. "I remember speaking with an analyst at the Gartner Group," notes Warnock, "and she said: Why would anyone use this instead of just sending around 'Word' files and 'Lotus 123' files? She did not understand the issues." Warnock believes that the early problem with PDF adoption "was to charge for the reader" instead of focusing on the creator/publisher side. However, as compositing became a de-skilled profession[86] and with the "explosive growth of the use of the internet" (Warnock's words), a commensurate success came to Adobe and its PDF format.[87]

What is significant is that the creation of writeable pagination within word processor contexts comes well before the advent of disseminable

WORM paginated formats such as the PDF. While the former appeared early, the PDF did not emerge until 1993 and was almost cancelled for being commercially unviable and technologically undesirable. In short, despite the importance, for example, of this pagination in any transition of hot lead to computerized production at newspapers, its potential was not fully understood by industry at the time. That is to say that perhaps the most widely used computer file format for paginated document dissemination nearly never existed.

The Messy Histories of Visual Display Units

> We commonly sublimate the physical form of the book and suppress the connections between format and design and the history of their meanings.
>
> Mark Bland[88]

There are many social and material suppositions beneath the creation of the PDF and other trans-media pagination formats that, despite having had profound influences upon our digital world, were taken as mere engineering problems in the Camelot specification for the design of PostScript. The first is the assumption that "view and print anywhere" means that the digital document must have trans-media compatibility with print. As one example of this paradigm, Kathleen Fitzpatrick accurately writes that most e-book texts result from "simply translating texts from paper to screen."[89] In this respect, it is asserted that the digital will never truly be "paperless" if it must maintain this inflexible boundedness, the common accusation against digital pagination. For instance, in academic publishing circles, one of the core arguments that sustains the supremacy of the PDF is the use of page numbers in citation styles. Even though paragraph enumeration or any other locative marker could work, almost all major academic citation styles still insist on a page number maintained between an electronic edition and its print-material relation.[90] Yet, I will argue that it is *not* only this trans-media oscillation between print and digital that has most conditioned the virtual page; although in some industries, such as newspaper printing, the former may have played a greater role.[91]

For example, consider that a particular type of page aspect ratio has come to dominate the virtual landscape of text production, outside of the continental Americas: the ISO 216 A4 standard at an aspect ratio of 1:1.414.[92] This sizing, at 210mm × 297mm, maintains the same aspect ratio as neither

the UK A-format paperback (110 mm × 178 mm; 1:1.618) nor the B-format (129 mm × 198 mm; 1:1.534), the two most common sizes for trade book sales. The ANSI Letter format used in the United States and elsewhere runs at 215.9mm x 279.4 mm, introducing another aspect ratio (1:1.2941). As a result, the pagination displayed in word processors and output into PDF format may be an abstract rectangle rather than any precise geometric equivalent of the user's available print correlates. Instead, the sizes of most print pages were derived initially from the sizes of human hands.[93] That is, the layout to which most authors sit down to write in the digital world is not necessarily the same spatiality at the same scale in which the final document will be set. Hence, Butler is only partially correct to note that "all that remains consistent from author to reader is the page's basic geometry; its coordinates and dimensions, by contrast, inevitably shift."[94] For what is the basic geometry if not determined by coordinates and dimensions, which are varied?

The history of this particular technological choice can be traced back to 25 October 1786, when Georg Christoph Lichtenberg proposed, in a letter to Johann Beckmann, a system of paper sizes based on the square root of two (the A-series of paper sizes).[95] This ratio has distinct commercial advantages when producing paper since the precise linear subdivision allows for the least waste when cutting.[96] Given that, in Mark Bland's terms, "we commonly sublimate the physical form of the book and suppress the connections between format and design and the history of their meanings," it is unsurprising that this lineage holds hidden repercussions for the digital space.[97]

This matter of aspect ratios comes into conflict with the history of display technologies. Various aspect ratios have evolved and seen widespread adoption throughout visual display unit development: 4:3, 5:4, 3:2, 16:10, 16:9, 21:9, and 32:9. Of these, 4:3, 3:2, 16:9, and 16:10 are the closest to the A4 page aspect ratio of 1.414:1. These latter ratios, adopted in contemporary widescreen monitors, allow for the simultaneous display of two A4 sheets side by side, without the economy of zero-waste prevalent in the space of physical paper production.

There are, in fact, two primary historical determinants of aspect ratio sizes for visual display units: the print and the photonic. On the former front, early machines used line printers to produce a hard-copy output of their programming. In this sense, all contemporary computing systems do have a print legacy to their graphic display outputs. However, the paper form used by such systems was continuous (i.e., it was a type of scroll or

rotulet rather than leafed paper), and it ran at 215.9 mm x 279.4 mm. As such, there is greater continuity for this form with the scroll than the default A4 or Letter form of later word processing. The latter of these types—the light-based displays that we use now—is descended from early computational systems that used light bulbs to indicate the internal register state. As the television took hold of home entertainment, the earliest computer monitors adopted the aspect ratio from this form (4:3, from the arbitrary Academy Ratio of 1.33:1 standardized in 1932), which, although close, had no predication on document production and consumption in A4/Letter or any other medium.[98]

A series of conflicting determiners and predecessors of contemporary display technology and norms around digital pagination now come into view:

- continuous paper through line-printing output akin to the scroll
- A4 paper sizing based on root-two economies of physical paper slicing
- 4:3 aspect-ratio display technologies from television and film environments

Importantly for the latter two determinants, the digital environment's relationship to economy is the inverse of what it would be in the material paper environment. In the paper environment, the goal is to ensure that no space is wasted. In contrast, the virtual environment uses some degree of spacing to alleviate eye strain and cognitive burden. Such spacing also, though, is used to ensure that the perception of the virtual page is seen as A4 or Letter. For, were the zoom to fill the entire screen, the rectangular nature of the virtual page would disappear.

It is in this realm that the multiple histories of digitally paginated *format* also re-converge. Gérard Genette notes that, "over time, the meaning of this word," *format*, "has changed once or twice."[99] Originally referring to the folding techniques that would distinguish the folio from the quarto, octavo, duodecimo, sextodecimo, and octodecimo—which "became a shorthand way of estimating [the] flat dimensions of a book"—the term *format* shifts in the era of the paperback, or the *livre de poche*, to represent notions of mass reproducibility and accessible reprinting.[100] Page dimensionality here takes on a political economy of class demography, even as the entire history of print pagination and paper production has been entwined with material economics and achieved broader dissemination than was possible with hand-copied manuscripts.[101]

File formats, by contrast, are not usually thought to refer to size (or social demography) in any dimensional way, although compression formats relate to storage space in a functional sense. Instead, file formats refer to layout in memory of interpretable bits and bytes and the decoding routines required to render their contents legible to human users. Except PDF. With its multiple scaled resolutions, PDF attempts to synthesize discontinuous histories of visual display into a homogenized format size; it does so for a mass audience, on the world wide web, where format has a messy history that does not support linear historical conclusions. Visual display unit technologies condition virtual pages, which are descended from sources other than discretely printed pages.

Conclusion

It has long been assumed and asserted that the persistence of the page in the digital era is due to a desire or need to replicate print. In some instances, such as newspaper production, this is true. However, digital files that maintain trans-media pagination continue to dominate for reasons of practicality, prestige, or encapsulation and portability.

At the same time, seeking such continuity can mislead us.[102] I have shown how pagination metaphors are more diluted, how format histories are more convoluted, and how the display media forms are more varied than the conventional argument can accommodate. In the new history that I have attempted to trace, the path forks and winds a great deal more than might be expected, and the lineages, histories, and functions of these virtual pages are heterogeneous. The conditioning of the virtual page has been sculpted by a range of forces beyond its print correlate.

The prevalence of digital pagination—albeit in its estranged form—has also influenced other hardware designs. We have PgUp and PgDown keys on almost all computer keyboards worldwide. Note, though, that this is not *flip left* or *flip right*, but more of the conjoined logic of now-discrete, rather than purely continuous, scrolling to which I referred earlier. Pages continue to flow, top to bottom, in discrete yet continuous modes. However, it is also worth noting that we have a Scroll Lock button on most keyboards, a legacy of alternation between controlling the cursor with arrows and controlling the movement of text flow. We have the Print Screen button that captures a screenshot. Screens and scrolls have as much metaphorical impact on our keyboard technologies as do pages.

E-reading forms continue, however, to evolve in ways that go beyond the traditional page. For example, new markers in formats such as the Kindle untether reading experiences from the page's traditional language and metaphorical imaginary while providing trans-device locative functionality. This textual, rather than page, rootedness has possible precedent in Biblical and philosophical discourses (such as the Bekker numbering used in scholarship on Aristotle or the Stephanus pagination for Plato). However, the proprietary nature of the Kindle's location function has come in for critique on accessibility grounds.[103] Such devices attempt to give a virtual sensation of relative placement, with their progress bar indicating the percentage of a text that has been read. While such an indicator is clearly intended to replicate the haptic sensation of progression through a book, the inextricable imaginary interlock between computer progress bars and the tedium of waiting for a task to complete lends an uneasy air to such an approach.

There are also, though, retroactive questions to be asked of our print cultures. As Jerome J. McGann put it, we need "a thoroughgoing re-theorizing of our ideas about books and traditional textualities in general."[104] One of the questions we might go on to ask now is: Do digital pages simply behave as material pages would, if they could? Or is it more likely that material pages were always themselves trying to harmonize rival technologies of tablets and scrolls into new forms that were subject to incommensurable read/write demands? I would suggest, from the messy metaphors, hacked histories, and strained syntheses that sit behind our histories of digital pagination, that a more careful interrogation of such features shows always-hybrid entities that emerge from complex conjunctions, rather than singular object inheritance.

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Notes

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14. Henry Burton, *A Divine Tragedie Lately Acted, or A Collection of Sundry Memorable Examples of Gods Judgements upon Sabbath-Breakers, and Other like Libertines* (Amsterdam: J.F. Stam, 1636), H2r; cited and further remarked upon in Helen Smith and Louise Wilson, eds., *Renaissance Paratexts* (Cambridge: Cambridge University Press, 2011), 8–9.

15. Shane Butler, *The Matter of the Page: Essays in Search of Ancient and Medieval Authors* (Madison, WI: University of Wisconsin Press, 2011), 10.

16. At least part of the reason for PDF's eventual dominance over its rivals—Novell's Envoy, No Hands Software Inc.'s Common Ground, and others—must be attributed to the

fact that Adobe had better font distribution deals in place than its rivals, leading to a cleaner look and feel to the format. By contrast, emergent markup forms did not try to replicate such aspects and so were less beholden to such constraints. As George White put it, "Currently, the documents for which PDF offers the greatest advantage are those that use specialized fonts (e.g., math), which leads to the problem of licensing proprietary fonts for WWW distribution." George White, "Re: SGML Compliance and Future Directions," Com.Omnigroup.Omniweb-l - MarkMail, December 19, 1994, https://markmail.org/thread/ccmkujipwmsmg5nw. PDF also won out over the print industry's 'Tiff/IT' specification because it was able to incorporate a text underlay in its approach to hidden, searchable, readable verbal content beneath an image. For more on this, see Charles Bigelow, "The Font Wars, Part 1," *IEEE Annals of the History of Computing* 42, no. 1 (2020): 7–24, https://doi.org/10.1109/MAHC.2020.2971202; Charles Bigelow, "The Font Wars, Part 2," *IEEE Annals of the History of Computing* 42, no. 1 (2020): 25–40, https://doi.org/10.1109/MAHC.2020.2971745. There were also other formats, such as TeX, that were not strictly rivals here, but that merit mention: Barbara Beeton, Karl Berry, and David Walden, "TeX: A Branch in Desktop Publishing Evolution, Part 2," *IEEE Annals of the History of Computing* 41, no. 2 (2019): 29–41, https://doi.org/10.1109/MAHC.2019.2893731.

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